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OFFICE OF SECRETARY
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UNITED STATES OF AMERICA
BEFORE THE
NUCLEAR REGULATORY COMMISSION

In the matter of Westinghouse Electric Corporation (Exports to the Czech Republic for the Temelin Nucl ar Power Plant)

Docket No. 110-04699
Application No. XSNM-02785

PETITION FOR INTERVENTION AND REQUEST FOR HEARING OF GREENPEACE AUSTRIA

Pursuant to C.F.R. §§ 110.82 and 110.84 (1993), Greenpeace Austria ("Petitioners") hereby (1) petition for leave to intervene as full parties in this proceeding; and (2) request that a hearing be held on wether issuance of a license to Westinghouse Electric Corporation (Westinghouse) to export nuclear fuel to the Czech Republic for the Temelin nuclear Power Plant Units 1 and 2, should be denied because "issuance of a license to such person would be inimicial to the common defense and security or to the health and safety of the public, "within the meaning of Section U.S.C § 2133(d). Specifically, Petitioners request that the Commission hold a hearing to determine the health, safety and environmental impacts of the export of substantial amounts of nuclear fuel to the Temelin nuclear reactors, in light of serious issues about their safety. Petitioners support the "Petition for Intervention and Request for Hearing of the Natural Resources Defense Council, Friends of the Earth, Hnuti DUHA, and Global 2000", which was served on the Commission on March 17, 1994.

Description of Petitioners

Greenpeace Austria is a nonprofit organization founded in 1983 and registered under the laws of the Republic of Austria with a professional staff of 35 people. Greenpeace Austria works to promote environmental protection in Austria and neighbouring countries. It has approximately 100.000 members, including many individuals living just 40 miles from Temelin. Greenpeace Austria has participated in several environmental licensing proceedings. A major focus of the organisation's work has been public education and action regarding energy policy in former-Communist neighbouring countries. Greenpeace Austria has a long tradition in working on environmental issues in former Czechoslovakia; particular before Greenpeace Czechoslovakia was founded. Therefore Greenpeace Austria has a lot of expertise on environmental and energy subjects concerning the Czech and Slovak Republic. Numerous studies and reports are the result of this work (f.e. BOSSEW, P.[1990]: Radio-Ecological Investigations in the Surroundings of MAPE Uranium Ore Processing Plant near Ceske Budejovice in Southern Bohemia [CSFR]"-Report on behalf of Greenpeace Austria).

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Members of Greenpeace Austria have a substantial interest in the proposed fuel export for Temelin since they live near to the plant and would be most immediately and potentially most severely at risk from its proposed operation. The interests of the members of the Petitioner cannot be adequately represented by any other party.

PETITION FOR LATE INTERVENTION

Although this petition for intervention is untimely pursuant to 10 C.F.R. § 110.82(c)(2), good cause exists for granting this petition to intervene. The Petitioners did not learn until mid-March of 1994 that the Commission had received the instant export license application from Westinghouse. The interests which the Petitioners represent, and the issues they seek to raise in this proceeding, are substantial. Moreover, to the best of our knowledge the Commission has not yet received the comments on Westinghouse's application from the Executive Branch, pursuant to 42 U.S.C. § 2155 and 10 C.F.R. § 110.44. The Commission does not act on any petition to intervene or request for a hearing until it has received and reviewed the Executive Branch's comments. 10 C.F.R 3§ 110.84(d). Thus, granting Petitioners'untimely petition would not unduly prejudice any party. See Westinghouse Electric Corporation (Exports to the Philippines), 11 NRC 631, 633-34 (1980), aff'd, NRDC v. NRC, 647 F.2d 1345 (D.C Cir. 1981) (petition for intervention and hearing granted; petition filed 29 months after the filing of the initial export application and eight month after the filing of a second export application; the petition for intervention and hearing was filed after the Executive Branch had commented on the first license application, but before the Executive Branch had commented on the second application). Furthermore, granting this petition and hearing request would not cause any undue prejudice to any party because the Commission has not yet acted on the "Petition for Intervention and Request for Hearing of the the Natural Resources Defence Council, Friends of the Earth, Hnuti DUHA, and Global 2000", which was served on the Commission on the 17th of March, 1994. Granting this untimely intervention and hearing request would not unduly broaden or delay the proceeding, because evaluation of the health, safety and environmental effects of the export of nuclear fuel to Temelin are squarely within the Commission's mandate

REQUEST FOR HEARING

The Petitioners join and support the "Request for a Hearing of the Natural Resources Defence Council, Friend of the Earth, Hnuti DUHA, and Global 2000", served on the Commission on the 17th of March, for the reasons stated therein. Moreover the Petitioners believe that issues as the mix of Western and Eastern technology for the completion of the Temlin power plant, probabilistic safety assessment, environmental impact assessment, earth quake hazards, and liability has to be adressed adequately. Furthermore Greenpeace Austria has access to several energy studies which show clearly that the power produced by the Temelin plant is not needed. This all we would like to present at the proposed hearing.

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for Greenpeace Austria

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OEI-GAM--24

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Radio-Ecological Investigations in the Surroundings of MAPE Uranium Ore Processing Plant near Ceske Budejovice in Southern Bohemia (CSFR)

Report on behalf of Greenpeace Austria, (C) Nov. 1990

content

0. Introduction and summary

During the last years problems associated with uranium mining and processing have been given more attention than before. For 50 years, uranium has often been mined with neither regard to economical nor to ecological and radiological concerns. The results are landscapes devastated by open cut mines, dumps and pit heaps, radiological hazards by tailings which have not been disposed properly, contaminated ground water and health statistics showing elevated cancer fatality rates of uranium miners and workers. But also recently built uranium mining facilities involve various radiological problems, as can be seen, for example, in new Australian mines like Ranger, though much better safety efforts are now being made.

It has turned out that the part of nuclear fuel "cycle" which contributes most to the total dose induced by the use of nuclear energy is uranium ore mining and processing (normal operation with minor accidents assumed, i.e. nuclear wars and Chernobyl-type events excluded). Thus, though less spectacular than other parts of the fuel "cycle", the head end is most probably the dirtiest one.

It must be emphasized that uranium ore mining and processing has not only radiological hazards. There is also a potential impact due to "conventional" chemical pollutants like sulphuric acid and heavy metals which take part in or are a byproduct of uranium processing. Furthermore, other types of negative impact have to be considered as well. These are

(1) the land consumption which is very high for uranium mining and processing compared to the exploitation of other minerals and

(2) the social impact on indigenous peoples as it occurs, e.g., in the U.S.A., Canada, Africa, Australia, e.g. (This aspect, however, does not apply to Czechoslovakia).

This report is restricted to some radio-ecological aspects of MAPE operation. Due to lack of time and money the investigations could

not be done as systematically and completely as they should be for providing a data base being sufficient for a quantitative estimation of the radiological impact of MAPE.

Furthermore, part of the investigations had to be made illegally, since co-operation with MAPE was not possible. Therefore, samples from the MAPE plant area had to be taken without permission (which was not difficult, however, since there are no fences).

First investigations about MAPE began in spring 1989 and were carried out by the Austrian Green-Alternative Party together with the Österreichisches Ökologieinstitut (Austrian Ecological Institute). The background was a hint from anti-nuclear activists in Western Germany that W German uranium ore is processed in Czechoslovakia.

During these initial investigations we learned about rumors on severe accidents which are said to have happened at MAPE in the past and we got the impression that tailings and waste management was not done very carefully. Later in 1989, after the Czechoslovakian revolution, Greenpeace got engaged in MAPE.

The main results of this report are:

(1) There is a significant influence of MAPE on the environment.
- Outside the MAPE plant and associated facilities area, at locations where public access is possible, external dose rates up to several times the natural background can be found.
- Outside the actual MAPE plant area, but whithin the area of associated facilities like waste and tailings disposals, at locations where public access is possible, external dose rates up to 200 times the natural background can be found.
- In soil and crop samples taken in the vicinity of MAPE elevated radium levels can be found.
- The situation is unclear with respect to drinking water. Some results of surveys made by Czechoslovakian authorities suggest that ground water contamination has already occurred.

- Contamination of creek, lake and Vltava river sediments can be found.
- Whereas elevated dose rates and elevated soil and crop contamination levels could only be found in the immediate vicinity of MAPE area, ground water (possibly) and sediment contamination can occur also in relatively far distances.

(2) Places with material highly contaminated by radium like tailings or waste and debris material, with Ra-226 contaminations up to 800 000 [Bq/kg], are easily accessible to the public.

(3) The present operation of MAPE would most probably not be legal in Austria and in West Germany.

(4) It can be assumed that the time range of exposure due to MAPE operation will be some 100 000 years. The reason for that are the long half lives of Ra-226 (1620 years) and its parent nuclide Th-230 (75 200 years), both being accumulated in the tailings. (Uranium itself (4.5 billion years halflife) is not taken into account for this consideration. But although extracted by MAPE the U content of the tailings is still much higher than the natural background level in the region is.) This is why the tailings can be considered to be a potential radiological hazard.

(5) Data are not sufficient for an estimation of doses received by the local population. Several exposure pathways must be taken into consideration which requires a large amount of contamination data. However, a non-occupational additional exposure due to MAPE of several 100 [uSv/a] (several [mrem/a]) seem easily possible to us. We have no data about occupational exposure.

Epidemiology is not subject of this project.

Acknowledgement:

We thank Zuzanna Brikcius from Greenpeace Vienna for organizing, translating and arguing with bureaucrats, Dalibor Strasky from Greenpeace Ceske Budejovice for preparing the local infrastructure, translating and driving, Karel Mondspiegel and Jaroslav Svehla from the Czechoslovakian Academy of Science in

Ceske Budejovice for support in taking and preparing samples and for many useful discussions, and last not least our local informants who want to stay anonymous for obvious reasons.

1. External Radiation

At many locations in the vicinity of MAPE the dose rate has been measured using a Geiger Müller counter. The results are shown on a map (fig. 3). Values up to 180 [nSv/h] are considered normal for the region (see sections below). At many places around MAPE much higher dose rates have been found.

External gamma radiation can be divided by origin in several components:

(1) Cosmic Ray radiation;
(2) Gamma radiation from the ground;
(3) Gamma radiation from airborne radioactive material.

Both (2) and (3) can be subdivided into (a) natural, (b) technologically enhanced natural and (c) artificial radioactivity sources respectively.

Cosmic rays:

The natural cosmic ray level in the Cs. Budejovice region with an average elevation of 400 [m] above sea level is 40 [nSv/h]. Variations of this value due to changes in altitude can be neglected in this region.

Ground radiation: natural sources

The natural source of ground radiation is the content of uranium, thorium, their respective radioactive decay products, and of potassium in the soil. Values of the activity concentrations of these naturally ocurring radionuclides being representative for the region can be assumed as follows:

Ra-226: 50 [Bq/kg soil,dry weight]
Th-232: 35 [Bq/kg soil,dry weight]
K-40: 400 [Bq/kg soil,dry weight]

These radionuclide concentrations, uniformly distributed in soil, give rise to a dose rate (1 [m] above ground) of about 52 [nSv/h]. The contributions of the U-238, the Th-232-series and K-40 are 14, 18 and 20 [nSv/h], respectively.

Artificial sources:

Radioactive soil contamination due to atomic bomb tests of the Sixties and the Chernobyl accident still contribute to the dose rate. The average Cs-137 contamination of the region can be assumed to be 3.5 [kBq/m²]. Taking into account a contribution of Cs-134 this contamination results in a dose rate of approximately 10 [nSv/h] (reference date summer 1990).

The sum of cosmic ray and natural and fall-out ground radiation is about 100 [nSv/h]. Considering a background of the Geiger Müller counter used of about 20 [nSv/h], and the fact that the counter is oversensitive to cosmic rays, measured dose rates of 120-180 [nSv/h] can be assumed as typical for the region and fit well the calculated value.

Technologically enhanced natural sources:

Effluents from the MAPE uranium processing plant may be the source of an additional amount of radioactivity from radionuclides of the U-238 and U-235 series, mainly Ra-226 and its decay products. Increased levels of these radionuclides can clearly be identified in the vicinity of the MAPE plant.

Since it can be assumed that no other radiation sources exist in the region, a significant increase in dose rate is an appropriate indicator for an increased radium level. In the MAPE area "hot spots" with dose rates of more than 20 [uSv/h] have been found. On agricultural areas near MAPE values of more than 300 [nSv/h] have been measured, which is about twice the background value.

