RADIOACTIVITY CONTROL OF THE DANUBE AT YUGOSLAV-HUNGARIAN BORDER AREA

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INTRODUCTION

The first unit of the Paks Nuclear power plant (NPP) in Hungary was started on December 29, 1982. Therefore 1982 was considered the last year for determination of the "initial state" of radioactivity of the Danube. The results of these measurements were presented in the Report of the Institute "Ruđer Boškoviæ" in 1989 [1].

The test operation of the second unit of the Nuclear power plant started in August 1984, of the third unit in September 26, 1986, and trial run of the forth unit began on August 15, 1987.

Accordingly, since December, 1987, the Paks Nuclear power plant has had the total capacity of 1760 MWe, namely, all four units were completed according to the scheme.

In the period 1987-2000, all four units of the Paks Nuclear power plant were running regularly, except in the maintenance periods, which according to plan, may last one month a year, for each unit alternately, or two months annually every four year.

The maximum permissible annual activity release and radioactivity emissions from Paks Nuclear power plant during 1997-1999 are presented in Table 1.

Table 1: Radioactivity emission from Paks NPP during 1997-1999

Year		**Gross beta**	**^{3}H**	**^{90}Sr**
	Permissible annual activity release (Bq/year)	$1.48 \cdot 10^{10}$	$3.00 \cdot 10^{13}$	$1.48 \cdot 10^{8}$
1997	Radioactivity emission (Bq/year)	$6.66 \cdot 10^{8}$	$1.56 \cdot 10^{13}$	$1.04 \cdot 10^{7}$
	% of limit	4.5	52.0	7.0
1998	Radioactivity emission (Bq/year)	$8.83 \cdot 10^{8}$	$1.99 \cdot 10^{13}$	$9.06 \cdot 10^{6}$
	% of limit	6.0	66.3	6.1
1999	Radioactivity emission (Bq/year)	$1.08 \cdot 10^{9}$	$2.02 \cdot 10^{13}$	$7.1 \cdot 10^{6}$
	% of limit	7.3	67.3	4.8

According to INES (International Nuclear Event Scale) [2] few anomalies and incidents have happened in the Paks Nuclear power plant. In 1997, there was one anomaly (level 1) and one incident (level 2), in 1998 - four incidents (level 2) and in 1999 three incidents (level 2). These events had no effect to the environment.

YUGOSLAV-HUNGARIAN COLLABORATION

The radioactivity control of the Danube by two countries was performed from 1988 to 1991, when this collaboration was discontinued due to war in former Yugoslavia.
Pursuant to the Protocol of XXXV session of Yugoslav-Hungarian Commission for management of water resources, held in Valence from December 9-12, 1996, it was concluded to keep on monitoring the radioactivity of the Danube river through the Subcommissions for water quality protection which were founded in both countries.
The water samples from the Danube were taken at the border profiles: Bezdan (Yugoslavia) and Mohacs (Hungary), from 1997 to 1998 four times a year, and from 1999 six times annually.
Gross beta activity and gammaspectrometry were measured in the samples of filtrated water, suspended material, sediment, algae and fish. ^{90}Sr activity was determined in all samples but algae due to small quantity of the sample. Tritium activity was measured only in water samples.

SAMPLING AND SAMPLE PREPARATION

The samples are taken one time, at three profiles of the Danube (left bank, middle, and right bank of the river), by peristaltic pump (5 l of water sample) into plastic containers. The water sample is filtered through Quantitative ashes Advantec 0.45μm filter-paper (11cm in diameter) (suspended material). The filtrate is evaporated at the heating panel in crystallizer.
One by one kilogram of river sediment is taken by sampler and placed into plastic containers. The sediment is dried at 105^{o}C to constant weight, sieved through sieve and the fraction less than 250μm is taken.
Depending upon the catch, the measurement is carried out in two kinds of fishes (catch of 3kg each). The fish is dried at 450-500^{o}C to constant weight, fragmented and homogenized.
The algae are collected from the old boats being sunken in river water for a long time and from the docks of river ports. They are dried at 105^{o}C to constant weight, fragmented and homogenized.

METHOD OF MEASUREMENT

The measurement of gross alpha and beta activity is carried out by α-β-proportional gas counter “COUNTMASTER”. The level of basic radiation is from 1 - 1.5 imp/min. The size of planchet is 2.3 in diameter. The performance of counter is defined by KC1 standard of the same thickness as the sample.
Tritium activity is determined in water sample which is filtered, distilled and electrolytically enriched. The water volume of 9 ml is added with 11 ml of scintillation

solution. ^{3}H activity is measured by Liquid Scintillation spectrometer in plastic bottles of 20 ml. Immediately prior to measurement, the sample stands for a while in the counter for thermostasis [3].

