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PREDICTION MODEL FOR ^{90}Sr LEVEL IN MILK

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A model used by *UNSCEAR* (1) to describe the transfer of ^{90}Sr from deposition to milk is presented. The data collected in 25 years concerning ^{90}Sr levels in fallout and milk are given for the Zagreb area.

The model shows a very good agreement with empirical data and a statistically significant relationship between ^{90}Sr level in milk and ^{90}Sr level in fallout (correlation index is 0.987).

Since 1945 ^{90}Sr has been present in the environment as a product of nuclear fission following nuclear weapon tests. It is a pure beta emitter with a half-life ($T_{1/2}$) of 29.1 years. During a nuclear explosion ^{90}Sr is produced in the amount of approximately 3.7×10^{15} Bq per Mt of fission energy. Measurements of the fission debris from large nuclear tests gave a ^{90}Sr fission yield estimate of 3.5% (1). Although ^{90}Sr is not released in nuclear experiments in amounts as large as some of the short-lived radionuclides, its deposition in bone makes it one of the most toxic osteotropic radionuclides along with ^{210}Pb and ^{210}Ra. Due to chemical similarity to Ca, ^{90}Sr is secreted into milk and therefore ingested by infants which makes it a major environmental contaminant.

The behaviour in the environment of ^{90}Sr produced in nuclear explosions has been extensively studied, especially the fallout — vegetation — milk pathway which is generally the most significant route by which humans are exposed. Much of the literature has been referenced in *UNSCEAR* reports (1, 2). To assess the transfer of ^{90}Sr from fallout to milk *UNSCEAR* (1) recommends a transfer model expressed by equation:

$$C(i) = b_1 f(i) + b_2 f(i-1) + b_3 \sum_{m=1}^{\infty} e^{-\mu m} f(i-m) \qquad (1)$$

C(i) — the $^{90}Sr/Ca$ (Bq/g) quotient in milk in year »i«
f(i) — the annual deposition density of ^{90}Sr (Bq/m²) in year »i«
f(i—1) — the annual deposition density of ^{90}Sr (Bq/m²) in year »i—1«
$\sum_{m=1}^{\infty} e^{-\mu m} f(i-m)$ — the cumulative deposit ^{90}Sr (Bq/m²) in the soil in all previous years

b_1, b_2, b_3 — the parameters which can be derived from reported data by regression analysis (Bq/gCa per Bq/m²)

μ — the parameter which can be derived from reported data by regression analysis (year^{-1}).

The model defines the ^{90}Sr fraction in milk which comes from direct deposition onto foliage, the fraction due to stored food for cattle contaminated by radioactive fallout in the previous year and the ^{90}Sr fraction transferred from the soil.

Because of the correspondence in the behaviour of strontium and calcium in the environment and in man, it has been the practice to express measurement results in food and bone as quotients of ^{90}Sr to Ca concentrations. Discrimination is reflected as ratios of strontium to calcium quotients in samples to those in precursor samples in the transfer chain:

Atmosphere (1) → Earth's surface (2) → Diet (3) → Tissue (4)

By applying the correlation model (1) it is possible to determine a transfer factor, referred to in literature as P_{23}, representing the transfer from radioactive fallout to milk (1):

$$P_{23} = b_1 + b_2 + b_3 \left(\frac{e^{-\mu}}{1-e^{-\mu}} \right) \qquad (2)$$

MATERIAL AND METHODS

Since 1961 samples of fallout and milk have been continuously collected in the Zagreb area. ^{90}Sr was determined by the conventional radiochemical analysis with fuming nitric acid separation (2) and since 1970 to date by extraction with tributyl phosphate (3).

To assess ^{90}Sr levels in milk in the Zagreb area a transfer model based on the ^{90}Sr fallout levels was applied. The data were processed by regression analysis for optimal assessment of parameters in the mathematical model which is quantitatively most approximate to variations of the obtained data. The degree of agreement between observed variations enables the assessment and behaviour prediction of the derived variables (4, 5).