Air radiation:

The contribution of radionuclides in the air, mainly decay products of the U-238 and Th-232 series, to the dose rate is very small and can therefore be neglected. However, certain meteorological conditions (rain) lead to concentration of radon daughters near the ground which may significantly increase the dose rate.

2. Soil

At several locations in the vicinity of MAPE an elevated content of Ra-226 in soil has been found. Results are shown in table 1 and some additional ones in table 6. Values of Ra-226 higher than 100 (Bq/kg dry) can certainly be attributed to the influence of the nearby plant. The mean value of Ra-226 content of "normal" (Ra < 100) soil samples is 60 ± 20 (Bq/kg dry) with n=10.

In two cases the soil profile has been analyzed. It turns out that the radium profile shape is not the one usually occuring in nature (with Ra-226 distributed more or less homogeneously) but similar to the one known from fall-out situations. Fig. 6 a-f show the profiles of the nuclides Ra-226, U-235 and Cs-137 for two soil locations, respectively. The results are shown in table 9.

Having no data about the contamination history we cannot make any assumptions about soil migration behaviour of radium.

For the radiological consequences of soil contaminaton see next section and section 8.

3. Plants

Several plant samples, most of them grass, have been analyzed. Results are shown in table 1. The Ra-226 content ranges between 2.4 and 53 [Bq/kg dry]. For some of the plant samples the soil has been checked as well. If we consider only grass samples from locations where the Ra-226 activity concentration of dry soil is lower than 100 [Bq/kg], the mean Ra-226 content of grass is 5.6 ± 2.3 [Bq/kg dry] (n=6). This value may be assumed as a typical value for the region.

For the locations where soil and plant samples have been taken concentration factors (CF) can be calculated. The CFs listed here are defined as [(Bq/kg dry plant)/(Bq/kg dry soil)]. In table 2, the statistical error is in 1.65 s [%]. The first sub-column of each radionuclide denoted by "soil" shows the soil activity in [Bq/kg dry].

Table 2

sample No.	Ra-226		K-40		Cs-137	
	soil	CF	soil	CF	soil	CF
5-2/5-3,4	49.4	0.11±20	371	2.7±30	110	0.03±50
5-5/5-20,20A	51.4	0.047±88	531	2.0±20	16	< 0.09
5-8A/5-16	282	0.068±17	666	1.4±18	16.2	< 0.15
5-12/5-12A	78.4	0.074±55	605	1.8±6.7	27	< 0.06
5-13/5-13A	62.7	0.12±40	456	2.4±18	31	0.04±130
5-15/1X25	2284	0.011±30	376	1.4±25	98.3	1.5±30
5-17/5-17A	87.8	0.10±48	619	1.5±13	19.4	0.06±96
5-18/5-18BI	53.7	< 0.16	647	1.3±16	37.5	< 0.1
5-18/5-18BII	53.7	< 0.35	647	0.97±31	37.5	< 0.2
5-18/6-10	53.7	< 0.02	647	1.4±11	37.5	0.02±64

For the grass samples from "normal" soil (i.e. Ra-226 < 100 Bq/kg dry), the mean CF for Radium is 0.090 ± 0.030 (arithmetic mean) or 0.086 (geometric mean) with n=5.

From literature /SIM 90/, for "normal" Ra soil activities a value of CF = 0.20 could be expected. This value is calculated according to a formula (presented in /SIM 90/) which takes into account the significant unlinearity in radium uptake by plants: The CF decreases with increasing soil activity. The sample pair 5-15/1X25 with a CF = 0.011 shows this effect. However, the cited formula would yield a CF = 0.046 for this case.

The difference in CFs from literature and experiment may be explained by the facts that (1) in /SIM 90/ they consider all kind of plants for deriving the formula and (2) they don't take into account soil properties.

In reality the CF certainly depends on both plant species and soil type.

The high CF for Cs-137 of the sample 5-15/1X25 may be explained by the effect that the plant has been contaminated by leaf uptake of Chernobyl fall-out.

An interpretation of the finding of a low CF for Ra-226 cannot be given as long as no information about soil properties is available. (1) It is known that the radium uptake rate by plants is the lower the higher the Ca^{2+} concentration in soil is. (2) Furthermore, in the presence of high SO_4^{2-} concentrations Ra may be less readily available to plants, as $RaSO_4$ (co-precipitated with Ba^{2+}) has very low solubility. And (3) radium is particularly well fixed in soils with high content of clay and even better in soils with high content of organic matter due to their high cation exchange capacity.

A low CF for radium uptake is a mitigating factor for the radiological consequences of pollution caused by MAPE.

4. Sediments and surface water

A number of sediment samples has been analyzed. The results can be found in table 3. It is not easy to compare the results of aquatic sediment samples as long as there is no information about the particle size spectrum, as it is the case with our samples. Since pollutants can be assumed to be attached on the particle's surfaces, values of weight-based activity concentrations can only be reasonably compared if the mean surface:volume ratio of a given amount of particles is the same.

For getting roughly reasonably comparable samples, all dried sediment samples have been 1 mm sieved, so that at least stones and bigger gravel could be eliminated which would have distorted the results.

However, the bigger the particles the more information one can get about the natural background radionuclide concentrations, since they can be thought to be homogeneously distributed in the material and since then the surface:volume ratio is small so that the relative contribution of surface attached pollutants is small.

Statistic evaluation of the results considering only Ra-226-activity concentrations below 100 [Bq/kg] yields a mean value of 48 $\pm$ 20 [Bq/kg] (n=17) which fits well the mean soil activity of 60 [Bq/kg] (see section 2). Ra-226 activity concentrations higher than 100 [Bq/kg] can certainly be attributed to the influence of MAPE.

The samples 4-1 to 4-4 are taken from Soudny potok creek at locations with increasing distance from MAPE (see map 2). It turns out that the most distant sample (4-4) has the highest Ra-226 activity. From this fact and the very high concentrations in lake Bezdrev (sample no. A) and Vltava (sample 1-20, several 10 km downstream MAPE) sediments, we can learn that the accumulation of Radium in sediments does not necessarily linearly decrease with increasing distance from the source (if we don't assume any other major radium source along the river).

A number of soil and sediment samples have been analyzed by Czechoslovakian authorities. The results are given in table 7. Only two of them originate from locations outside MAPE and associated facilities (like the retention pond): nos. 17 and 18 are taken from places a few km downstream Soudny potok. Whereas in no. 17 the influence of MAPE is obvious, the Ra-226 activity is normal in no.18.

Only few data about surface water Ra-226 concentrations are available to us. They are from Czechoslovakian sources and can be found in table 6. Sample no.72 is taken from the tailings dam water, i.e. from within the MAPE plant area, the other samples from locations outside the plant area. Also locations 10, 71, 39 and 11 belong to MAPE, however, they are outside the actual plant area (see map 3). Only nos. 12 and 13 can really be said not to belong to MAPE. The Ra-226 activity concentrations of 9 [mBq/l] found in these samples are probably not too far away from background values. This means that the impact of MAPE on surface water is low under normal operation conditions. However, further investigations are necessary.

(These values can be compared to the ones reported in /IYE 90/: Generally, Ra-226 activity concentrations from less than 1 to some 100 [mBq/l] are found, for Czechoslovakia the values range from 3.7 to 292. For the Danube river in Austria 18.5 [mBq/l] are reported.)

In another survey /KLI 85b/ gross-alpha and gross-beta activity concentrations of surface water samples have been analyzed. Generally the results are similar to the groundwater values reported in /KLI 85a/ (see next section), but gross-alpha activities of more than 1 [Bq/l] are found. Special attention has been given to Vltava river water. Vltava water from Tyn (about 30 km downstream MAPE) was checked periodically. In most samples the gross-alpha activity concentration is below 0.1 [Bq/l], only once it was remarkably high, namely 0.92 [Bq/l] on Sept.2,1982.

A particularly interesting result is reported for the location where the MAPE effluents were led into Vltava river near the town

of Hluboka. Upstream of this location the authors found 0.03 [Bq/l] gross-alpha, at the inlet the activity was 1.66 [Bq/l] (samples taken Sept.18,1980).

Information about the interaction of water and sediment with respect to Radium exchange can be found in /HAL 90/. They report values of 200 - 50000 [(Bq/kg wet sediment)/(Bq/l water)] and state that "while the data presented ... suggest that radium is strongly removed from water to sediment, it has also been found that the mechanism of removal is highly reversible. Sediments in aquatic systems, therefore, may act as a significant sink or source of radium. This aspect has important implications in modelling the long term effects of uranium based industries."

The above cited reference and /JUS 90/ also provide data about the radium uptake of freshwater fish. However radium accumulation is stronger in scales and bones (inedible parts) than in flesh.

5. Ground water

For obvious reasons the ground water contamination pathway has to be paid particular attention.

As far as we know, no Ra-226 analyses have been performed before operation of MAPE begun in the early Sixties. For geological reasons the natural radium background of ground water can be expected to be very low. The crystallinicum in this region is gneiss which has very low radium content as compared to granite. The gneiss surface is highly fissured and can be found in a depth of between some 10 and 200 m.

The Ra-226 contents of all well water samples analyzed by us have been below 0.1 [Bq/l]. The Ra detection limit of some samples is quite high since we had only about 1 Liter of water of these sample. Results are shown in table 4. Sample no. 6-13 is from a location which for hydrological reasons is supposed certainly not to be affected by MAPE. Since it's Ra content is extremely low, it is not sure, however, whether it can be considered typical for the Ra background of the region.

Also most of Rn-222 values are within a normal range. Only one well water sample in Nakri showed an elevated Rn-222 content.

A survey of Ra-226 and uranium in private wells in Nakri, carried out by the Czechoslovakian authorities in 1990 showed most samples to have Ra-226 contents below 50 [mBq/l]. Eliminating extreme values > 0.1 [Bq/l] the mean value is 0.043 $\pm$ 0.021 [Bq/l] (n=36). This can be assumed not to be too far from the natural background value if we consider 0.03 as a rough average for groundwater /FRI 90/.

However, two values of this survey show significantly elevated Ra-226 concentrations: 0.28 and 0.34 [Bq/l]. They are still below the legal limit which is 3.3 [Bq/l].

(For comparison: Vienna tap water Ra-226: 1.9 [mBq/l], Rn-222: 2.4 [Bq/l]; Waldviertel (Lower Austria granite region) Ra-226: 52 [mBq/l], Rn-222: 100 [Bq/l] both in summer 1990. /OI1/)

Another drinking water survey was made by the hygienic board in Ceske Budejovice in 1985 /KLI 85a/. Drinking water from several

regions (okres) in Bohemia has been analyzed for gross-alpha and gross-beta activity. For all samples, the geometric mean of gross-alpha activity concentrations is 35 [mBq/l] (for the ln: x = 3.55, s = 1.27, n = 81), for the samples from the Ceske Budejovice okres the geometric mean is 40 [mBq/l] (ln(x): x = 3.70, s = 1.69, n = 14). For this calculation, the values from the region which may be affected by MAPE and values above 1000 have been omitted. (The geometric mean has been chosen because the frequency distribution of the values is very asymmetric and suggests a lognormal rather than a normal distribution.)

If a value of 40 [mBq/l] gross-alpha activity is regarded typical for the region, values of up to 35.9 [Bq/l] found in Olesnik, a village near MAPE (see map 2), must be considered as far beyond the normal level.

A series of groundwater Ra-226 analyses has been carried out by MAPE through the last 15 years. A number of boreholes has been drilled in the surroundings of the plant for environmental control reasons, and ground water analyses were made periodically. Values for Ra-226 activity concentration of some 100 [mBq/l] are reported, however most of them are below 100 [mBq/l] and many < 20. Only between 1985 and 1988 a dramatic rise in Ra-226 activities can be observed, with peak values 5 times or more the "background" value reported before. In 1988 and 1989, a clear decrease in Ra activity can be observed. (Fig. 7)

Since we have no information about the hydro-geological conditions in the region, we cannot predict to which extent an elevated Ra-226 level in the boreholes indicates a potential impact on the ground water quality. The radium migration velocity in groundwater is believed usually to be very low, but this may be different under certain chemical and hydro-geological conditions. Furthermore, high amounts of radium will be present in the environment for very long times, Ra-226 being additionally supplied by the U-238 daughter Th 230 (half life 75000 years) which is accumulated in the tailings.