Radiochemical method of ^{90}Sr separation is based on oxalate isolation of Ca and Sr, ignition to oxides and usage of aluminum as ^{90}Y carrier. The equilibrium is achieved in 18 days, and after that time ^{90}Y is isolated on $Al(OH)_3$ carrier [4], which is then ignited to oxide that is subsequently measured by α-β anti-coincidence counter. The size of planchet is 2.3 cm in diameter. The performance of counter is 24% and is determined by ^{90}Sr standard.

Gammaspectrometry is carried out on pure germanium detector manufactured by EG&G "ORTEC", which is connected with multichannel analyzer (8192 channels) produced by the same manufacturer and with adequate computer facilities. Energetic calibration, as well as calibration of detector efficiency is performed by means of Amersham radioactive standard [5-9]. The time of measurement for a single sample is 60000 to 100000 s, while it is 250000 s for basic radiation.

RESULTS OF MEASUREMENT

The results of measured sample radioactivity, in the period from 1997 to 2000, are illustrated in the graph, comparing with the results of measurements in the "initial state" [1].

Mean annual values of measurements of gross beta activity of filtrated water, suspended material, river sediment, algae and fish are presented on graphs 1-5, respectively, the results of ^{90}Sr measurement on graphs 6-8, and the measurements of tritium activity in filtrated water of the Danube are illustrated on graph 9. Mean annual values of ^{137}Cs activity in sediment are presented on graph 10, while in algae and fish are demonstrated on graphs 11 and 12, respectively.

CONCLUSION

The results of radioactivity measurements in samples of the Danube river, from 1997 to 2000, were compared to the measurements carried out for determination of the "initial state" (before the Paks Nuclear power plant started running). The results of measurements of gross beta activity (water, sediment, algae and fish), ^{3}H activity (water), ^{90}Sr activity (water, sediment and fish) and gammaspectrometry (water, sediment, algae and fish) reveal that the values are at the same level as they were before the Paks Nuclear power plant started running. The measurements of ^{137}Cs activity in sediment samples, from 1997 to 2000, show some increase of activity in relation to the "initial state", what could be assigned to contamination caused by Chernobyl Nuclear power plant accident in 1986.

Our results of measurements correlate well with the results of Hungarian part.