RESULTS AND DISCUSSION

Figure 1 illustrates the ^{90}Sr values measured in fallout in the Zagreb area. Peak values were recorded in 1963, a year following the most active nuclear tests. From 1963 to 1967 ^{90}Sr levels were exponentially decreasing (6) and since 1967 ^{90}Sr fallout levels have been gradually declining with periodical oscillations due to Chinese nuclear weapon testing. Owing to its metabolic behaviour, which is similar to that of calcium, ^{90}Sr is transferred from plants to animals and its level in milk follows the one in fallout as shown in Figure 2.

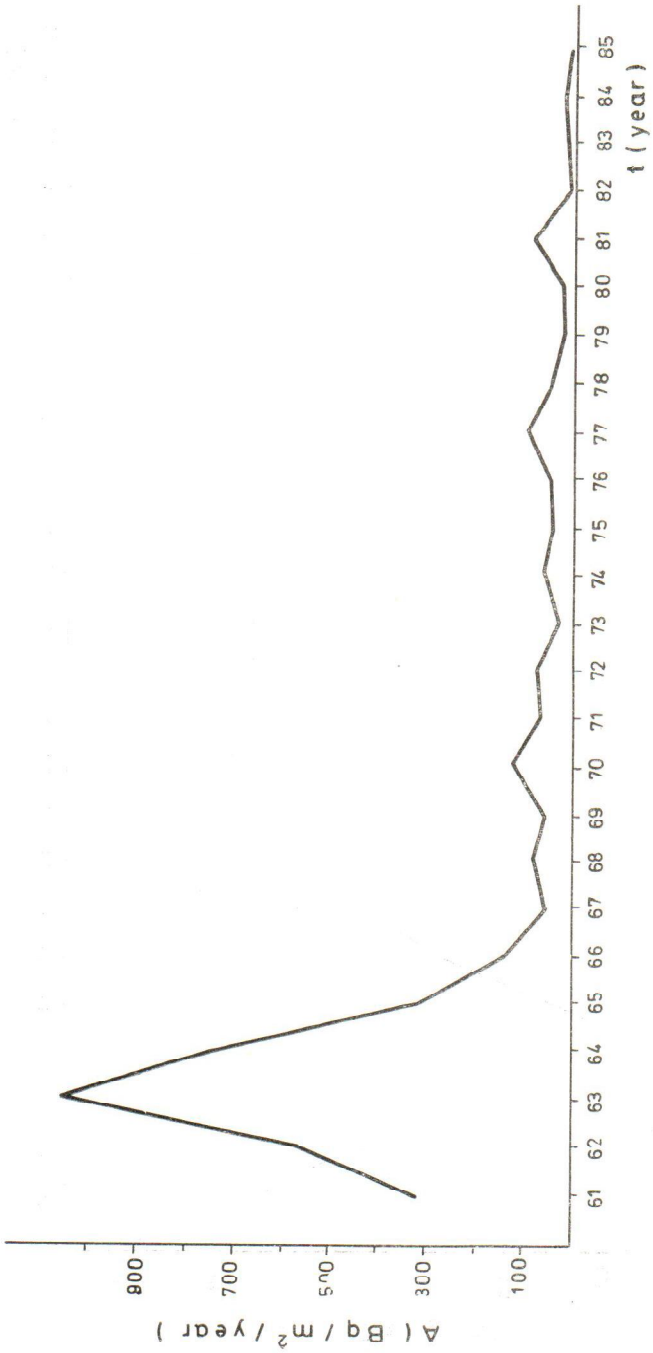

Fig. 1. — *^{90}Sr in fallout in the Zagreb area*

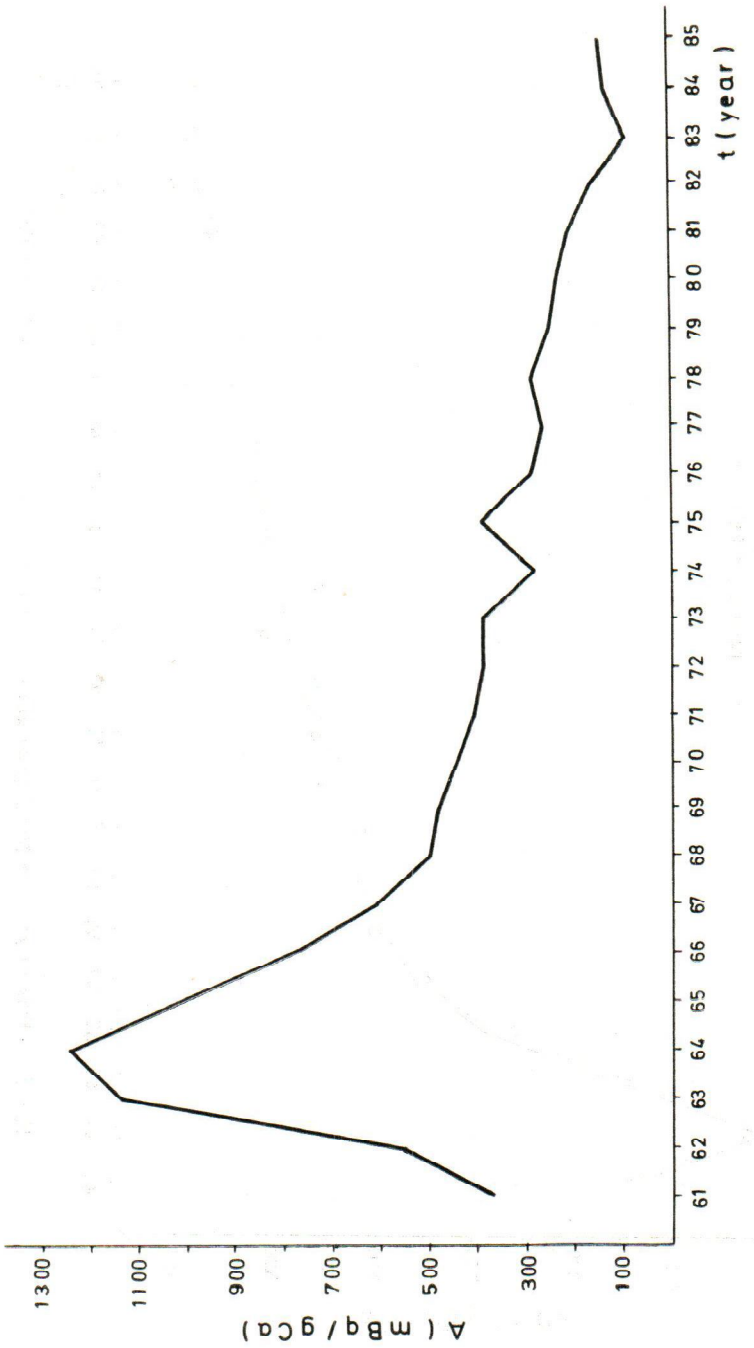

Fig. 2. — ^{90}Sr *in milk in the Zagreb area*

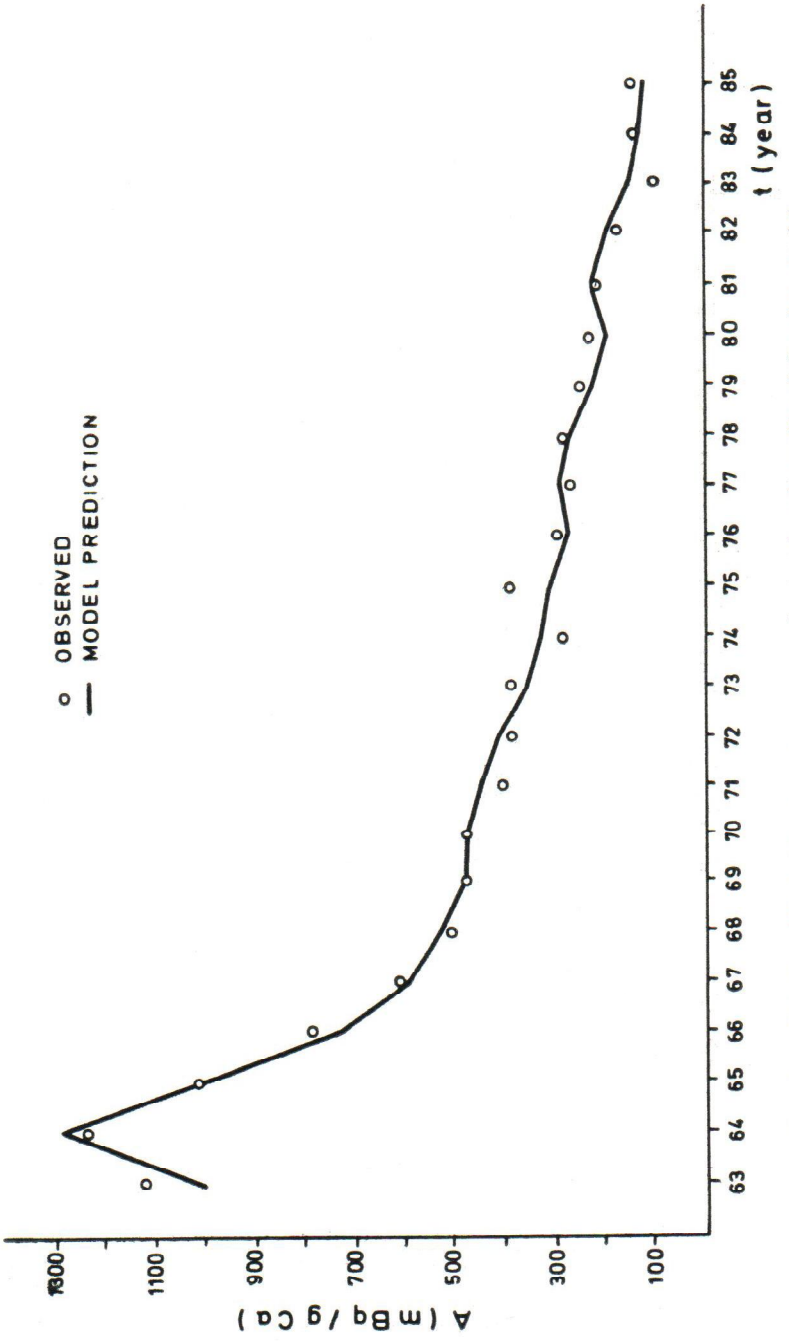

Fig. 3. — *^{90}Sr in milk in the Zagreb area — observed and predicted by the model*

