RADIOENVIRONMENTAL SURVEY OF THE MEGALOPOLIS LIGNITE FIELD BASIN

P.K. Rouni, N.P. Petropoulos,
M.J. Anagnostakis, E.P. Hinis and S.E. Simopoulos

Nuclear Engineering Section, Mechanical Engineering Dept.
National Technical University of Athens,
15780 Athens, Greece

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Megalopolis Lignite-fired Power Plants in operation :

- Megalopolis-A (600 MW – 3 units) since the early 70's and
- Megalopolis-B (300 MW – 1 unit) since the early 90's.

The main pathways of radiation exposure of the plants staff and the population living around the plants, due to the radionuclides emitted, are considered to be:

- **inhalation during the passage of the plume,**
- **external exposure,**
- **inhalation and ingestion resulting from the radionuclides deposited on the ground.**

The UNSCEAR report suggests that:

The production of 1 GWa of electrical energy, under certain **assumptions** and **estimations,** leads to a total collective effective dose equivalent commitment of **2 manSv**.

Main assumptions :

- concentration of natural radionuclides in ash,
- efficiency of the emission control system,
- population density around the plant

During the past 25 years, the Megalopolis plants fuel cycle has been repeatedly investigated by our Laboratory, in order to :

- **determine** the natural radioactivity content of the lignite and the produced ash,
- **map the natural radioactivity** of surface soil around the plants,

Questions raised

- Natural radionuclide concentrations in lignite and ash may not be considered as representative of the whole life of a plant, but they are dependent upon the lignite deposit feeding the plant.
- The efficiency of the emission control system does not remain constant with time.
- The dose rate is not only due to the fuel cycle but also due to external g-irradiation from the ground and radon exhalation from the surface of the ground, because of the natural radiation environment around a lignite deposit.
- Fly ash deposits also contribute to the radioenvironmental impact.

Due to the above reasons an **integrated approach** leading to the dose assessment to the public and to the plants staff **is necessary**.

This approach should mainly **consist of** an **integrated radioenvironmental survey**.

Integrated Radioenvironmental Survey Steps

- ***Systematic sampling, for a certain period of time, of :***

  1. lignite and barren at the mine(s) feeding the power plants, and

  2. lignite and ash at the power plants under investigation, to allow for a representative determination of the natural radioactivity content of the above materials.

- ***Sampling of the input (lignite) and output (ashes) of the plants, in order to investigate their radioactivity balance, and subsequent estimation of the releases to the environment.***