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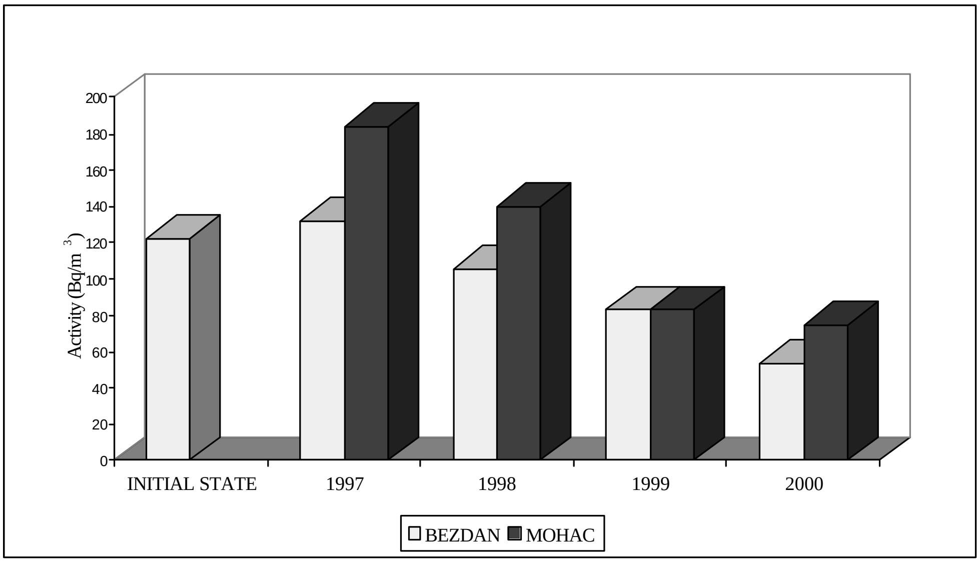
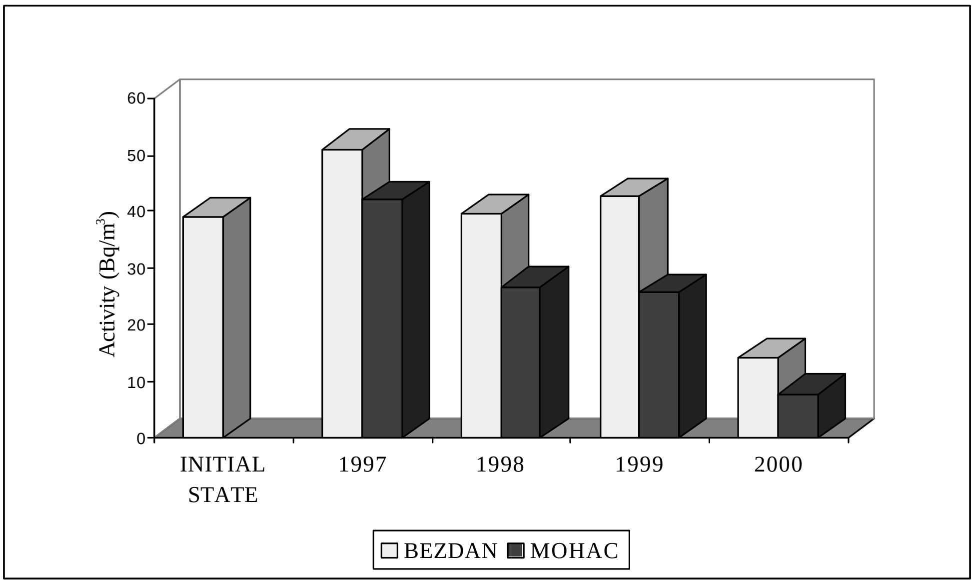
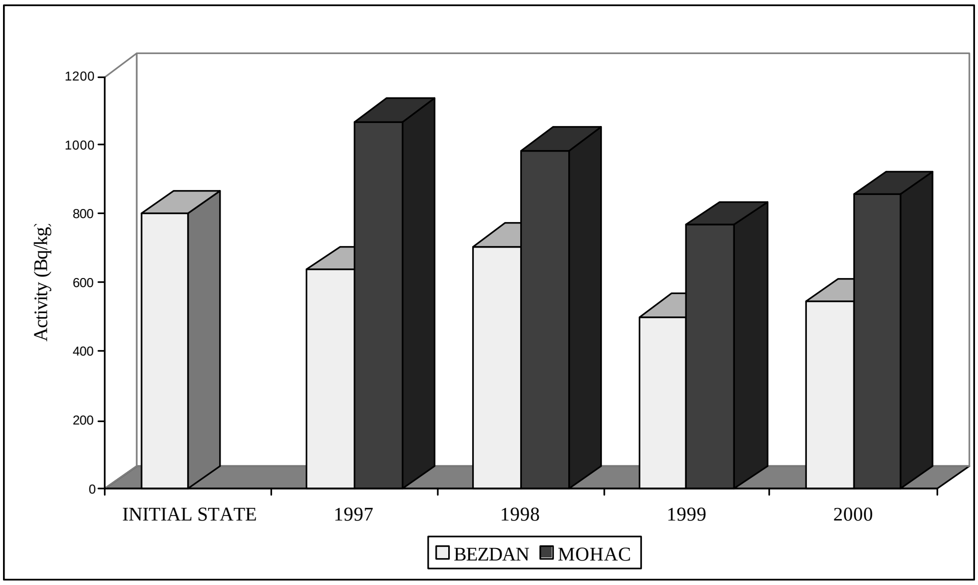