6. Air

No data are available about the U-238 and its decay products in aerosols in the MAPE region. However for calculating exposure paths resuspension of radioactive dust from tailings must be taken into account, since this can contribute to the radiological impact of the plant. Parts of tailings dams not being used anymore have dried out (see next section), so that there is serious concern about this exposure path.

In the immediate vicinity of tailing dams the radon exhalation can lead to high local activity concentrations of Rn-222 and it's decay products in air. However, from a radiological point of view this seems to be a minor problem since the radon "clouds" disperse very quickly with increasing source distance.

7. Tailings

In several tailings samples very high radium content have been found. Results are shown in table 5. As can be expected there is no eqilibrium between uranium and radium for both the U-238 and U-235 series. The samples have been taken from locations within the MAPE plant area, but many of them from sites which are very easily accessible to the public. Some of the tailings and deposits of drainage sediments and waste material have been found in immediate vicinity of agricultural areas. Therefore, they can be considered to be a potential radiological hazard.

At some places sediments excavated from a drainage creek (sample No. 3-9) have been disposed on the site so that migration of radium into agricultural land and surface contamination of crops due to weathering processes seems easily possible. The very small particle size of this kind of sediment favours resuspension of dust being highly contaminated by radium (disregarding chemical toxicity). The latter process has to be considered also for parts of tailings dams which are not in use any more and tend to dry out, like the eastern part of K2 dam near Mydlovary village (sample Nos. 2-5 and 2-6) (fig.13).

Waste and debris material from the plant, such as engine parts, have been disposed at a site which is very easily accessible to the public. The radium activity concentration of some of this material (sample Nos. 5-11, 7-3 to 7-5) is extremely high (higher than in uranium ore). The maxiumum Ra-226 activity concentration was 815 300 [Bq/kg].

Waste disposal as it is done at MAPE would not be legal in Austria. (1) According to Austrian nuclear regulations, storage of radioactive material of natural origin with activity concentrations of more than 500 000 [Bq/kg] is only allowed in especially marked containers and rooms (Par.4.9 new, Par. 81 old). (2) Furthermore, the maximum activity of radium of natural origin which may be handled without particular safety requirements ("Freigrenze") is 50 000 [Bq] (Par 4.10 new). (3) Solid radioactive waste (nuclides with halflives > 100 [d]) may be

disposed like inactive waste only if the volumetric activity concentration is below 370 000 [Bq/m³] (Par 92 old). For sample no. 7-3 we have a concentration of about $8*10^6$ [Bq/m³]. Waste management is part of operation of an industrial plant. Thus, we think that current operation of MAPE would violate Austrian nuclear regulations. ("old" and "new" refer to the old and the new version of the Austrian radiation safety law.)

A number of soil and sediment samples taken in early 1990 from locations at and near MAPE facilities have been analyzed by Czechoslovakian authorities. The results are shown in table 7. It seems to us that the samples have been taken in order to get information about still persisting consequences of the 1965 accident, when K1 tailings dam broke on Jan.31 and water and mud leaking out caused environmental contamination between the dam and Soudny potok creek (see map 3). Soil profiles analyzed show that soil layers deeper than 0.5 [m] are still contaminated by the effluents. However, the data available to us are not sufficient to give information about radium migration rates.

The preventive measures against radium proliferation into the environment seem to be very poor. A "recycling system" for the contaminated waste water from the plant has been installed. The water is re-pumped onto a former tailings dam (K1) which is now covered with soil and grass. Liquids leaching out of this dam are collected in a drainage creek (mentioned above) and pumped back again, and so on. However, the waste water creek is a non covered stream and is separated from the environment only by a wooden slider valve (see fig. 8)(samples 2-11 and 2-12). From there, excess waste water is led into a retention pond and subsequently into Soudny potok creek (see map 3 and fig.11). This creek leads into Bezdrev swimming lake and further into Vltava river.

In our view, this retention system does not provide an appropriate protection against spreading of radioactive pollutants, neither with respect to long term normal operation of MAPE, nor to accidental pollution.

In most cases the U-235:U-238 activity ratio is higher than the one occurring naturally, which is 4.66 %. A reason for this may be a systematic error in the U-235 series evaluation algorithm which is rather complex (see sect.9). However, the analysis of East German uranium ore samples /UI2/ with the same algorithm showed fairly good results for this ratio.

Other hypothetical explanations for the unexpected result may be (1) some environmental separation process unknown to us or (2) that MAPE has processed enriched uranium (e.g. not used nuclear fuel). But since we do not know which sense this would make this idea is really just hypothetic.

Addendum:
In the mean time (Dec. 1990), some of most contaminated waste (nos. 7-3 to 7-5) has been transfered into a tailings dam by MAPE. According to a press release by the regional hygienic Station (Jihoceska Pravda 10.11.1990) the original disposal is considered a serious violation of waste management regulations, but it is not supposed to have a dangerous impact on the public.

8. Impact on humans

Radium is known to be one of the most radiotoxic substances, being comparable to plutonium. But the effluents of uranium ore processing do not only consist of Ra but also of all other members of both U-238 and U-235 decay series with each of them having its specific toxicity plus a spectrum of "conventional" chemicals such as heavy metals, and processing products like sulphuric acid. However, we restrict ourselves to radiolocigal exposure and to Ra in particular.

However, since our data base is not sufficient to calculate the exposure pathways from source to man (reasons, see below), we are not going to consider physiological models of radium behaviour in man or other more sophisticated features. Instead, we just make some qualitative remarks.

Fig. 9 shows the pathways which can be assumed to give relevant contributions to the total radiological impact.

Since the exposure scheme is very complex, it is impossible for us to give quantitative figures about individual or collective doses. Even for making rough estimates, by far more detailed investigations would be necessary, requiring in particular more samples associated to some of the pathways, data about general environmental, e.g. hydro-geological conditions and demographic data. However, some exposure pathways which seem most relevant to us can be identified. They are marked in fig.9.

For an illustration of the order of magnitude of the doses which can be expected we add some very simple calculations.

(1) Drinking water pathway:

If we assume a Ra-226 drinking water contamination of 10 [mBq/l] above the natural level, a 1 [l/d] water consumption rate and a $8.4*10^{-4}$ [Sv/Bq] ingestion dose factor for the whole body according to ABG (W-Germany) this exposure yields an annual dose of 3.1 [mrem] (31 [uSv]).

(2) Resuspension:

Let us assume a dust load of 1 [mg dust /m³ air] (which is very much) with a Ra-226 dust activity concentration of 10^{4} [Bq/kg]. Then the inhalation of 1 [m³] air yields a dose of $9.2*10^{-3}$ [mrem] (92 [nSv]), again using the ABG whole body dose factor which is $9.2*10^{-6}$ [Sv/Bq] for inhalation. 1 [m³] is the amount of air consumed within about 1 to 1.5 hours of breathing. This result means that only long term inhalation of resuspended dust can have significant radiological consequences.

(3) External radiation:

Locations outside MAPE and associated facilities with an additional external dose rate of 200 [nSv/h] (20 [urem/h]) can easily be found. This equals 175.2 [mrem/a]. In W-Germany the nuclear regulations allows operation of nuclear installations only if the annual dose at the "critical location" does not exceed 30 [mrem]. This means that MAPE could not be operated legally in W-Germany (from the radiological point of view).

Dose and risk:

The radiation risk is currently assumed to be of an order of magnitude of 10^{-3} fatal cancers per [rem] received. Since the population density in the surrounding of MAPE is relatively low, the collective dose in the region, which is the sum of all individual doses, can be expected to be quite low. Therefore, a statistically significant health effect (i.e. a cancer rate significantly above the background rate) due to the radiation impact of normal operation of MAPE is unlikely.

Let us assume a mean individual dose of 10 [mrem/a] and a number of 10 000 people affected. Then the annual collective dose is 100 [rem] and the risk will be some 0.1 additional fatal cancers per year among this population. This rate is not detectable.

However, this applies only to the general population, but not to MAPE workers. Also, it does not apply to accident conditions when high amounts of radioactive material may be emitted into the environment.

Since the migration of radium in the environment is a very long-term effect (with a time scale of some 100 000 years) we can be shure that the major part of the radiological dose (integrated over many generations) produced by MAPE is still to come, even when the plant has been closed and even when nobody will remember that it ever existed.

9. Experimental

All contamination analyses have been made with a Canberra 19 % HPGe gamma spectrometer. Efficiency calibration has been performed using a PTB mixed radionuclide standard which is not actually adapted to radium daughters. However, summation peak corrections have not been made. Several geometries between 1 liter and some [cm^3] are used. Fig. 10 shows the gamma spectrum of (contaminated wood) sample no. 7-3.

A correction for sample density is used and for all natural nuclides except Pa-231 background corrections are made.

For the U-238 series, 2 lines of Th-234, 2 lines of Pb-214, 2 lines of Bi-214, one line of each Ra-226 and Pb-210 are used for the evaluation (Pb-210 results are not shown in this report). Th-234 can be assumed to be in equilibrium with U-238 which is not detectable by means of gamma spectrometry.

For the U-235 series, some 16 lines of U-235, Pa-231, Th-227, Ra-223, Rn-219 and Pb-211 are used. Many of these lines are interfering with members of the same series and with the U-238 and Th-232 series. An algorithm for correcting these interferences is used. Pa-231, Th-227, Ra-223 ff. are assumed to be in secular equilibrium.

For the Th-232 series, a line of Ac-228, another one of Pb-212 and a third one of Tl-208 are used.

Whenever several nuclides of one series can assumed to be in secular equilibrium, like Th-232 and its daughters for soil samples or Ra-226, Bi-214 an Pb-214 after a 3 weeks hermetic isolation, or Pa-231, Th-227 and Ra-223, they are computed together to yield an activity value of the parent nuclide. If several lines (of one or different nuclides) a used together, a weighted mean value is calculated with weighting factors being the inverse of the statistical errors of the single values.

Dose rates have been measured with a ?P 1220/1 Geiger Müller counter 1 [m] above ground.

Sample preparation:

Soil and sediment samples have been dried in an oven at about 110°C. Sediment samples were 1 [mm] sieved in general, no further preparation except rough homogenization was applied to soil samples. Soil samples 1X23 and 1X25 were taken as solid cubes (18*18*15 [cm³] approximately), then sliced in horizontal layers and the sub-samples treated as above.

Grass and crop samples were first dried with oven (the dry weight being determined since all values refer to dry value) and then ashed.

For radon analysis water samples have been measured immidiately. For Ra analysis they were evaporated to dry residue.

Before gamma-spectrometrical analysis all samples had to remain enclosed hermetically for 3 weeks to allow the Rn daughters (Pb-214 and Bi-214) to come into equilibrium with Ra-226.

10. References

/FRI 90/ Frissel, Köster: Radium in Soil. The Environmental Behaviour of Radium, IAEA Technical Report Series No. 310, Vienna 1990.

/IYE 90/ Iyengar, The Natural Distribution of Radium. The Environmental Behaviour of Radium, IAEA Technical Report Series No. 310, Vienna 1990.

/HAL 90/ Halbert, Chambers, Cassaday, Hoffman: Environmental assessment modelling. The Environmental Behaviour of Radium, IAEA Technical Report Series No. 310, Vienna 1990.

/JUS 90/ Justyn, Havlik: Radium uptake by freshwater fish. The Environmental Behaviour of Radium, IAEA Technical Report Series No. 310, Vienna 1990.

/KLI 85a/ Klima, Marsova, Hajkova, Hola: Screening Pitnych Vod. Report KHS-HZ-6, KUNZ-Krajska hygienicka stanice, odbor hygieni zareni, Ceske Budejovice 1985.

/KLI 85b/ Klima, Marsova, Matzner, Majkova, Kropikova: Screening Povrchovych Vod. Report KHS-HZ-7, KUNZ-Krajska hygienicka stanice, odbor hygieni zareni, Ceske Budejovice 1985.

/ÖI1/ Österreichisches Ökologieinstitut (Austrian Ecological Institute): Current analyses, unpublished.

/ÖI2/ Österreichisches Ökologieinstitut (Austrian Ecological Institute): to be published

/SIM 90/ Simon, Ibrahim: Biological Uptake of Radium by Terrestrial Plants. The Environmental Behaviour of Radium, IAEA Technical Report Series No. 310, Vienna 1990.