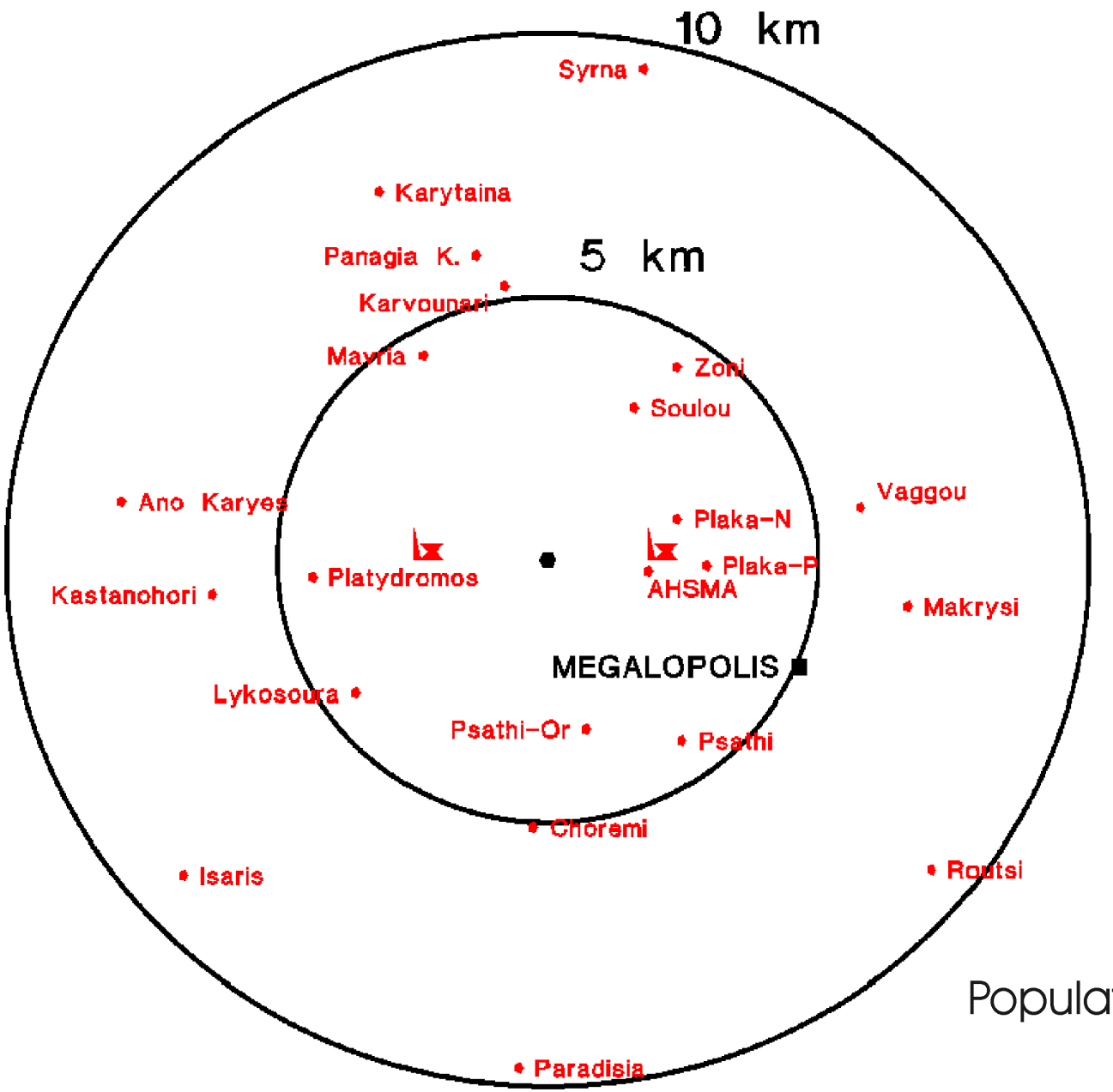
… and

- ***Grid Survey around the power plants:***

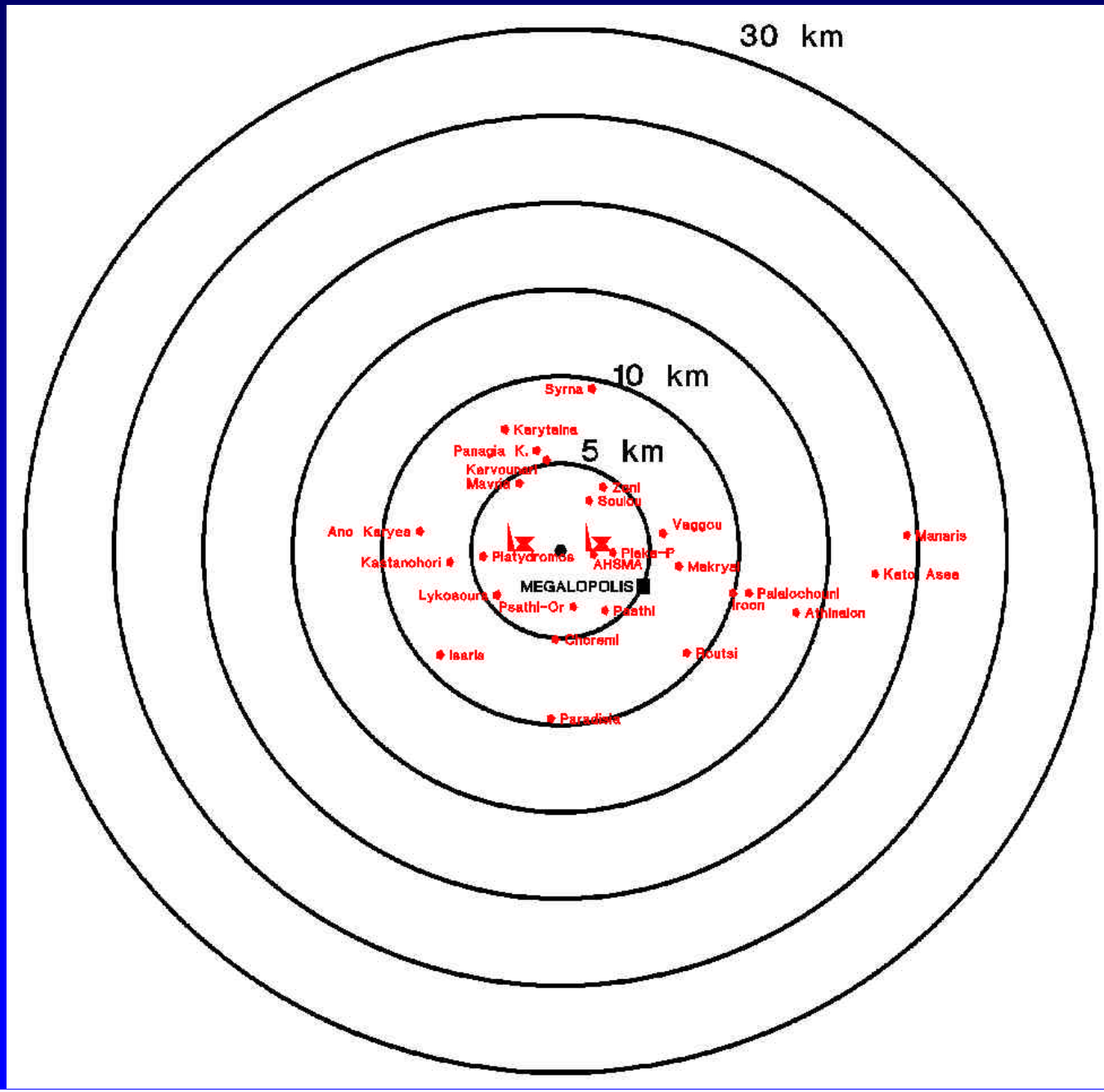
1. Sampling of the 0-80 cm surface soil layer to allow for the mapping of the surface concentration of natural radionuclides (^{226}Ra, ^{232}Th, ^{40}K, ^{234}Th and ^{210}Pb) and the study of their vertical distribution,
2. Soil gas radon concentration measurements – soil permeability measurements,
3. Surface soil radon exhalation measurements,
4. External total γ-irradiation dose measurements.
5. Ambient air radon concentration measurements, and particulate concentration measurements, especially under unfavourable meteorological conditions (wind blowing from the power plants towards the Megalopolis city).
6. Meteorological conditions (wind speed and direction)

Such an approach may lead to:

- Mapping of the fly ash deposition patterns within a critical area around the plants
- Dose assessment calculations for the plants staff and the population living around them, due to the fly ash releases



Population : 12,000


30 km
10 km
5 km
Syrna
Karytaina
Panagia K.
Karvounari
Mavrili
Zeni
Soulou
Ano Karyea
Vaggou
Manaris
Platydromos
AHSMA
Plaka-P
Kastanohori
Makryal
Kato Asea
MEGALOPOLIS
Lykosoura
Palaiochouni
Psathi-Or
Psathi
Athinaion
Iroon
Chorenni
Isaria
Boutsi
Paradisia

RESULTS

- Following systematic samplings over a period of 12 years at the plants Megalopolis-A and Megalopolis-B, it was well established that the ^{226}Ra content of the lignite feeding the plant and the ashes produced are not statistically different in the two plants examined.
- The ^{226}Ra concentration of the lignite, the fly ash and the slag at the Megalopolis-B plant was found equal to 348 ± 29, 905 ± 78 and 662 ± 62 $Bqkg^{-1}$ dry material, respectively.

- In the case of certain fly ash samples, it was found that they were highly enriched in ^{210}Pb, with the ratio $^{210}Pb/^{226}Ra$ reaching the value of 4, depending on the sampling location along the emission control system of the Megalopolis-B power plant.

- Given the ^{226}Ra content of the lignite, the ash content, the partitioning between slag and fly ash and the efficiency of the emission control devices, the ^{226}Ra radioactivity discharges from Megalopolis-B are estimated to about: **3500 MBq(Gwa)$^{-1}$**