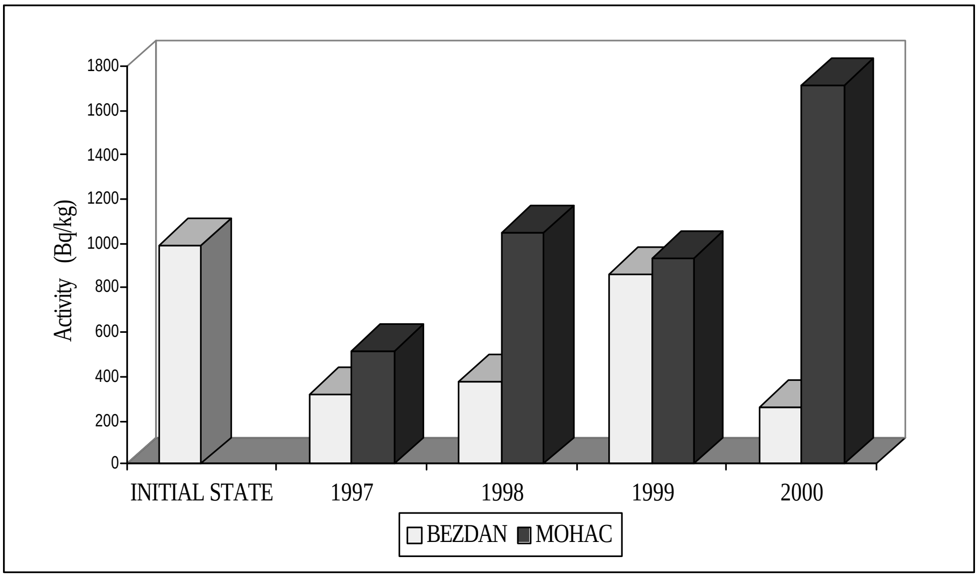
Graph 1: Gross beta activity in filtrated water of the Danube (mean annual values)



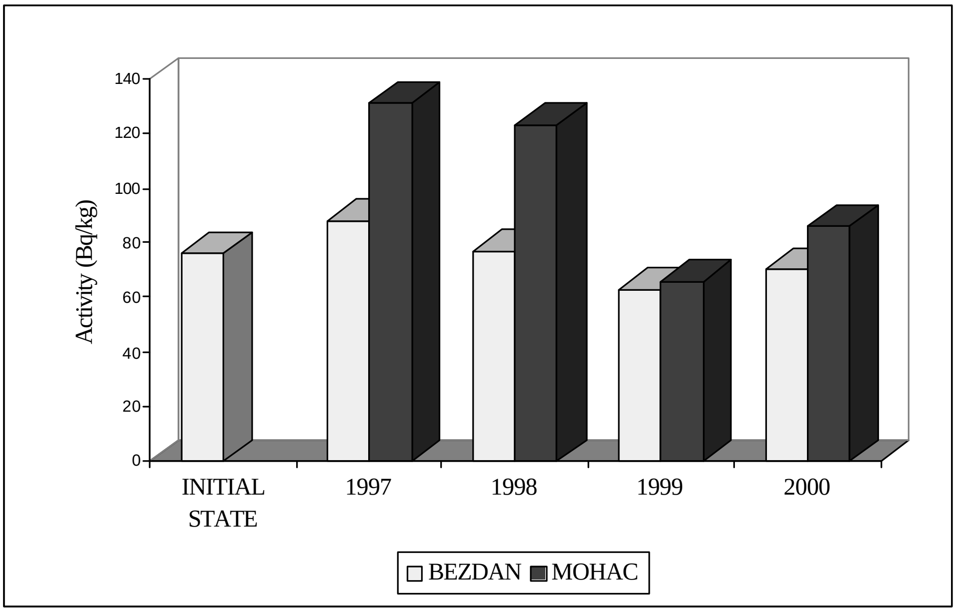
Graph 2: Gross beta activity in suspended material of the Danube (mean annual values)



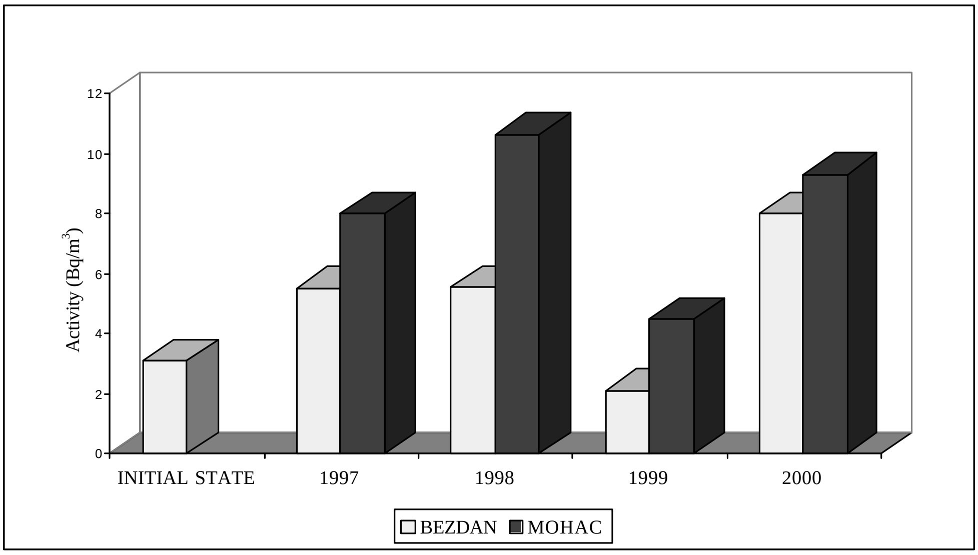
Graph 3: Gross beta activity in river sediment of the Danube (mean annual values)