11. Tables

Tables 1,3,4,5,6

All values in Bq/kg or Bq/l respectively. Statistical error: 1.65 Sigma in %
Detection limits are denoted by "< value" and calculated with 4.65 sqr(BG).

The samples 1-n have been taken between 11.1. and 29.1 1990,
2-n on 1.6 1990,
3-n on 18.7.1990,
4-n on 24.7.1990,
5-n on 26.7.1990,
6-n on 11.7 ,26.7 ,7.9 ,25.9.,22.10 1990,
7-n on 9.10.1990,
8-n on 19.10.1990
9-n on 14.11.1990

Soil and sediment samples have been dried. Activity concentration values refer to dry weight. Activity concentration of artificial radionuclides (Cs-isotopes) refer to the measuring date, which is generally about one month after the sampling date.

Grass samples have been ashed. The activity concentration still refer to the dry weights (not the ash weights) of the samples.

In the U-238-series column, 'Ra' means Ra-226 and 'Th' means Th-234. The Ra-226 activity concentration has been determined by using the decay products Pb-214 and Bi-214. For having secular equilibrium of Ra-226 and the its daughters, the samples were hermetically enclosed for 3 weeks.

In the U-235-series column, 'Pa' means Pa-231 and 'U' means U-235. The nuclides of the U-235 series have been determined with the use of 16 gamma lines and a number of corrections which seperate interfering lines.

Table.1

s o i l a n d g r a s s s a m p l e s

No	Sample and location	U-238-series	U-235-Series	K-40	Th-232	Cs-137	else
		Ra-226					
1-10	soil, field 400m away from MAPE	57.4±6d		318±30	63.3±10	10.7±27	
1-18	soil, soccer ground, Olesnik	17.4±33		483±22	22±27	53±13	Cs134:8.8±40
5-1	grass	3.8±65		1508±2.9		1.5±69	Be7:18±110
5-2	grass	5.3±75		1012±5.6		3.1±54	Be7:39±77
5-3	soil 0-3 cm	42.9±17		254±35	29.9±21	165±6.8	Cs134:20±19 Sb125:12±102
5-4	soil 3-7 cm	55.9±11		487±13	16.5±11	64±11	Cs134:53.6±11
5-5	grass	2.4±87		1080±5		< 1.5	
5-20A	soil 0-5 cm	51.0±10		556±11	44.8±13	12.7±39	Cs134:2.9±97
5-20	soil 5-20 cm	51.7±12		506±20	52±11	19.6±20	

TABLE 1 (CONT.)

5-5	hay	53.0±6.3		81±66		29±13	Cs134:2.4±7#
5-8A	grass	19.3±16		937±8.1		< 2.5	Be7:42±88
5-8BI	topinabura/roots	19.5±54		835±10		< 2.8	
5-8BII	topinabura/leaves	18.5±1#		1130±3.4		< 2.1	
5-12	grass	5.0±55		1105±5.8		< 1.7	
5-12A	soil	78.4±7.3		695±16	65.6±8.1	27.0±15	Cs134:2.8±89
5-13	grass	7.5±39		1093±5.9	2.6±108	1.2±13#	
5-13A	soil	62.7±10		456±17	56.7±8.8	31.2±14	Cs134:4.0±72
5-15	grass	25.0±28		514±21		145±8.#	Cs134:17.0±18 Be7:82±5#
5-15	soil	282±4.2		666±16	62.1±38	16.2±38	
5-17	grass	8.9±40		928±9.7	1.5±279	1.2±54	
5-17A	soil	87.8±5.7		619±9.2	96.5±7.3	19.4±19	
5-18	soil	33.7±3.7		647±11	43.6±14	37.5±14	Cs134:5.4±54
5-18BI	Topinabura/leaves	< 8.6		812±12		< 4.#	
5-18BII	Topinabura/roots	< 19		623±29		< 6.9	
6-1#	sawe	< 1.3		897±2.8		1.1±62	
5-21	soil	197±5		630±14	59±14	25.6±11	Cs134:5.4±10#
7-6	soil	Ra:79.4±10 Th:48.5±97		632±14	56.3±13	15.8±3#	
6-9A	soil 0-5 cm	Ra:735±3.3 Th:568±3#	Pa:84±102 U: 5#±3#	721±18	47.4±34	68.4±18	
6-9B	soil 5-15 cm	Ra:228±2 Th:235±17	Pa:21±63 U: 31±94	507±11	52.3±8	23.2±13	

Table 3

sediments from creeks and rybniks (ponds) outside MAPE

(sample no. A analyzed by Ceske Budejovice Institute of Ecology)

No	Sample and location	U-238-series	Th-232-Series	K-40	Th-232	Cs-137	else
		Ra-226					
1-9	sediment, rybnik Zliv	76.6±68		494±20	68.5±13	44.4±26	
1-20	sediment, Vltava near Tyn	540±3.9		900±14	48±30	76.5±12	Cs134:11.1±69
1-28	sediment, Mydlak	56±12		568±13	59±11	23±20	Cs134:4.4±70
2-4	sediment, Mydlak	52±8		440±12	61±6	22±13	Cs134:2±120
1-33	sediment, Bezdrev, inlet	97±11		445±22	54±19	45±19	Cs134:5.4±100
1-34	sediment, Bezdrev, location unknown	52.4±8.2		460±13	43±10		
2-1	sediment, Bezdrev, autocamp	21±15		555±12	20±17	3±70	
2-2	sediment, Bezdrev, outlet	59±8		770±11	49±9	15±25	Cs134:3±70
2-3	sediment, Bezdrev, inlet, near Zliv	36±11		630±10	21±18	17±16	Cs134:2±120
A	sediment, Bezdrev, middle of lake	3770					
2-7	sediment, rybnik between Divcice and Mydlovary	26.1±14		38±13	32.0±10	12.7±22	Cs134:1.9±36
2-8	sediment from creek par.to road Nakri-Olesnik	24±12		602±8	23±13	9.7±30	Cs134:1.7±100
2-10	sediment, rybnik s Divcice	35.1±13		265±22	38±12	6.4±49	
3-2	sediment, creek from MAPE to Soudny potok, after railway	Ra:2080±1.7 Th:1580±21	Pa:177±32 U: 84±27	482±36	77±27	16±74	
3-3	sake, first creek bending	Ra:1290±1.5 Th:1120±15	Pa:128±34 U: 60±16	339±35	67.4±17	32.9±27	

TABLE 3 (CONT.)

3-4	same, before ret. pond	Ra:1440±2.4 Th:1520±18	Pa:177±35 U: 108±24	396±33	68.1±28	61±23	Cs134:6.8±360
3-5	sediment, ret.pond	Ra:1020±2.8 Th:1170±16	Pa:85.5±54 U: 59.4±24	416±27	30.6±37	23±33	
3-6	water plants, tbd	Ra: 851±2.8 Th:2680±7.3	Pa:132±22 U: 193±9.6	237±56	48.7±37	36.7±31	
3-7	sediment, before Soudny potok	Ra:259±1.1 Th:132±14	Pa:20.0±32 U: 10.6±19	522±4.7	34.6±5.6	6.9±20	
3-8	sediment, creek near dam station	Ra:353±2.8 Th:343±25	Pa:63.7±54 U: 22.4±42	405±22	48.7±13	18.5±29	
		Ra-226:					
4-1	sediment, Soudny potok	35±11		597±6	39.6±10	40±10	
4-2	same	67±9.1		534±14	29.6±19	15.1±32	
4-3	same	34±14		617±14	32.4±14	6.9±58	
4-4	same	132±8.1		571±24	75.6±13	71±15	
5-7	sediment	166±9.8		420±29	98.1±14	71.3±17	Cs134:6.2±121
8-1	sediment, Nakri Stare rybnik, K2 side, near pump station	Ra: 46.9±15 Th: 63.8±65		687±10	56.6±40	3.5±100	
9-2	tbd , middle of lake	Ra: 59.1±3.1 Th: 51.4±28	Pa: 16±49 U: 6.1±82	613±3.4	36.5±4.8	10.9±9.5	Cs134:1.2±170
9-4	tbd.	Ra: 41.0±11 Th: 34.5±71		483±14	49.2±11	16.8±18	

Table 4

w a t e r s a m p l e s

No.	Sample and location	U-238-series	U-235-Series	K-40	Th-232	Cs-137	else
1-2	well water, Mydlovary	Ra < 0.12		2.4±77		0.03±39	
1-19	well water, Nakri, bus station	Ra < 0.13 Rn222:5.7±5.4		2.8±68		0.072±72	
1-21	well water, Zbudov near rybnik	Rn222:9.7±9.2		1.9±120	0.52±46		
1-22	drinking water, Zbudov, priv.well	Rn222:3.8±16			0.13±145	< 0.14	
1-23	drinking water, Nakri, priv.well	Rn222:4.9±9.7		1.5±126		0.09±140	
1-24	drinking water, Nakri, priv.well	Rn222:48.8±1.8		1.0±68			
1-25	drinking water, Nakri, priv.well	Rn222:4.9±0.2		9±78		0.43±75	
1-26	water, cattle drinking well	Rn222:24.7±3.3					
1-35	water, Zliv drinking water plant, #1	Ra < 0.095				0.014±170	
1-36	same, #2	Ra < 0.11				0.016±190	
1-37	same, #4	Ra < 0.057				0.061±200	
3-1	lab water, shop Divcice/Novo Sedly	Rn222:4.8±42					
3-10	well water, Zbudov main square	Rn222:9.7±33					
3-11	well water, Divcice	Rn222:14.4±30					
3-12	well water, Nakri bus station	Rn222:3.9±68					
6-7	well water, Nakri	Ra: 0.021±39				0.0054±35	
6-11	same, Nakri/Kravin	Ra: 0.017±20				0.0052±63	
6-12	same, Mydlovary	Ra < 0.027				0.0032±157	
6-13	same, Radomilice	Ra: 0.0026±160				0.0018±100	

Table 5

Sediments and effluents from MAPE tailings

No.	Sample and location	U-238-series	U-235-Series	K-40	Th-232	Cs-137	else
1-8	sediment, W tailings dam (K2), ri. pipe	Ra:4284±0.3 Th:-	Pa:2270±7.5 U: 240±21	873±62	103±166		
1-11	sediment, W tailings dam, le. pipe	Ra:4550±1.0 Th: 650±120	Pa:256±34 U: 84±24	255±83	55±80		
8-2	sed., K2 tailings dam, Velky Makri side	Ra:3960±1.0 Th:1900±41	Pa:253±57 U: 95±38	357±50			
8-3	sediment, ibd.	Ra:3580±0.86 Th:2070±61	Pa:395±29 U: 54±69	203±177			
9-1	sediment, K2	Ra:12160±0.97 Th: 1950±101	Pa:699±30 U: 139±78				
9-2	same	Ra:9410±9.70 Th:2040±64	Pa:500±25 U: 12±466	220±142	109±82		
9-5	same	Ra:10400±1.0	Pa:520±42 U: 181±28	331±145	193±69		
9-6	same	Ra:17780±0.55 Th: 3430±55	Pa:854±26		155±85		
1-16	sediment, tailings, loc. unknown	Ra:1940±2 Th: 910±88	Pa:235±59 U: 36±55		19±118	29.2±44	
1-38	liquid from MAPE, dark fraction (?)	Ra:1200±4.4 Th:2060±30	Pa:192±52 U: 91±28	238±42	57±107		
	same, sediment	Ra:12990±0.9 Th:10770±3.4	Pa:765±23 U: 774±8.6	440±120			
2-5	sediment, E (old) tailings dam MAPE	Ra:14260±0.5 Th:1040±84	Pa:714±14 U: 113±66	316±76	124±56	20±66	
2-6	same, white crystals	Ra:137±10		160±90	16±75	64±70	Cs134:11±60
2-9	sediment, N tailings dam (K3) near Olesnik	Ra:224±3.6		573±12	23±24	5.8±68	
2-11	sediment, waste water creek from MAPE, near K1 pump station, after wooden valve	Ra:3280±1.0 Th:4080±7.9	Pa:212±25 U: 190±12	612±19	21±85	10±119	

TABLE 5 (CONT.)