which is much lower than those of Megalopolis-A

50000 MBq(Gwa)$^{-1}$

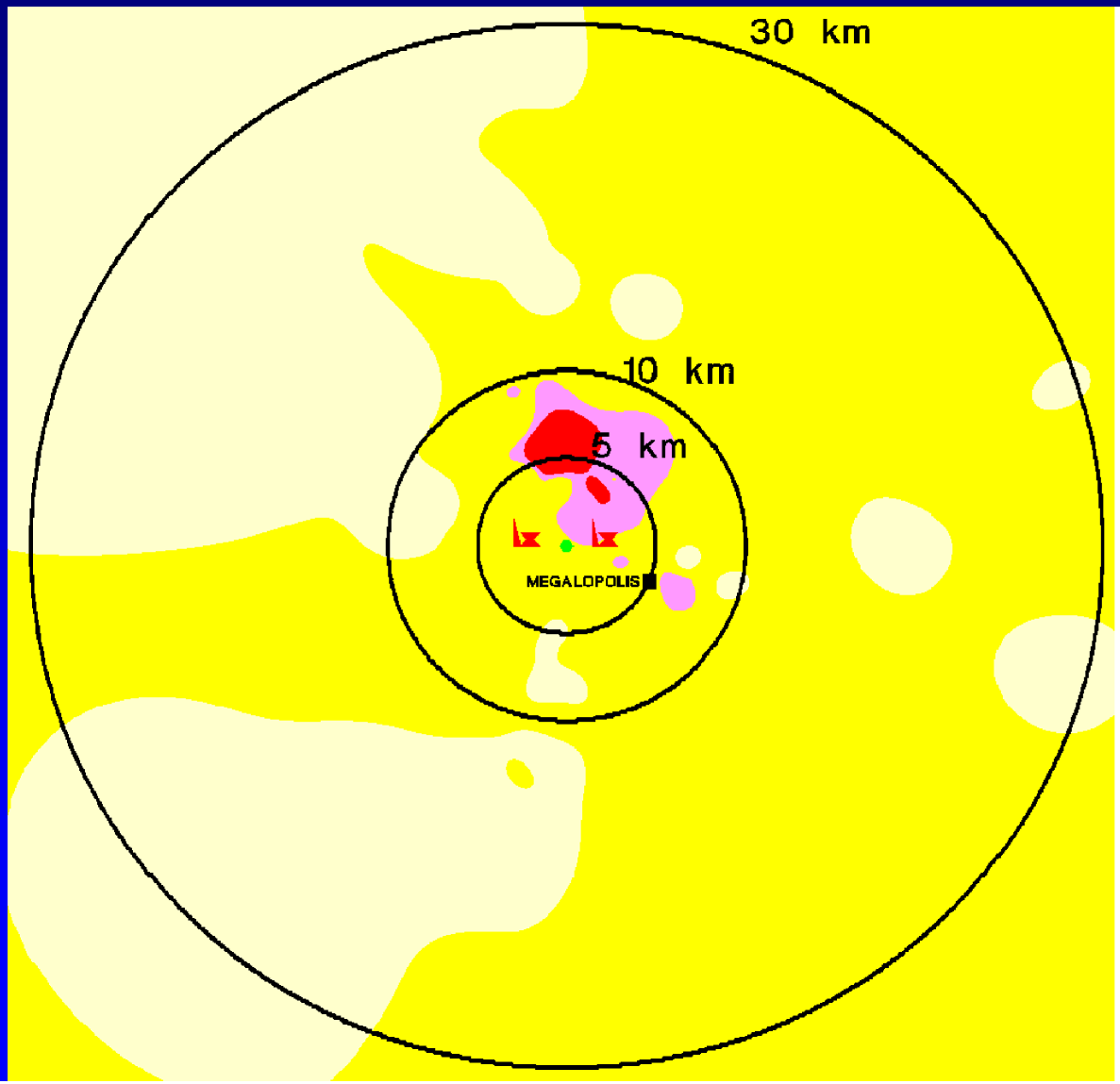
This is attributed to the high difference in the efficiency of the electrostatic precipitation devices in the two plants.

- Further to the previous results nuts were collected from a walnut plantation located at a restored mine field within the 5 km radius from the power plants. The nuts were analyzed for natural radioactivity using ?-spectroscopy. The results showed that the ^{226}Ra content is not significantly different from the lower limit of detection of the method (1 $Bqkg^{-1}$). Further investigations are underway.

Table : Results of the survey within the 30 km radius from the Megalopolis power plants (74 sampling locations).

	Range			Reference data range	
	0 – 5 km	5 – 10 km	10–30 km	Value	Site *
Surface soil ^{226}Ra concentration [Bqkg^{-1}]	26 – 337	23 – 42	7 - 69	9 – 20	1
				18 – 53	2
Surface soil ^{232}Th concentration [Bqkg^{-1}]	24 – 41	12 – 43	1 - 43	10 – 23	1
				7 – 38	2
Surface soil ^{40}K concentration [Bqkg^{-1}]	154 – 477	218 – 631	8 - 646	168 – 238	1
				39 – 485	2
Total external g-dose (calculated) [nSvhr^{-1}]	40 – 187	28 – 72	12 - 75	17 – 33	1
				14 – 68	2
Total external g-dose (measured) [nSvhr^{-1}]	63 – 331	50 – 180		45 – 60	1
					2
Soil gas radon (monitored at 0.6 – 0.8m) [kBqm^{-3}]	4 – 90	2 – 81		0.2 – 2.8	1
				0.3 – 1.6	2
Soil permeability [m^2]	10^{-15} – 10^{-9}	10^{-14} – 10^{-9}		10^{-12} – 10^{-11}	1
				10^{-13}–10^{-11}	2
Surface soil exhalation rate [mBqm^{-2}s^{-1}]	0 – 2166	0 – 230		0 – 12	1
				7 – 122	2
Radon in air concentration [Bqm^{-3}]	0 – 835	0 – 222		15 – 102	1
				0 – 200	2
Air particulate concentration [µgm^{-3}]	25 – 248	18 – 124		139	1
					2
Radon in water concentration [BqL^{-1}]	5 – 26			0 – 10	1

(*) Site 1: National Technical University of Athens, Zografos Campus.
Site 2: Lavrion lead mine (now exhausted), 50 km SE of Athens.



Surface (1cm) Soil Mapping
^{226}Ra (Bq/kg)