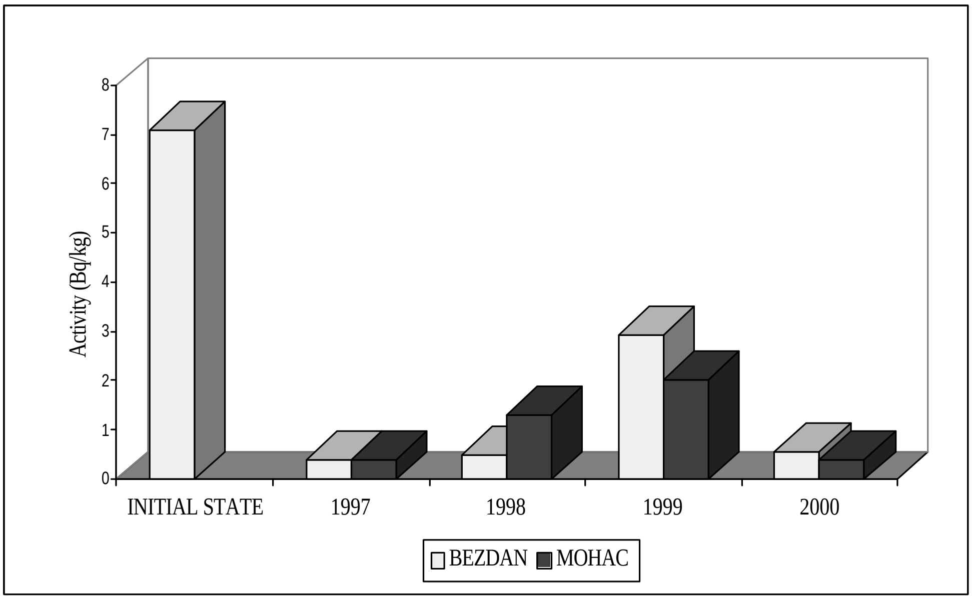
Graph 4: Gross beta activity in algae of the Danube (mean annual values)



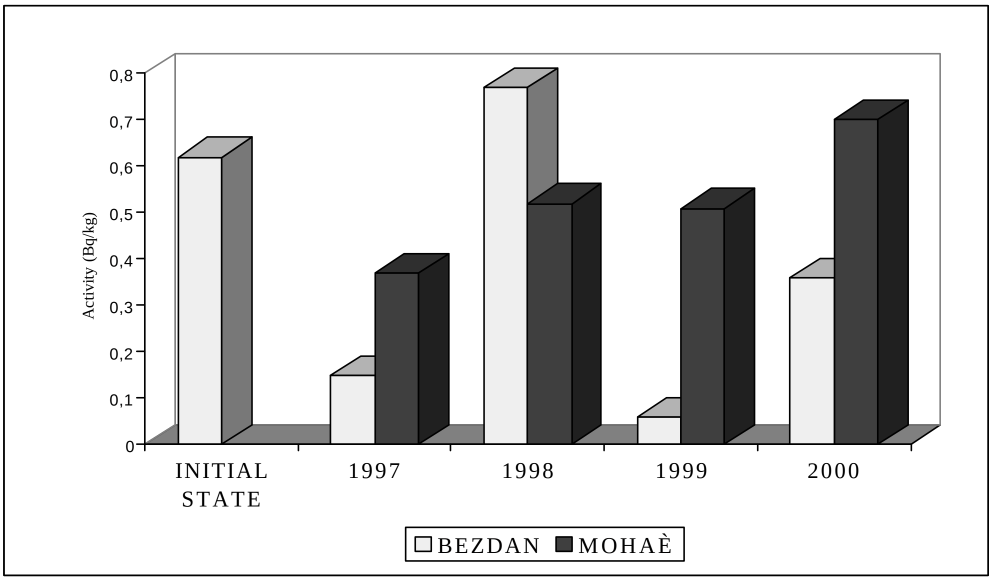
Graph 5: Gross beta activity in fish of the Danube (mean annual values)