2-12	same, before valve	Ra:4030±1.6 Th:4130±12	Pa:277±30 U: 285±11	424±78	87±53	81±32	Cs134:16±316
3-9	sediment from drainage K1	Ra:23340±0.13 Th: 1990±7.8	Pa:1300±4.1 U: 199±13	664±18	64±62		
9-7	same	Ra:14430±0.50	Pa:819±16 U: 87±62	504±68			
9-8	same	Ra:16430±0.84 Th: 1600±160	Pa:947±24 U: 135±77	1220±44			
9-9	same	Ra:24830±0.59	Pa:1610±17 U: 96±71				
9-10	same	Ra:2660±1.1 Th: 714±41	Pa:242±25 U: 55±39	640±22	72.8±35		
5-9	sediment K1	Ra:861±1.4 Th:769±17	Pa:49.3±42 U: 38.7±22	507±12	49.7±14	7.3±58	
5-10	same white crystals	Ra: 99.6±5.4 Th:250±21	Pa:41.4±62 U: 14.6±27	173±20	4.3±81	2.0±74	
5-11	waste disposal, & HAPE	Ra:324±1.1 Th:198±16	Pa:27.6±37 U: 11.5±28	540±5.0	59.5±3.9		
7-3	wooden waste, ibd	Ra:815300±0.25 Th:513400±2.3	Pa:42600±5.7 U: 2910±3.4				
7-4A	moss, ibd	Ra:538900±0.28 Th:278600±3.4	Pa:25300±8.0 U: 1680±4.6				
7-4B	glass wool, ibd	Ra:233300±0.58 Th:179500±5.5	Pa:10900±21 U: 8730±8.1				
7-5	waste, ibd	Ra:524900±0.53 Th:143300±15					

Table 6

other samples

(for some of them, location is unknown)

No	Sample and location	U-238-series	U-235-Series	K-40	Th-232	Cs-137	else
1-1	milk, Mydlovary 11.1.			56±32	0.30±170	< 0.67	
1-4	straw, Olesnik				8.1±130	0.9±50	
1-17	apple, Zliv			38±50		0.74±140	
6-1	barley/corn	Ra: 1.1±66		131±10		0.53±65	
6-2	barley/straw	Ra: 6.1±56		674±8		3.0±63	
6-3	agaricus hortensis I	Ra: 10.7±39		1663±8		4.9±80	
6-4	agaricus hortensis II	Ra: 1.0±50		1378±5		4.7±63	
6-8	milk, Nakri 25.3.	Ra: 0.02±320 Th: 0.05±160		47.4±2.8		0.47±0.8	Cs134:0.046±53
7-1	mushroom	Ra: 168±33 Th: 178±75				46±73	
7-2	soil	Ra:4500±1.3 Th:1660±53	Pa:242±36 U: 98±46	605±43	67±100	104±24	
7-7	mushroom	Ra:66.7±50 Th:233±35		1200±56	37±125		
7-8	soil	Ra:59.5±7.5 Th:21.2±46		473±10	56.2±7.4	15.6±21	Cs134:1.7±138

Table 8: surface water samples

second column: description of sample locations:
no. 72: tailings dam
no. 10: drainage waters from creek under railway bridge
no. 71: same
no. 39: waste water creek
no. 11: retention pond
no. 12: little lake near Bezdrev lake
no. 13: Bezdrev creek, outlet into Vltava river

4. and 5. column: gross alpha and beta activities.
6. column: the unity should certainly be [Bq/l], not mBq.

Table 7: soil and sediment samples

first column: sample location descriptions:
1: base of tailings dam, where in 1965 the accident took place; transverse to railway and road (track).
2: probe at the road
5: hole 80 m away from the pump station
6: at railway embankment
7: tailings dam, place of the 1965 accident
8: tailings dam, first probe in dam body
12: mud from the slider valve
13: mud from retention pond
14: mud from a little lake near Bezdrev lake
15: mud from Bezdrev creek, outlet into Vltava river.

2. column: sample no.
3. column: depth

Měrné aktivity radionuklidů ve zmuku na odkališti a zeminách v okolí ~~skliště~~ MAPE Mydlovary, 26.1. a 22.2.1990

Charakteristika místa odběru	Označení vzorku	Hloubka odběru (cm)	typické radionuklidy /Bq/g sušiny ~~v~~ dry weight								
			uranová řada		thoriová řada		aktiniová řada			ostatní	
			^{226}Ra(^{214}Pb, ^{214}Bi)	^{228}Ra($^{228}U_{Ac}$	^{224}Ra(^{212}Pb)	^{208}Tl	^{231}Pa	^{227}Th	^{223}Ra	^{40}K	^{134}Cs	^{137}Cs
sondy od paty odkaliště pod místem nehody v r. 1965 ve směru kolmém na silnici resp. železniční násep 1	80,19	0-10	4,131	0,074	0,069	-	-	0,225	0,210	0,554	-	0,052
	20	10-20	4,391	-	0,063	-	-	-	-	0,571	-	0,013
	21	20-30	4,859	-	0,063	-	-	-	-	0,562	-	0,005
	22	30-40	0,210	0,013	0,088	0,025	-	-	0,034	0,622	-	0,002
	23	40-50	0,153	0,096	0,090	0,025	-	-	-	0,625	-	-
	24	50-60	0,095	0,088	0,081	0,022	-	-	-	0,579	-	-
	25	60-70	0,127	0,088	0,080	0,023	-	-	-	0,544	-	-
sonda u silnice 2	81,40	0-10	0,121	0,094	0,086	0,025	-	-	-	0,598	-	0,045
	41	10-20	0,094	0,091	0,086	0,024	-	-	-	0,619	-	0,019
	42	20-30	0,074	0,096	0,087	0,024	-	-	-	0,612	-	0,004
sonda 50 m 3	82,43	0-10	0,418	0,091	0,083	0,025	-	-	0,032	0,589	-	0,045
	44	10-20	0,083	0,087	0,081	0,023	-	-	-	0,575	-	0,006
	45	20-30	0,075	0,092	0,087	0,024	-	-	-	0,588	-	-
sonda 100 m 4	83,46	0-10	0,073	0,091	0,083	0,023	-	-	-	0,581	-	0,013
	47	10-20	0,073	0,089	0,084	0,023	-	-	-	0,586	-	-
	48	20-30	0,072	0,096	0,086	0,025	-	-	-	0,619	-	-
příkop 80 m od čerpací stanice 5	26	20-30	0,271	0,090	0,083	0,024	-	-	0,020	0,563	-	-
	27	50-60	0,110	0,083	0,076	0,021	-	-	-	0,620	-	-
u železničního násypu 6	28	20-30	0,084	0,096	0,090	0,025	-	-	-	0,595	-	0,004
	29	50-60	0,074	0,087	0,081	0,023	-	-	-	0,476	-	-
odkaliště nad místem nehody r. 1965 7	0 15	povrch	27,13	-	0,043	-	0,593	0,973	-	0,440	-	0,026
odkaliště I. sonda těleso hráze 8	I 73	0-30	14,71	-	0,041	-	0,570	0,757	0,637	0,554	-	-
odkaliště II. sonda těleso hráze 9	II 74+)	0-30	26,74	-	0,041	-	0,998	1,316	1,140	-	-	0,006
odkaliště III. sonda těleso hráze 10	III 75	0-30	27,78	-	0,040	-	1,064	1,486	1,217	0,479	-	0,008

TABLE 7.

pokračování tabulky

odkaliště IV. sonda těleso hráze 11	IV	76++)	0-30	15,28	-	0,035	-	0,562	0,745	0,613	0,529	- 0,006
kal za stavidlem uzavřeného okruhu 12		14	-	2,936	-	0,034	-	0,131	0,182	0,152	0,443	- 0,014
kal - retenční nádrž 13		16	-	0,554	-	0,058	-	-	-	-	0,544	0,027 0,173
kal - Signálka u Bezdrev. rybníku 14		17	-	0,179	-	0,063	-	-	-	-	0,413	- 0,085
Bezdrevský potok 15 kal, ústí do Vlt.		18	-	0,033	0,046	0,044	0,013	-	-	-	0,824	- 0,004

+) celková měrná aktivita alfa 209,6 $Bq.g^{-1}$, aktivita beta 53,2 $Bq.g^{-1}$

++) celková měrná aktivita alfa 92,7 $Bq.g^{-1}$, aktivita beta 20,7 $Bq.g^{-1}$ výdejnost ~~účelnost~~ radonu-222 (emanační schopnost) definovaná jako podíl objemové aktivity radonu-222 a měrné aktivity radia-226 ~~daného~~ suššeného vzorku je 23 %.

TABLE 7.
(CONT.)

Objemové aktivity radioaktivních látek ve vzorcích vod z odkaliště MAPE a recipientech v okolí

Číslo vzorku	Odběrové místo	Datum odběru	α celková Bq/l	β celková Bq/l	^{226}Ra mBq/l x)	Uran mg/l
72	Mydlovary MAPE - laguna odkaliště	22.2.	-	-	0,609	1,20
10	Mydlovary drenážní voda pod hrází	26.1.	151,5	75,4	0,200	6,50
71	Mydlovary MAPE - drenážní voda pod hrází	22.2.	-	-	0,099	1,74
39	MAPE - odp. kanál ČOV	7.2.	-	-	0,349	0,36
11	Mydlovary voda retenční nádrže	26.1.	1,12	0,95	0,083	0,01
12	Mydlovary Signálka u Bezdr. rybníku	26.1.	0,21	0,42	0,009	< 0,01
13	Mydlovary Bezdr. potok, ústí do Vlt.	26.1.	0,19	0,41	0,009	< 0,01

x) This should read Bq/l !

TABLE 8.

Table 9: soil profiles

sample No. 1X23

Soil cube divided in 7 horizontal layers.
Total fresh mass: 1007.8 [g],
total dry mass: 883.4 [g],
volume 1680 [cm³],
mean density 0.60 [g/cm³],
mean water content 12.3 %.

Mean activity concentrations between 0 and 6.5 [cm]:
K-40: 441 [Bq/kg]
Th-232: 35.3 [Bq/kg]
Ra-226: 245.1 [Bq/kg]
Th-234: 448 [Bq/kg]
U-235: 25.9 [Bq/kg]
Pa-231: 25.9 [Bq/kg]

Fall-out concentrations down to 6.5 [cm]:
Cs-137 (Chernobyl): 3.12 [kBq/m²]
Cs-137 (atomic bomb): 0.97 [kBq/m²]
Cs-134: 0.44 [kBq/m²]

sample No. 1X25

Soil cube divided in 7 horizontal layers.
Total fresh mass: 1597.9 [g],
total dry mass: 1086.6 [g],
volume 2866.3 [cm³],
mean density 0.56 [g/cm³],
mean water content 32.0 %.