Geogr. Mean : 39 ± 11 Bq/kg

: Bq/kg < 35

: 35<= Bq/kg < 65

: 65<= Bq/kg <100

: 100<= Bq/kg <337

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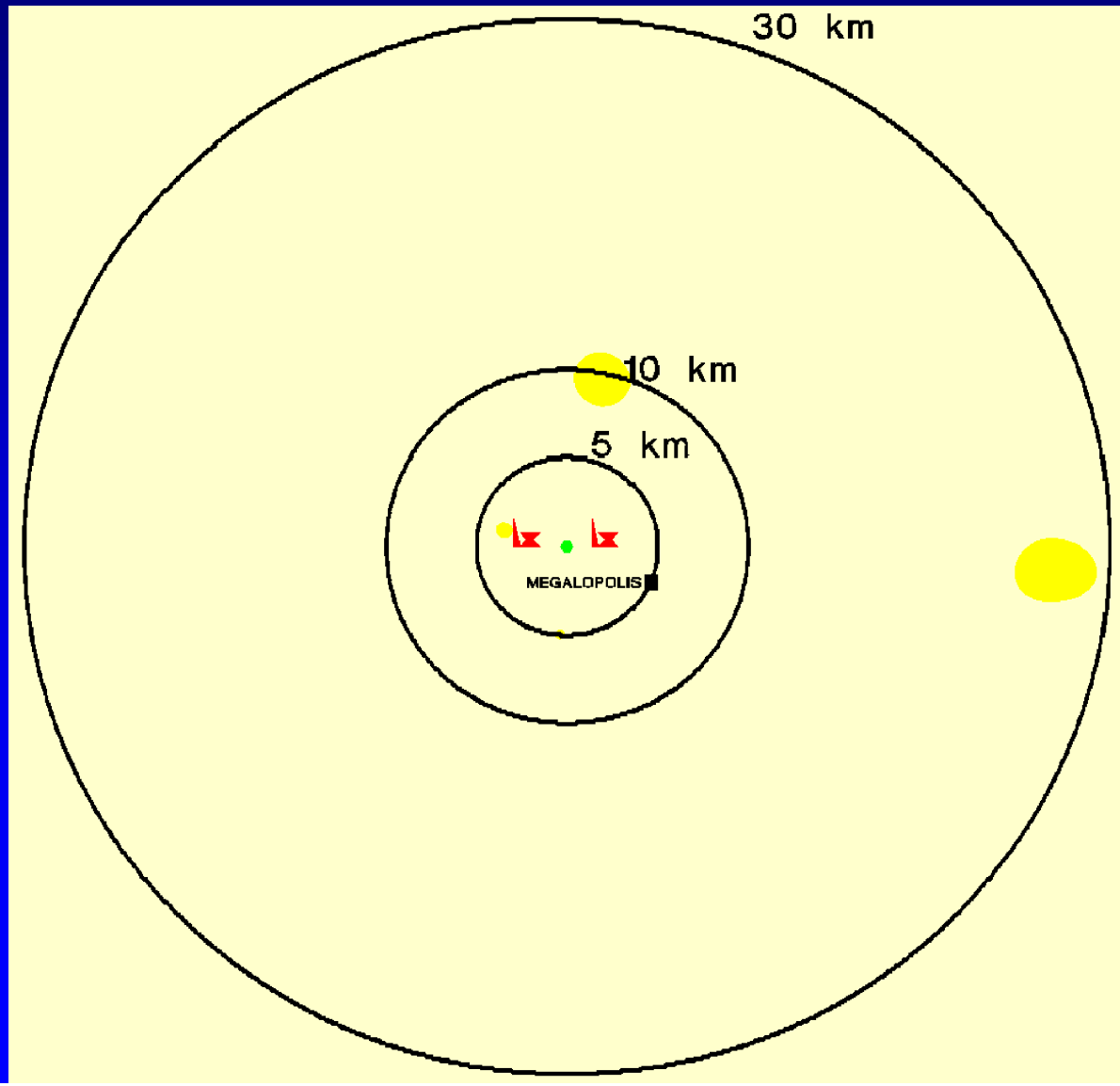

Surface (1cm) Soil Mapping
^{232}Th (Bq/kg)

Geogr. Mean : 18 ± 4 Bq/kg

: Bq/kg < 35

: 35<= Bq/kg < 65

: 65<= Bq/kg <100

: 100<= Bq/kg

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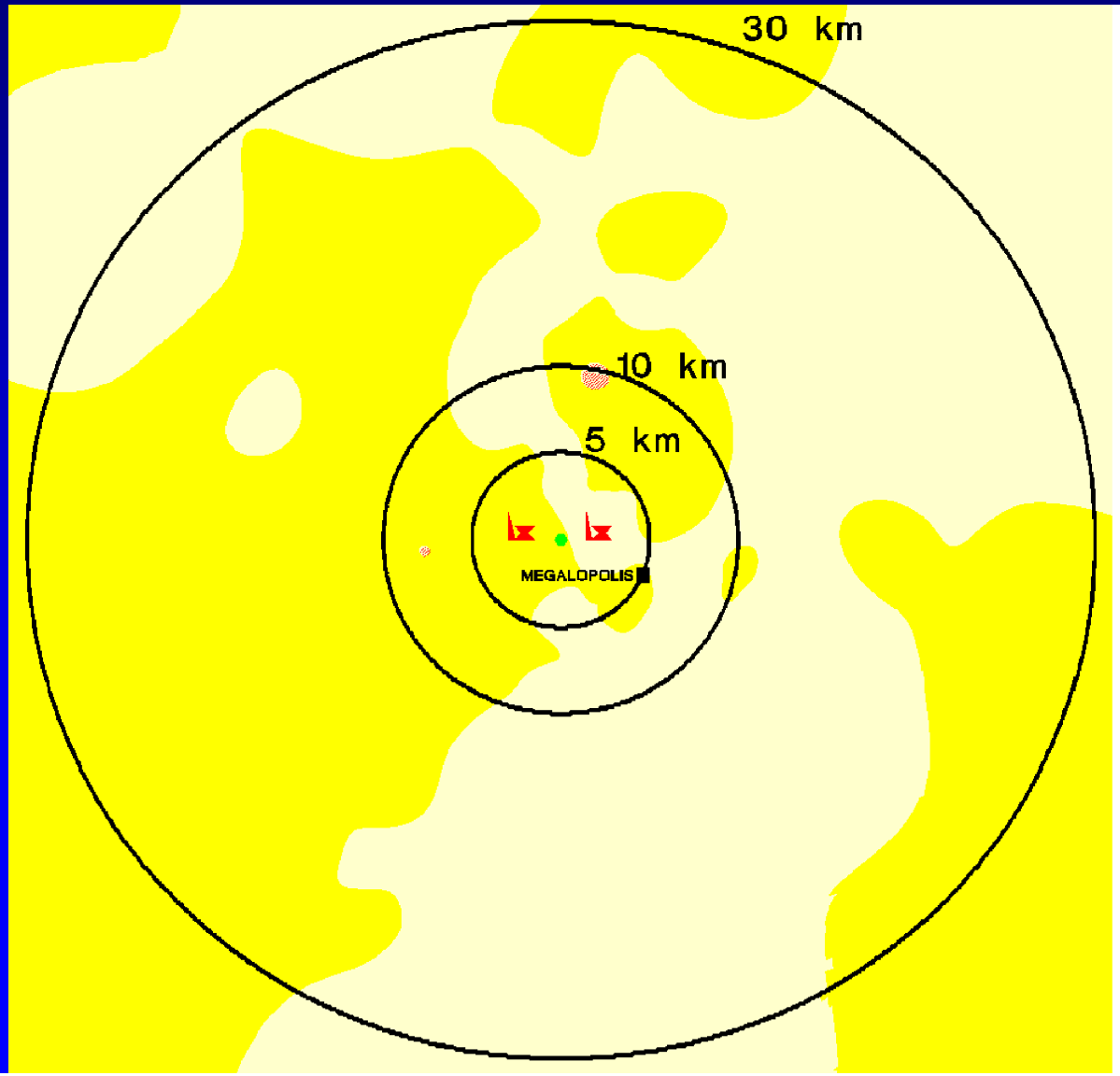

Surface (1cm) Soil Mapping
^{40}K (Bq/kg)