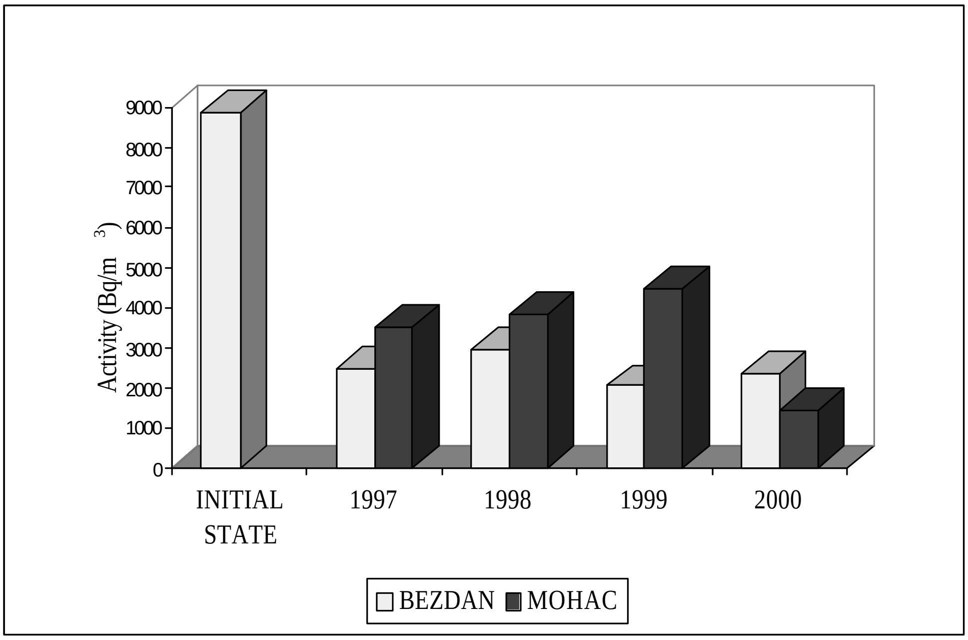
Graph 6: ^{90}Sr activity in filtrated water of the Danube (mean annual values)



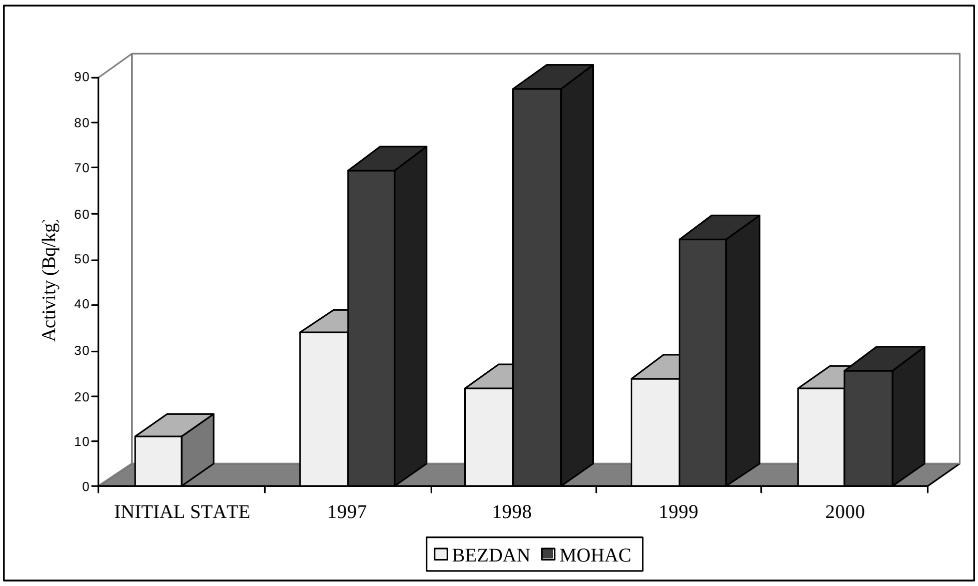
Graph 7: ^{90}Sr activity in river sediment of the Danube (mean annual values)



Graph 8: ^{90}Sr activity in fish of the Danube (mean annual values)



Graph 9: ^{3}H activity in filtrated water of the Danube (mean annual values)



Graph 10: ^{137}Cs activity in river sediment of the Danube (mean annual values)

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