The regression model provides a good correlation between ^{90}Sr/g Ca levels in milk and ^{90}Sr in fallout (Figure 3) and a correlation index of 0.987 points to a statistically significant relationship at the significance level of less than 1% ($P<0.01$).

In addition to this the model gives a possibility to estimate the amount of ^{90}Sr in milk which has been originally directly deposited on plants and of ^{90}Sr transferred fom the soil (by uptake it enters vegetable cattle feed).

The parameters for ^{90}Sr level assessment (b_1, b_2, b_3, μ) and transfer factor P_{23} are given in Table 1.

Table 1

Parameters and transfer factor for ^{90}Sr level assessment

b_1 (mBq/g Ca per Bq/m²)	0.66
b_2 (mBq/g Ca per Bq/m²)	0.35
b_3 (mBq/g Ca per Bq/m²)	0.27
μ (year^{-1})	0.14
P_{23} (mBqy/g Ca per Bq/m²)	2.87

If b_1 and b_2 values for 1985 are inserted in the model 95% of ^{90}Sr found in milk can be attributed to uptake from the soil, whereas according to *Klusek* (7) in 1954 direct deposition on plants due to frequent nuclear tests accounted for 100% of the ^{90}Sr contamination of milk.

The transfer factors P_{23} compared for New York (8, 9) and for the Zagreb area point at an approximately identical ^{90}Sr transfer to milk which is reasonable considering the geographical latitudes of the two cities.

The model to predict ^{90}Sr level for 1986 will be discussed in the future after ^{90}Sr levels in the environment caused by the Chernobyl reactor accident are evaluated.

ACKNOWLEDGEMENT

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Sažetak

MODEL ZA PREDSKAZIVANJE AKTIVNOSTI ^{90}Sr U MLIJEKU

U radu je opisan model transfera ^{90}Sr od radioaktivnih padavina do mlijeka koji je predložio UNSCEAR (1).

Sakupljeni su podaci o aktivnosti ^{90}Sr u radioaktivnim padavinama i mlijeku iz područja Zagreba. Model pokazuje vrlo dobro slaganje s empirijskim podacima i statistički značajnu povezanost između aktivnosti ^{90}Sr u mlijeku i radioaktivnim padavinama (indeks korelacije je 0,987).

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