Geogr. Mean : 328±191 Bq/kg

: Bq/kg <300

: 300<= Bq/kg <600

: 600<= Bq/kg <900

: 900<= Bq/kg

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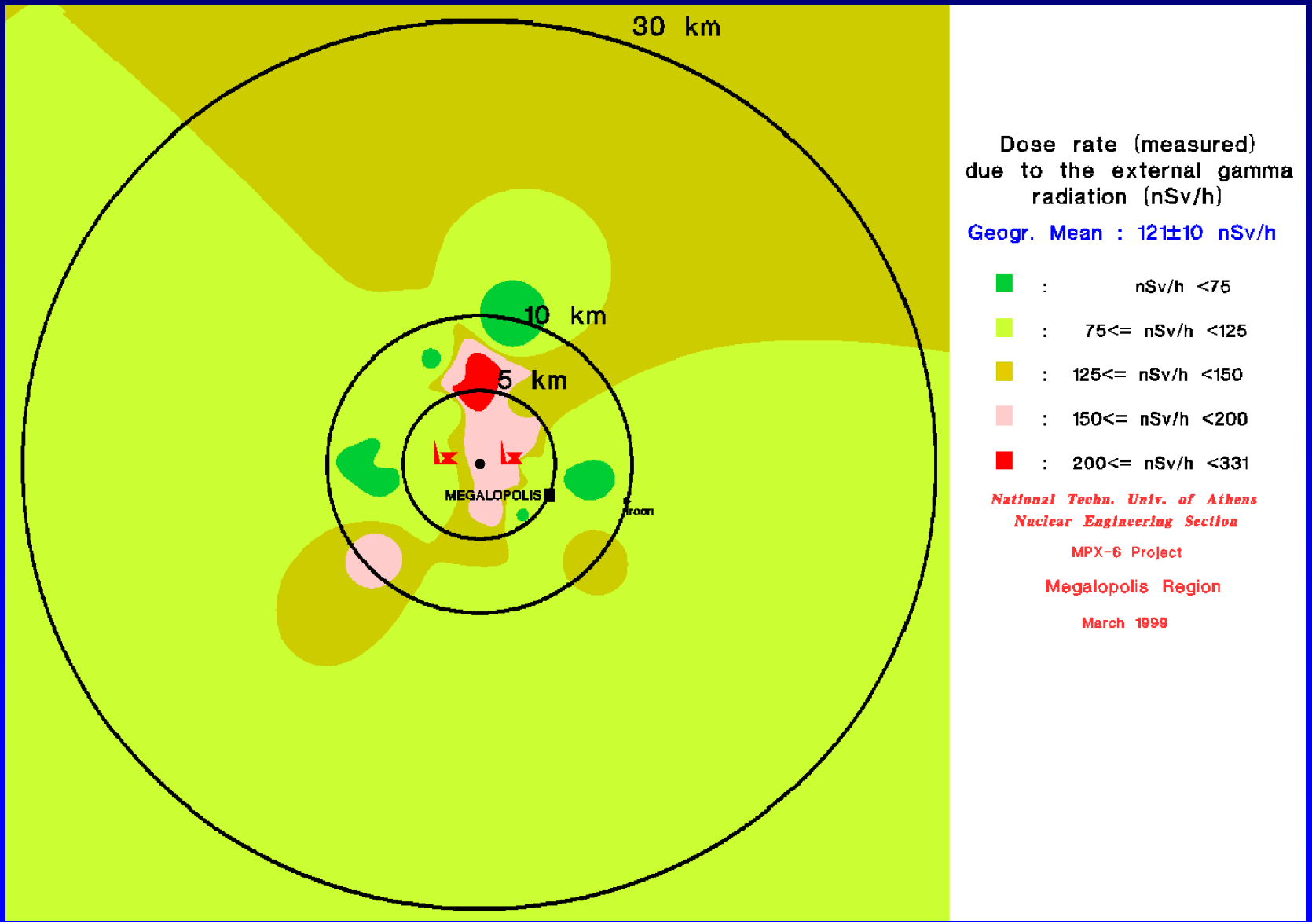
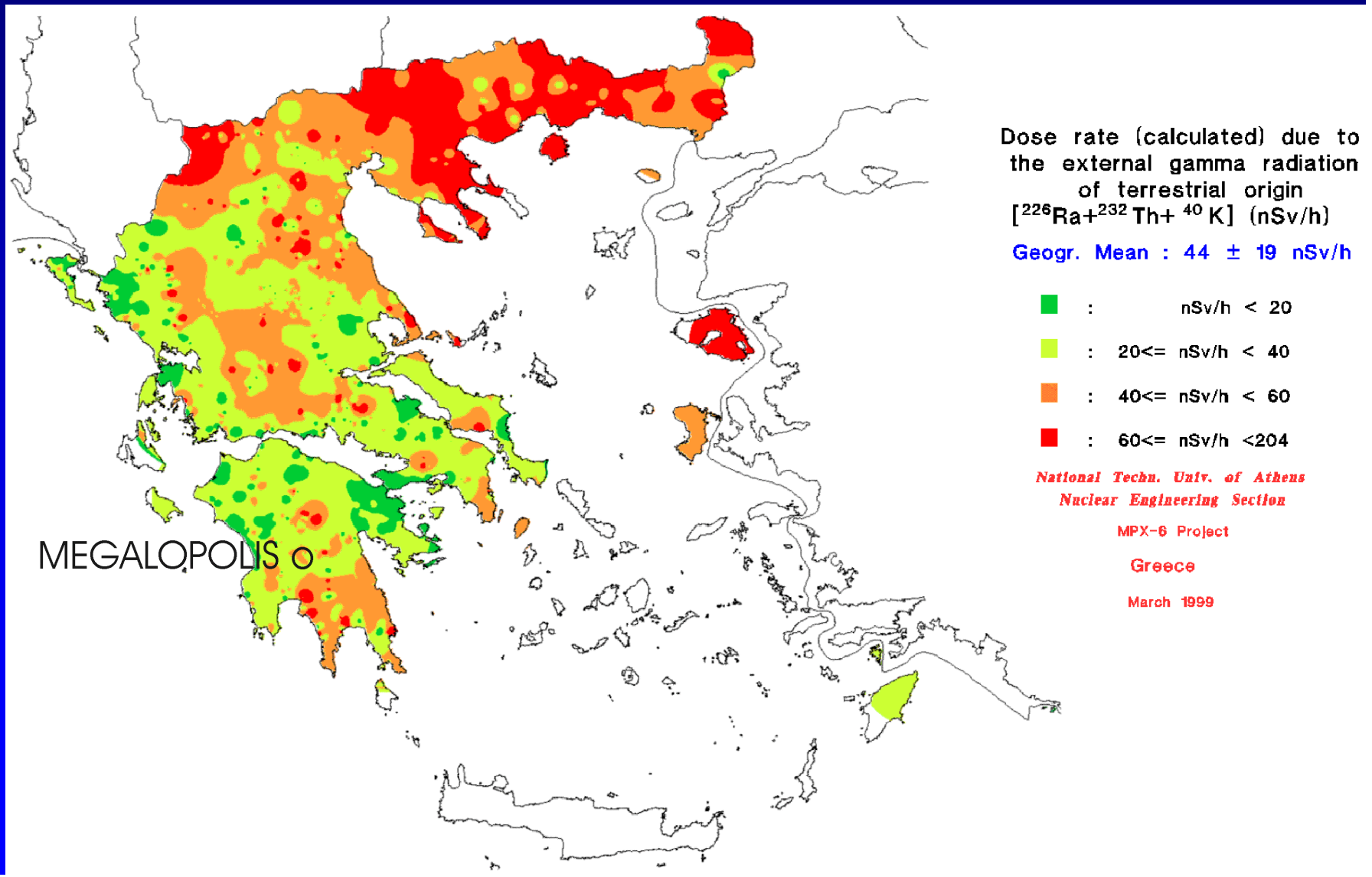
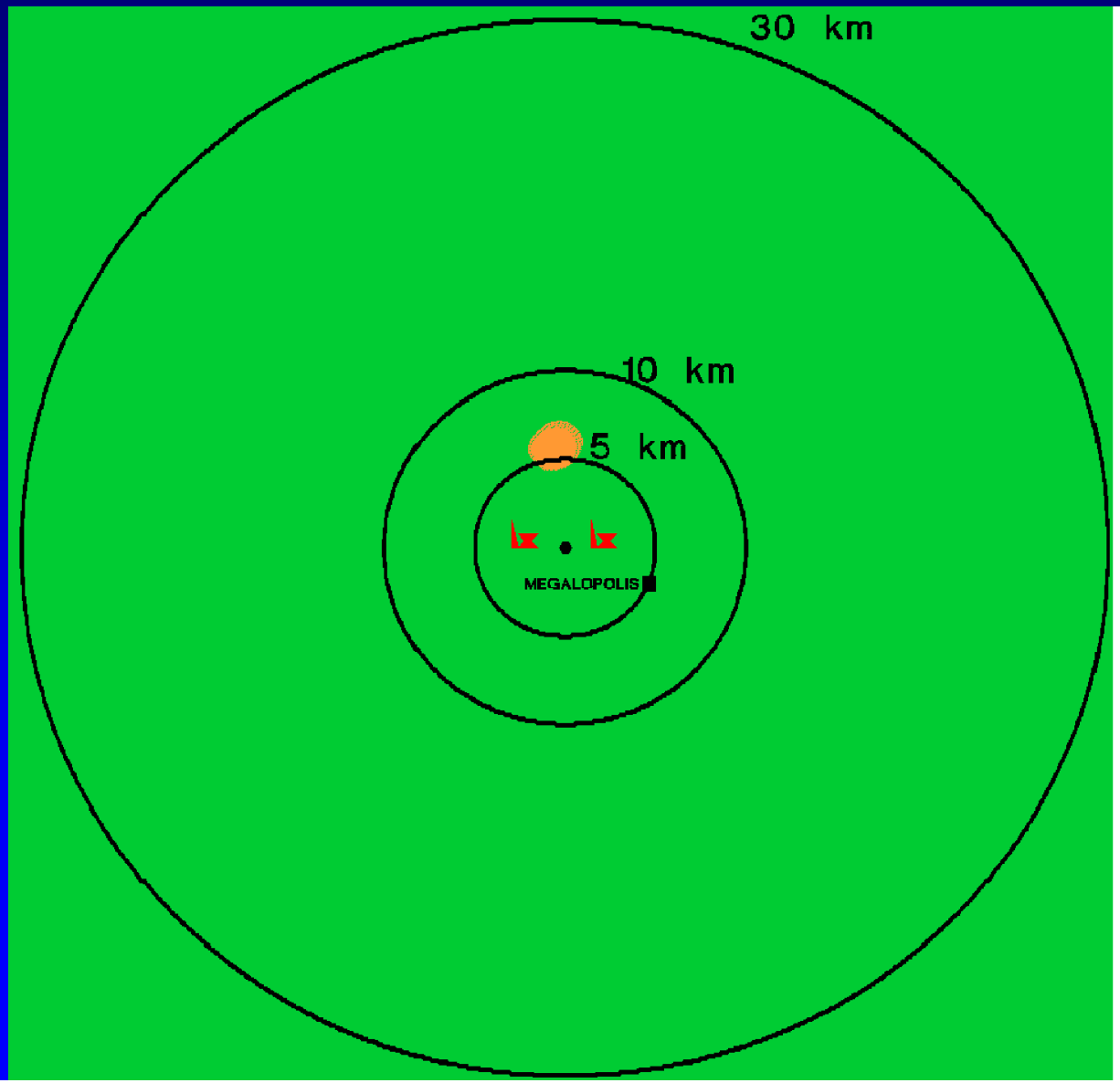
Dose Measurements