Mean activity concentrations between 0 and 8.5 [cm]:
K-40: 376 [Bq/kg]
Th-232: 34.6 [Bq/kg]
Ra-226: 2283.8 [Bq/kg]
Th-234: 1157 [Bq/kg]
U-235: 67.7 [Bq/kg]
Pa-231: 156.9 [Bq/kg]

Fall-out concentrations down to 8.5 [cm]:
Cs-137 (Chernobyl): 1.78 [kBq/m²]
Cs-137 (atomic bomb): 1.34 [kBq/m²]
Cs-134: 0.25 [kBq/m²]

12. Maps and figures

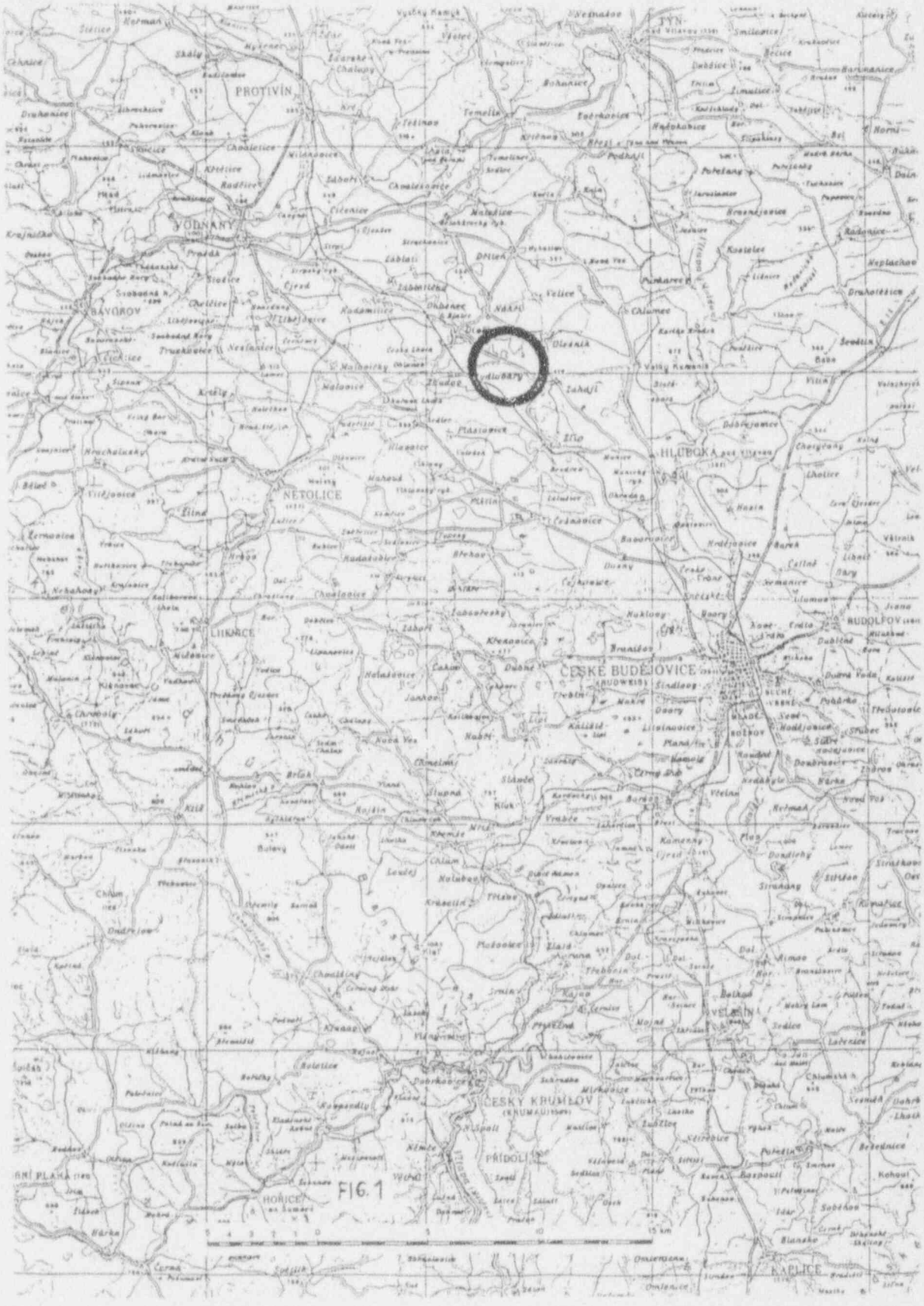

PROTIVÍN
VODŇANY
BAVOROV
NETOLICE
LIŠNICE
HLUBOKÁ
ČESKÉ BUDĚJOVICE
RUDOLFOV
ČESKÝ KRUMLOV
PŘÍDOLÍ
HORICE
KAPLICE
VELEŠÍN

FIG. 1

FIG. 2

K1, K2, K3 = tailings dams ; MAPE = plant ; Ret = retention pond

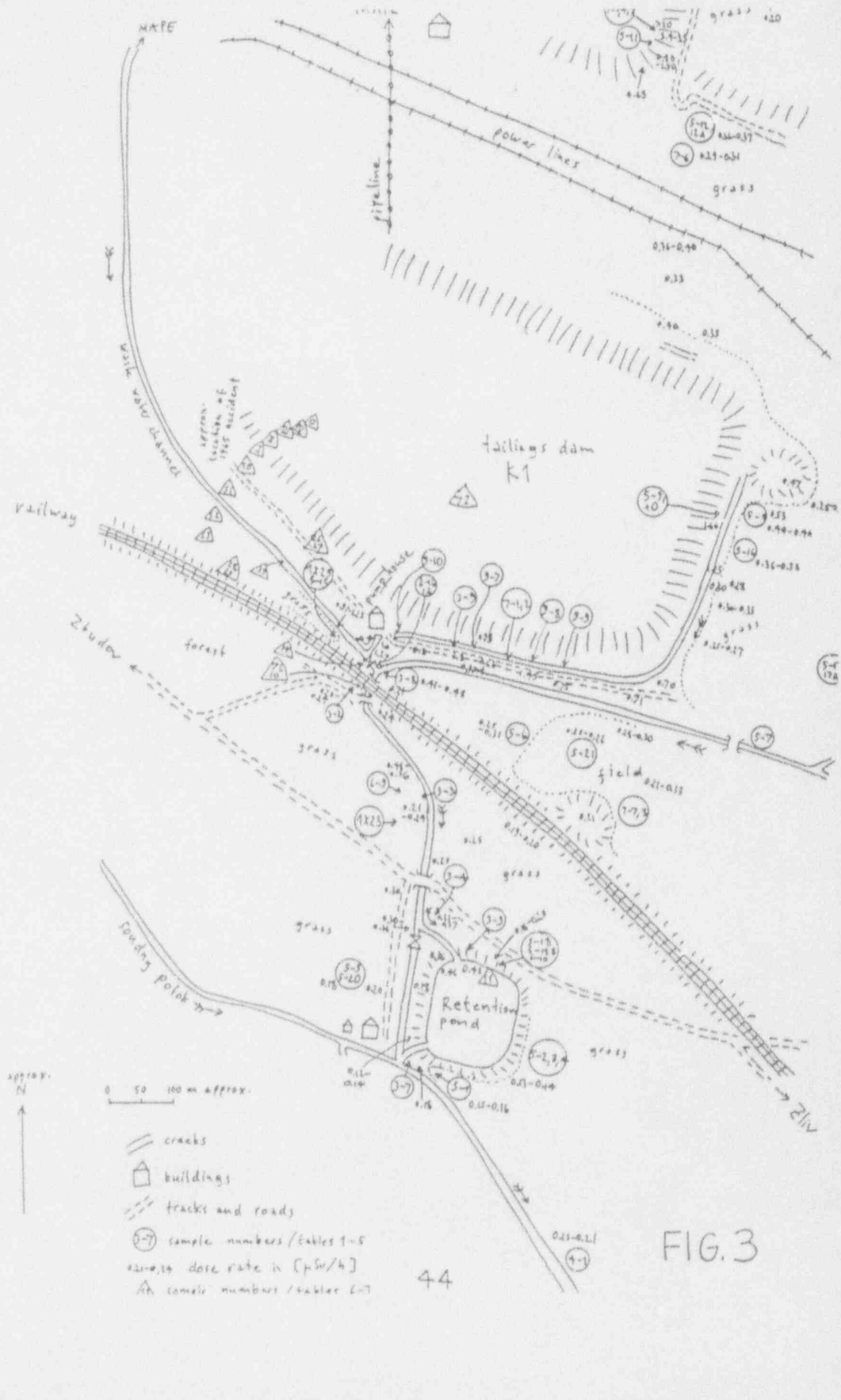

MAPE
pipeline
power lines
grass
waste water channel
approx. location of 1965 accident
tailings dam
K1
railway
pump house
forest
Zbudov
field
Retention pond
Sounding Polok
Zliv
approx. N
0 50 100 m approx.
cracks
buildings
tracks and roads
sample numbers / tables 1-5
dose rate in [μSv/h]
sample numbers / tables 6-7

FIG. 3

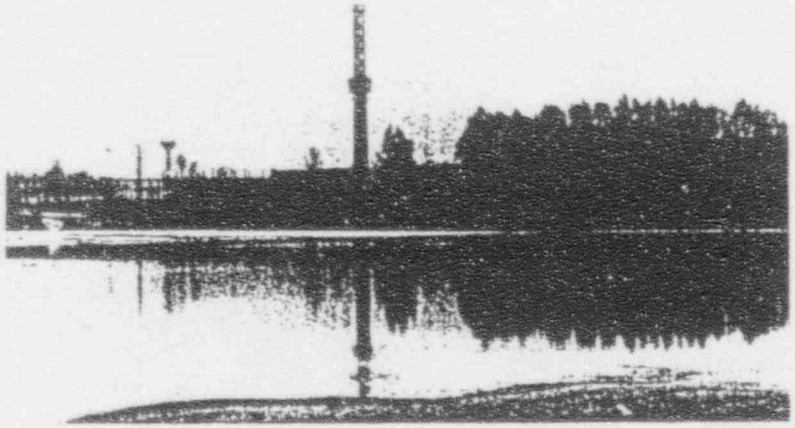


FIG. 4

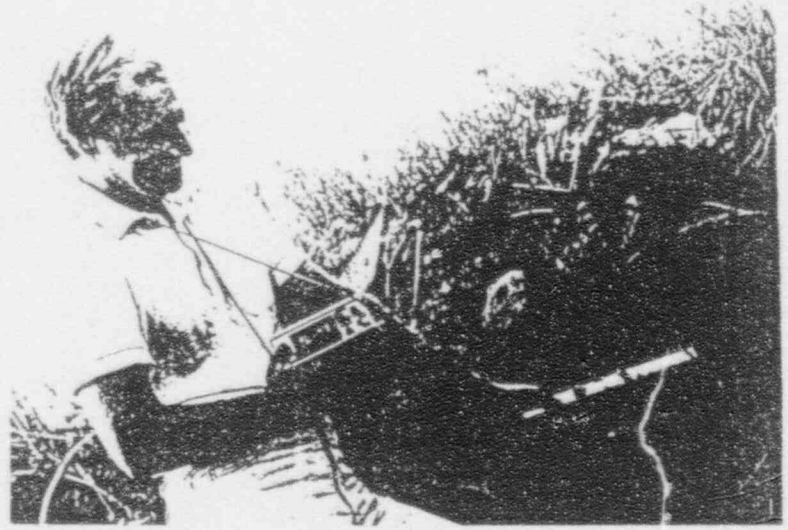
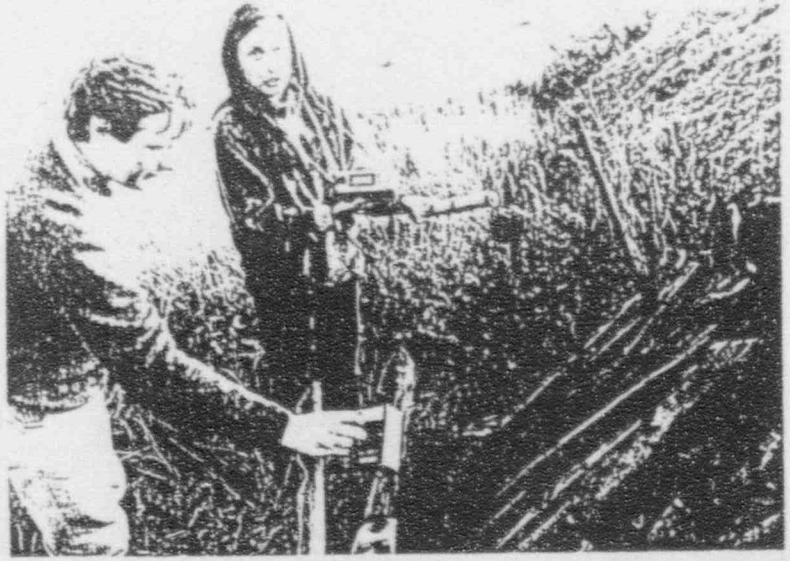
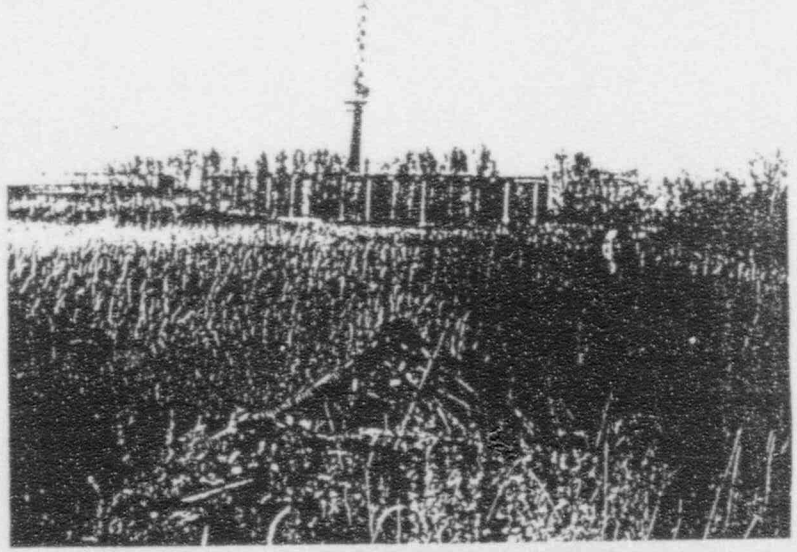