Dose calculation using measured surface soil concentrations and UNSCEAR-82



Dose calculation using measured surface soil concentrations and UNSCEAR-82



Dose rate (calculated) due to the external gamma radiation of terrestrial origin [^{226}Ra+^{232}Th+ ^{40}K] (nSv/h)

Geogr. Mean : 40 ± 9 nSv/h

: nSv/h <125

: 125<= nSv/h <150

: 150<= nSv/h <200

: 200<= nSv/h

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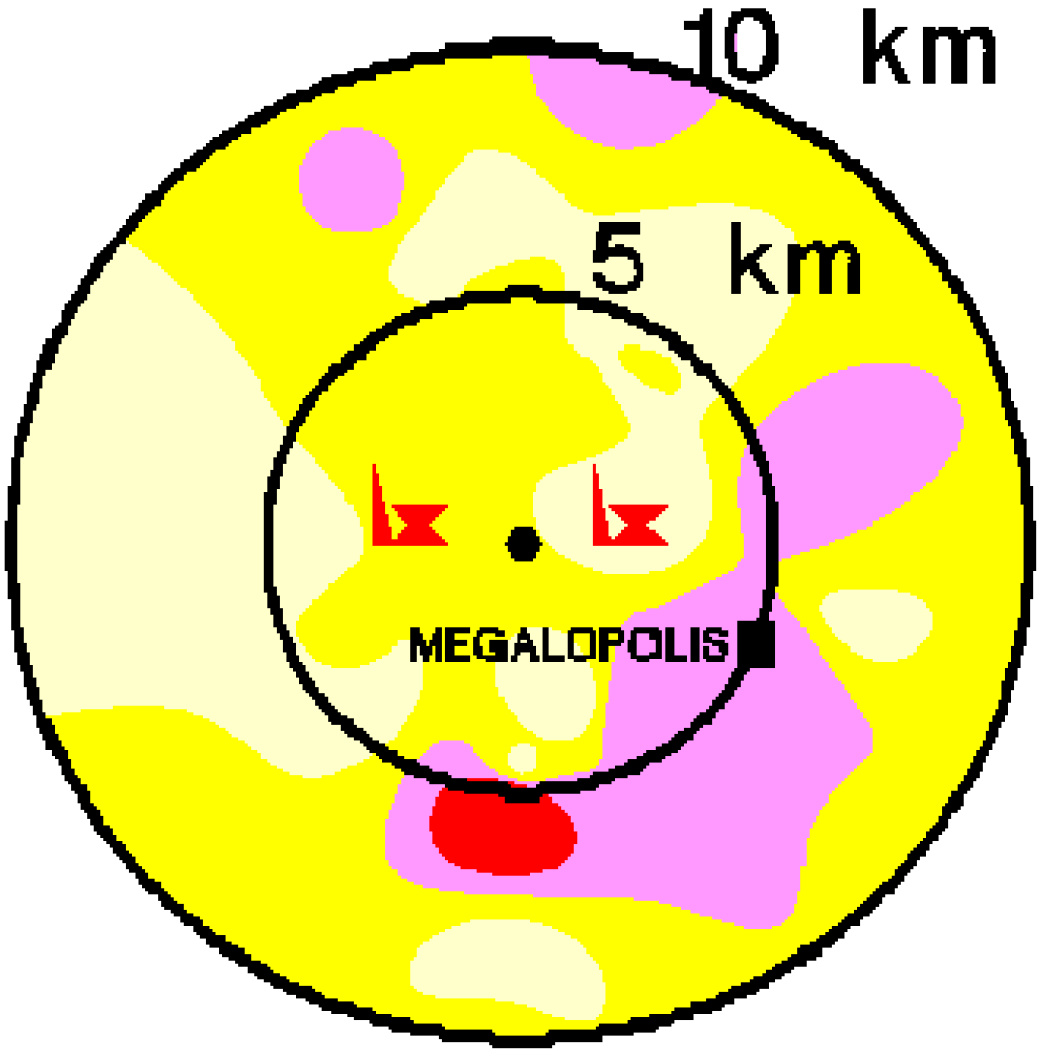
Comments on the calculated dose rate due to the external gamma radiation

- Within the 10 km area (mainly mine area):
  No satisfactory prediction of the external dose rate using dose conversion factors for ^{226}Ra, ^{232}Th and ^{40}K supplied by UNSCEAR-82.

- Outside the 10 km area:
  Satisfactory prediction using the above conversion factors.



Radon Concentration
in soil gas ($kBqm^{-3}$)

Geogr. Mean : 27 ± 4 kBqm-3

: kBqm-3 <20

: 20<= kBqm-3 <35

: 35<= kBqm-3 <50

: 50<= kBqm-3 <90

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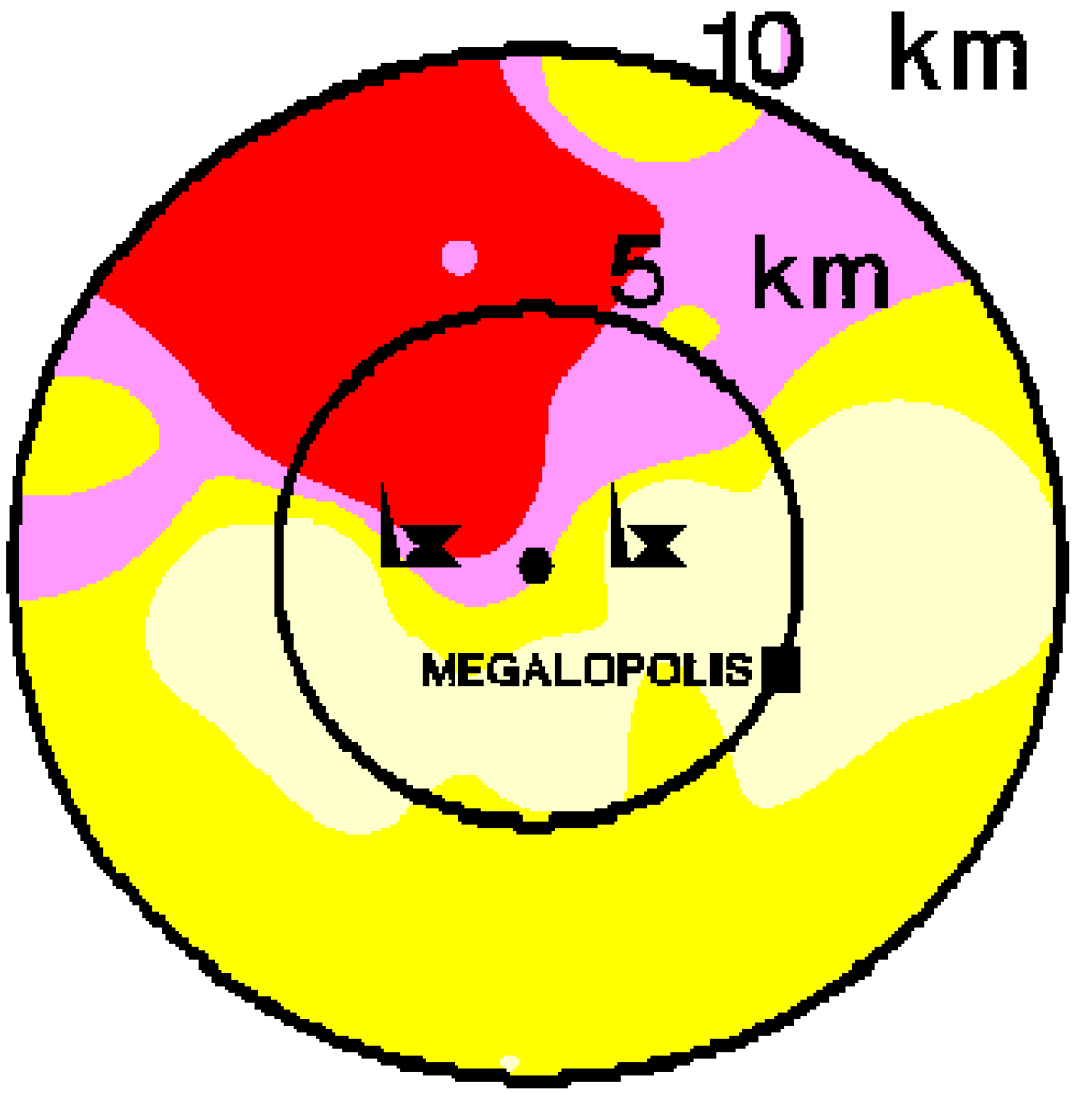

Radon Exhalation rate from soil ($mBqm^{-2}s^{-1}$)

Geogr. Mean : 130±76 mBq/m2s

: mBq/m2s <40

: 40<= mBq/m2s <100

: 100<= mBq/m2s <200

: 200<= mBq/m2s <2166

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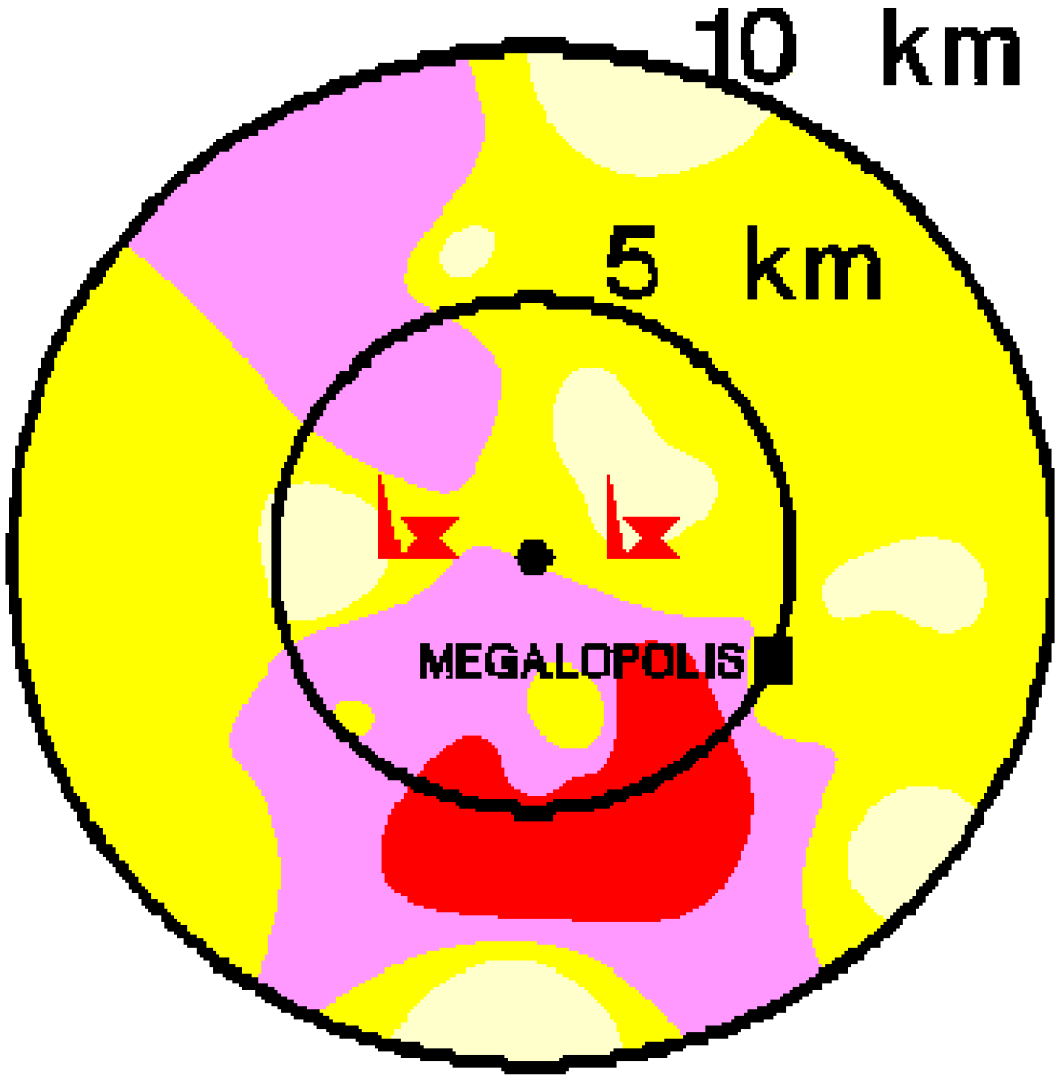

Radon Concentration
Outdoors (Bqm^{-3})

Geogr. Mean : 104±28 Bqm-3

: Bqm-3 <50

: 50<= Bqm-3 <100

: 100<= Bqm-3 <250

: 250<= Bqm-3 <835

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It seems that...

- The pattern of ^{226}Ra surface soil mapping is similar to that of radon exhalation.
- The pattern of radon concentration outdoors mapping is similar to that of radon concentration in soil gas.
- The fact that the patterns of radon exhalation and radon concentration outdoors are not similar, may be due to the hill effect in the south part of Megalopolis region and meteorological conditions.
- Further investigation needed.

C O N C L U S I O N S

1. The values of most of the radioenvironmental indicators examined, within the 0-5 km radius from the plants are higher compared to those within the 5 – 10 km radius; the latter seem reasonable.
2. It seems that within the 5 – 10 km radius from the plants, the examined indicators are not statistically different from reference values measured at the Athens greater area.
3. Assuming the worst case, that all air particulates detected consist of fly ash with ^{226}Ra concentration 1000 $Bqkg^{-1}$, the resulting ^{226}Ra concentration in the air does not exceed the level of 250 μBqm^{-3}, which is by far below the Derived Air Concentration Limit of 10 Bqm^{-3} (ICRP 30).

SOME PRELIMINARY DOSIMETRIC CALCULATIONS - WORST CASE SCENARIO

I. Gamma Dose rate

- Maximum external gamma dose rate ranging between 125 to 250 nSv/h .
- Population: 12000 inhabitants.
- The resulting Collective Dose (CD) ranges between 13 to 26 manSv/yr.
- UNSCEAR 1982: Collective Effective Dose Equivalent Commitment due to external irradiation because of the activity deposited following power plants atmospheric releases is estimated to 0.081 manSv/yr .
- Mean gamma dose rate for Greece (46 nSv/h) results to a CD of 4.8 manSv/yr.

SOME PRELIMINARY DOSIMETRIC CALCULATIONS
II. Dose due to Radon Concentration Outdoors

- Equilibrium Equivalent Radon Concentration (EEC) recorded outdoors in Megalopolis region up to 500 Bqm^{-3}
- Population: 12000 inhabitants.
- UNSCEAR 1982: The resulting Collective Effective Dose Equivalent Commitment (CEDEC) is estimated to 150 manSv/yr.
- UNSCEAR 1982: CEDEC due to Radon + daughters because of power plants atmospheric releases is estimated to 0.2 manSv/yr.

THE FUTURE

1. Future work should be focused on investigating the justification of the suggested UNSCEAR radiological assessment.
2. The dosimetric modelling of the plants staff and the population living around the power plants will be further investigated taking into consideration all the above collected information.
3. The various radioenvironmental processes of the basin will be modelled by extending and tuning existing appropriate numerical models.