FIG. 5A





1X23 CS-Mydlovary/MAPE 18.07.1990 , Cs-137 Bq/m2.cm

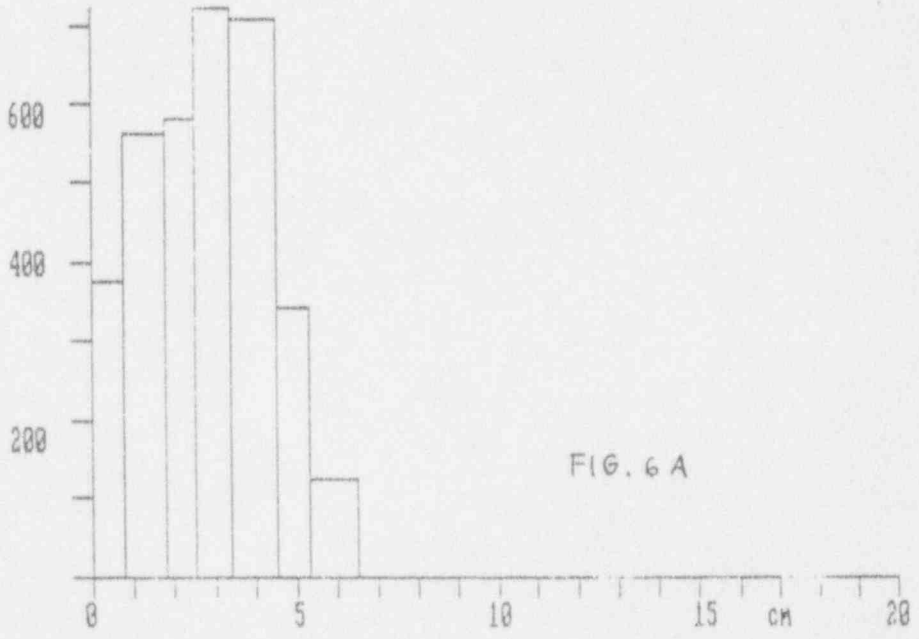


FIG. 6A

1X23 CS-Mydlovary/MAPE 18.07.1990 , Ra226,Bq/m2.cm

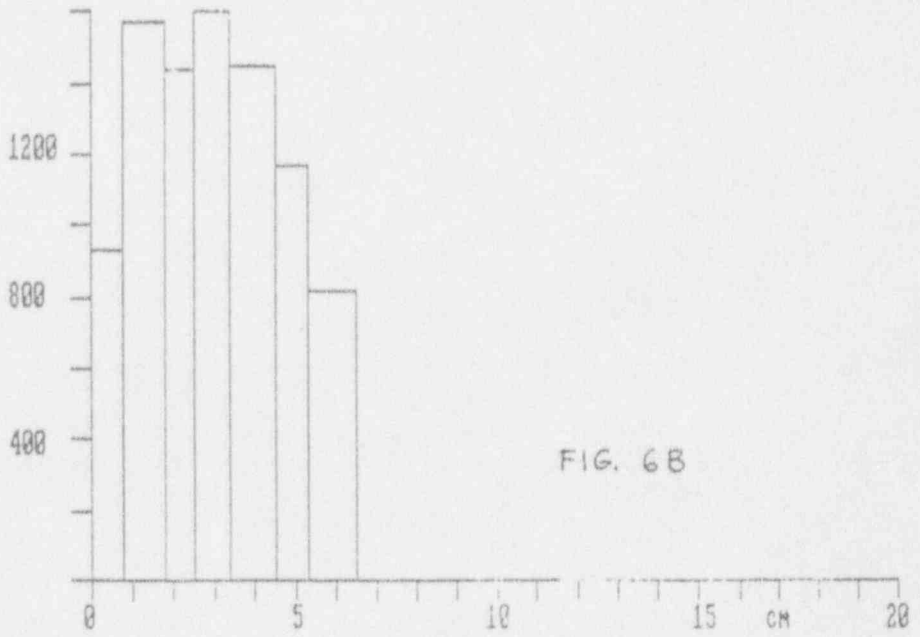


FIG. 6B

1X23. CS-Mydlovary/MAPE 18.07.1990 , U235, Bq/m2.cm

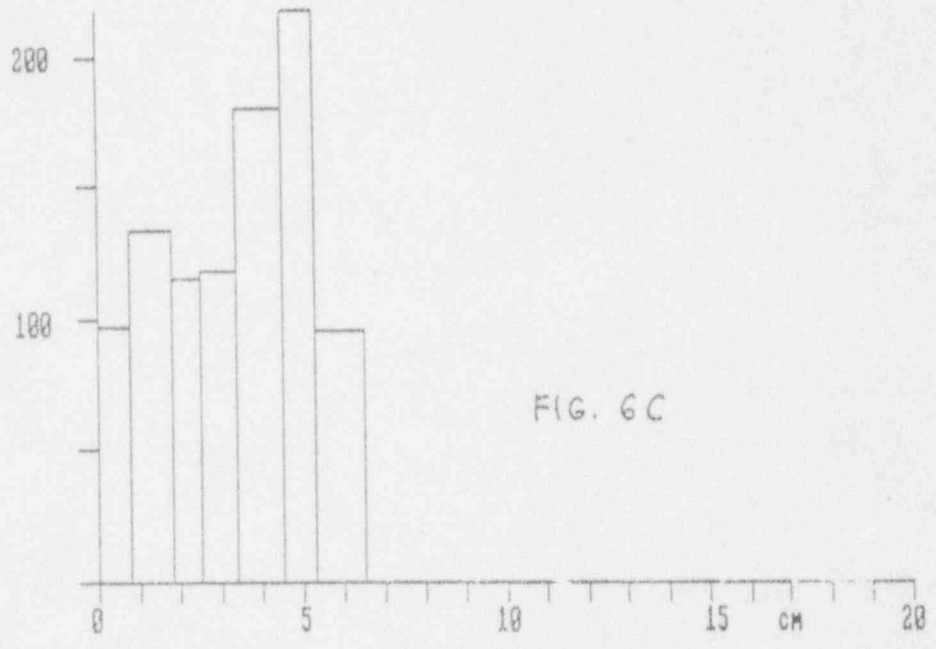


FIG. 6C

1X25 CS-Mydlovary/MAPE 26.07.1990 , Cs-137 Bq/m2.cm

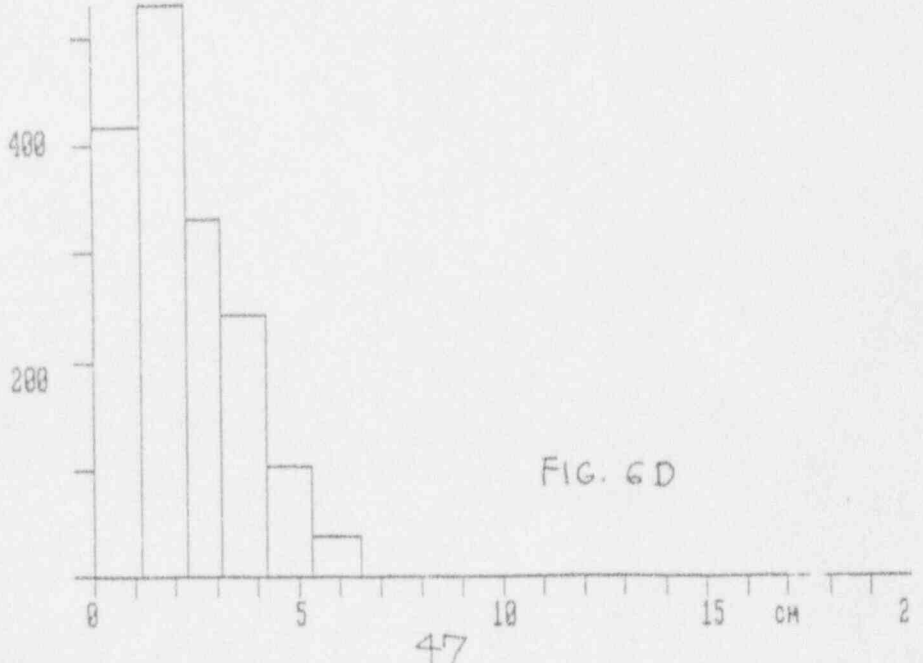


FIG. 6D

1X25 CS-Mydlovary/MAPE 26.07.1990 ,Ra226,Bq/m2.cm

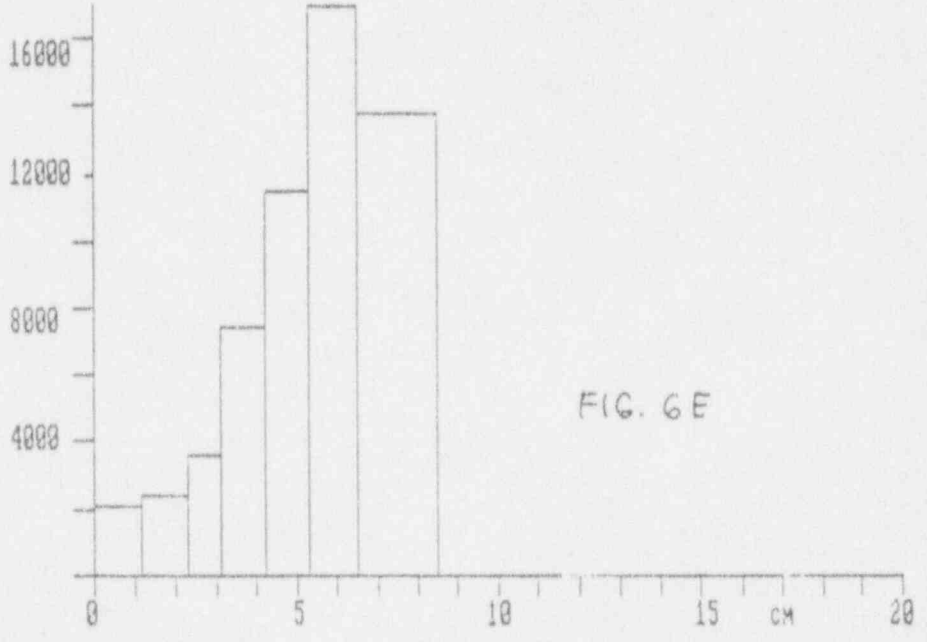


FIG. 6E

1X25 CS-Mydlovary/MAPE 26.07.1990 , U235, Bq/m2.cm

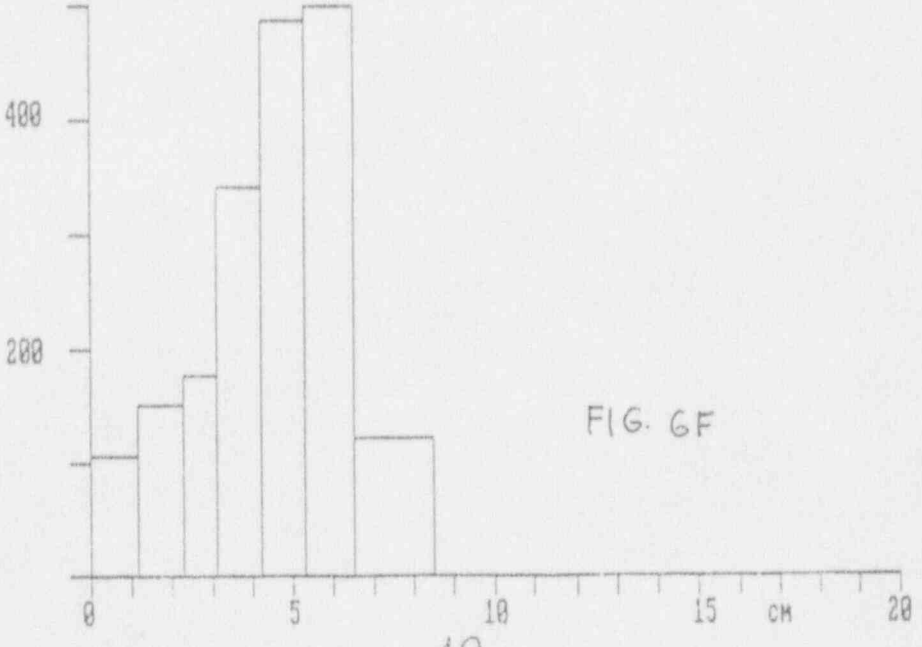


FIG. 6F

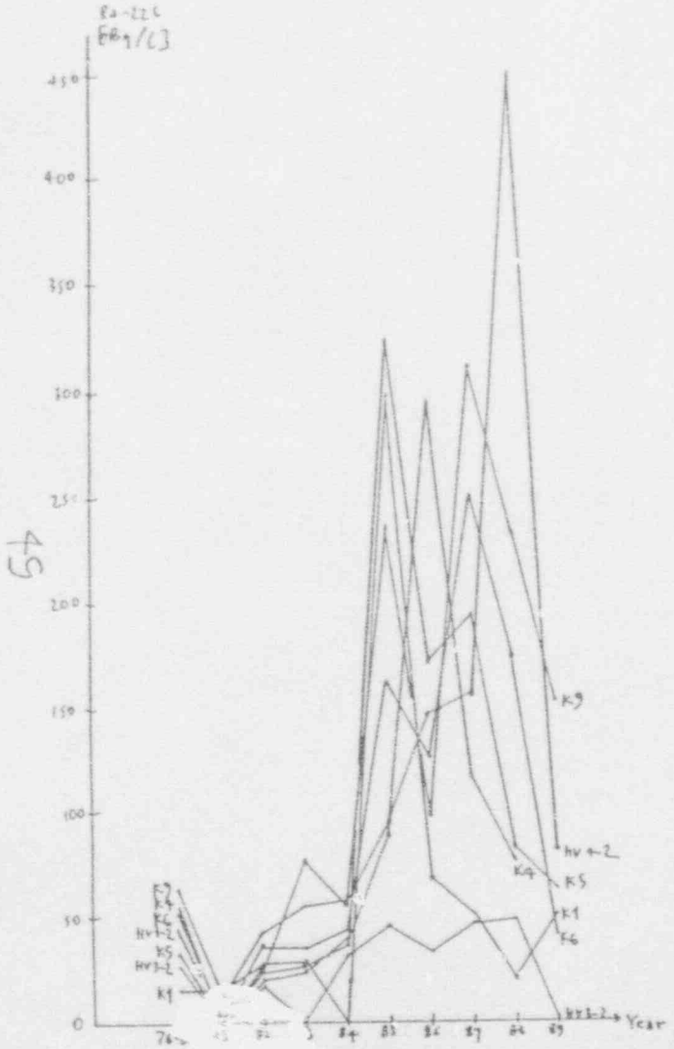


FIG. 7

FIG. 8A

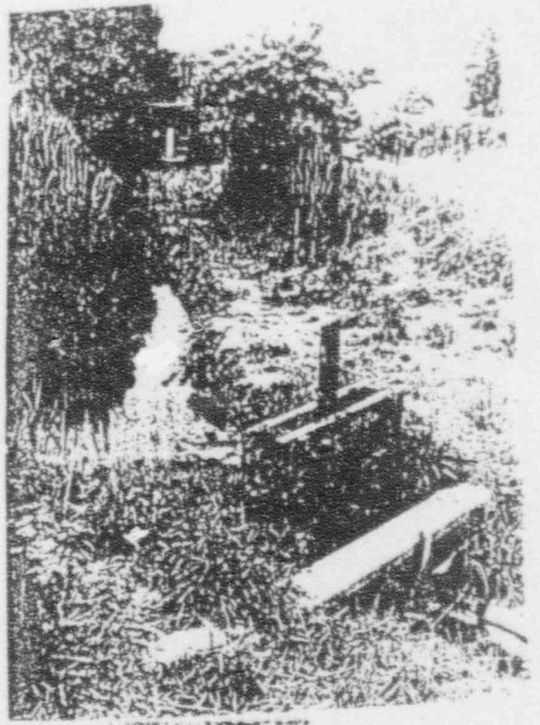
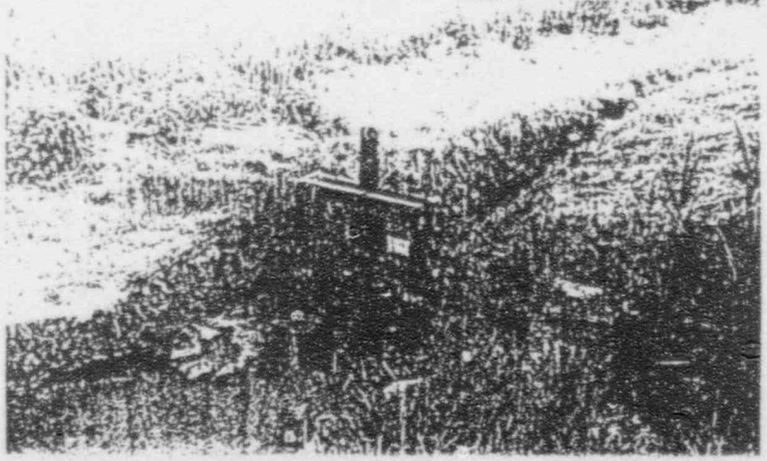
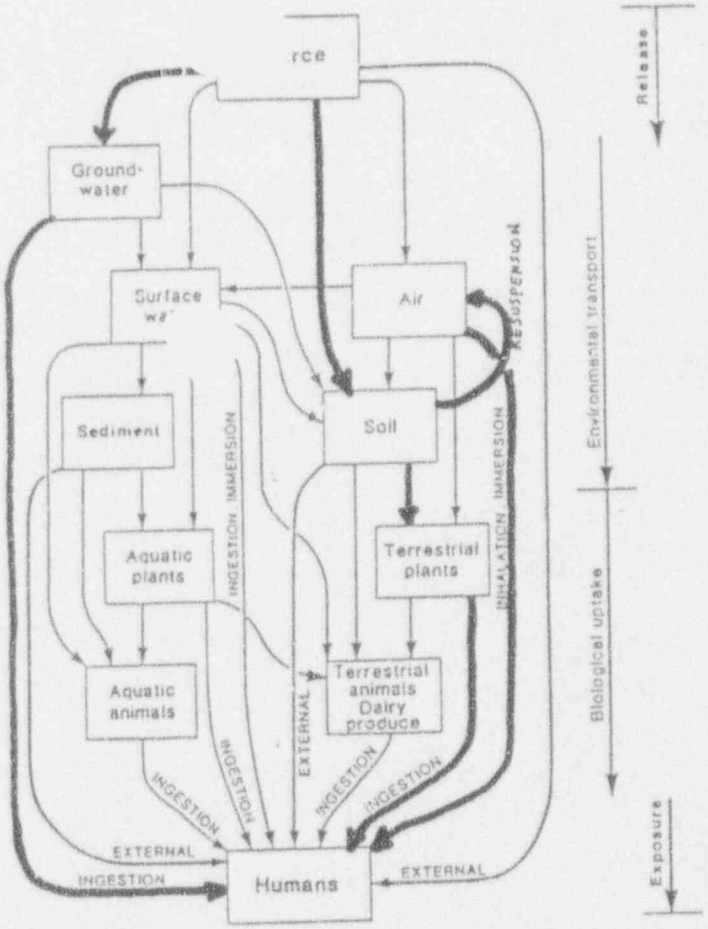


FIG. 8B





Pathways for the transport of contaminants from source to humans

/HAL90/

FIG. 9

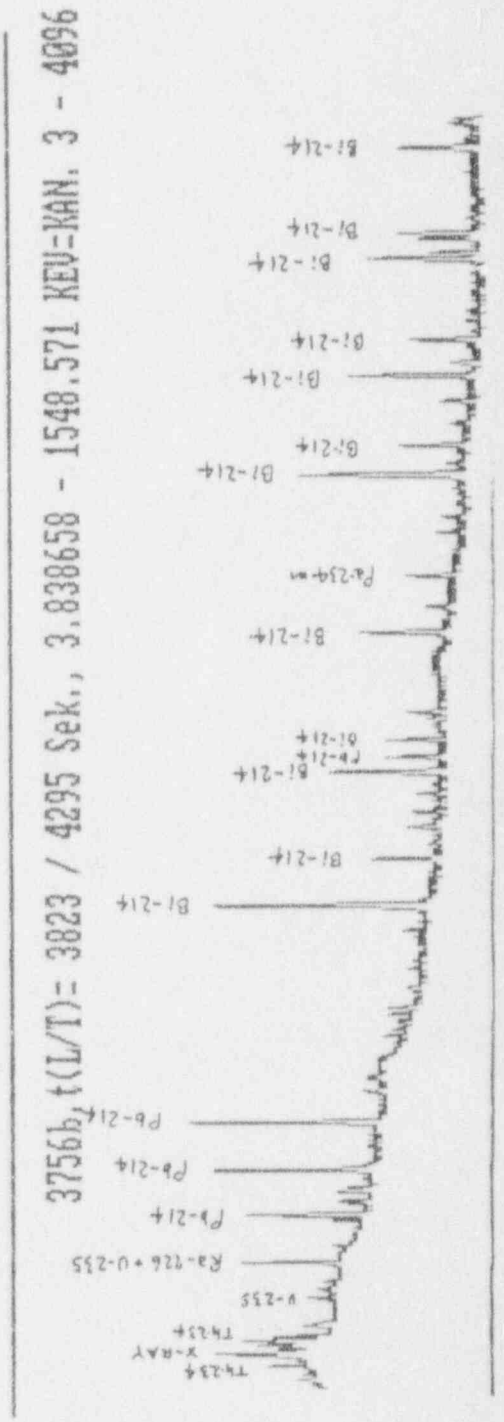


FIG. 10

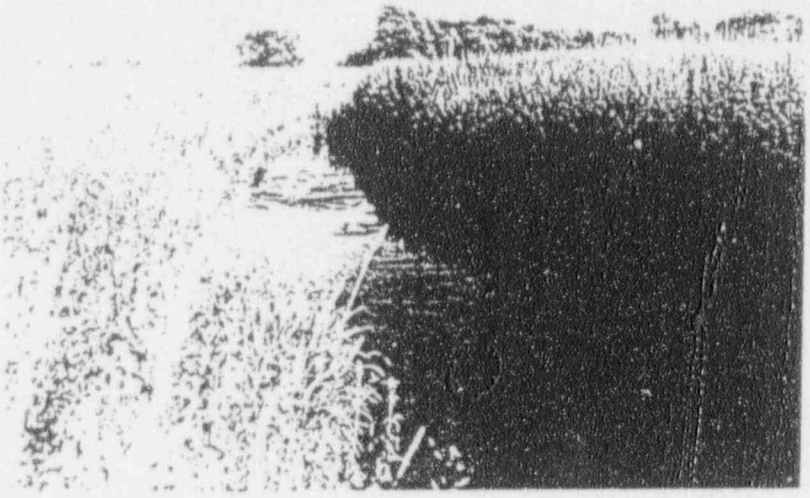


FIG. 11

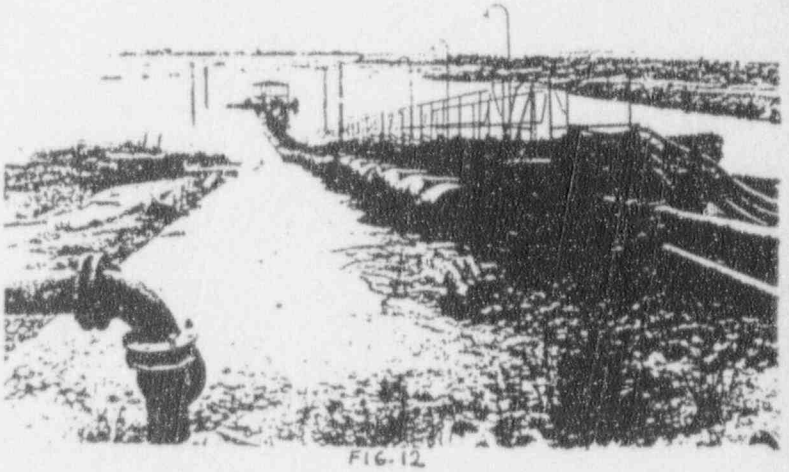


FIG. 12

FIG. 13