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On the reduction of internal radiation doses resulting from ingestion of Cs-137 in areas contaminated by the Chernobyl accident

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Abstract. After the Chernobyl reactor accident wide areas of Belarus were contaminated with radioactive fallout. A population group of special concern comprise children living in contaminated regions. Recent data on the radiation burden of children indicate that the international annual population dose limit of 1 mSv is still exceeded in some cases. In situations where common means of dose-reduction are not sufficient, the clarification of the usefulness of additional means, such as the cure-like application of pectin preparations, makes sense. A reduction of the equivalent biological half-life through the use of a pectin preparation by a factor of 2.5 has been observed in a double-blind study. Though for the age class of ten year old children a simplified scenario indicates that an avoidance of up to one third of the annual internal effective dose might be achievable by two 4-week cure-like pectin applications the most advisable way of averting dose remains the permanent use of clean food.

INTRODUCTION

After the Chernobyl reactor accident wide areas of Belarus were contaminated with radioactive fallout. The verification and documentation of the long-term development of radiation doses is still going on. A population group of special concern comprises the children

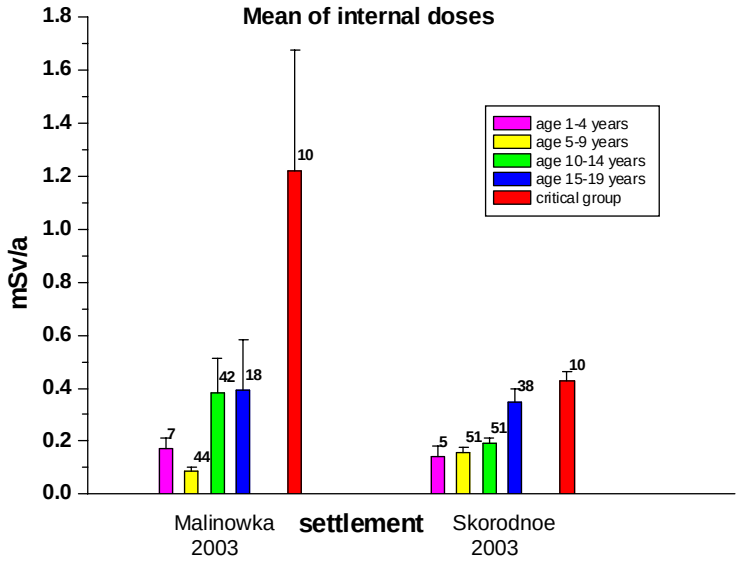

Fig. 1 : For two selected settlements the arithmetic mean of the internal dose is shown for different age groups as well as the critical group[1] [1]. Numbers at the bars indicate the number of persons measured.

[1] The critical group is defined as the 10 persons in the age range of 1-19 years with the highest dose.

living in contaminated regions. Of the two million Belarusian children, approximately 80000 live in regions contaminated after the Chernobyl accident by a ^{137}Cs deposition of more than 185 kBq/m². A German-Belarusian project has been investigating radiation doses of children in those regions for several years. In a recent paper [1] it had been shown, that the annual dose limit of 1 mSv is still exceeded in some cases (Figure 1), essentially due to high body burdens of Cs-137 as indicated by screening measurements with portable incorporation monitors.

Means of dose reduction such as remediation of agricultural land had been investigated in the past and generally already contribute to a reduction of food contamination. Also the use of clean food and the control of food contamination has generally proven its effectiveness and the latter is exercised by official authorities and private initiatives. In situations where this is not sufficient, the clarification of the usefulness of additional means, such as the cure-like application of pectin preparations, makes sense. A dose-lowering effect is presumed by Belarusian and Ukrainian scientists.

In the framework of the present German-Belarusian project special attention is given to the cure-like application of a Belarusian pectin preparation (Vitapect). Vitapect consists of apple pectins with added vitamins, mineral nutrients and flavour substances. It is currently in use in Belarus in accordance with legal regulations and licensed by the Belarusian authorities.

METHODS

During their stay in a Belarusian sanatorium eight groups of internally contaminated children were treated with the pectin preparation Vitapect (5 g twice a day) for a two-week period in a placebo-controlled double-blind study. For comparison the same number of control groups were given a placebo preparation. A total of 729 children participated in the study, each of the groups comprising between 40 and 50 children. All children were under medical control.

In the sanatorium it is general policy to supply children only with uncontaminated food. Thus any new ^{137}Cs incorporation is avoided, which may falsify the results of the study. The ^{137}Cs body burden of each child was measured at the beginning and end of the treatment with Vitapect and a placebo. For the whole-body measurements BELRAD's portable chair-type in-vivo monitors (Scrinner-3M) were used. The quality of these measurements was ensured by several intercomparison exercises with three mobile whole-body counters of the Research Centre Jülich [3] as well as internal quality assurance measures.

The relative reduction of the specific activity was calculated as the difference of the specific activities from the first and the second measurement divided by the specific activity from the first measurement. For a considerable number of children at least one of the whole-body counting measurements yielded results below the minimum detectable activity of the in-vivo monitors. Those children were excluded from the statistical analysis. To the remaining distribution of the relative reduction of the specific activity the outlier test of Nalimov was applied and after removing the outliers in the distribution, the data of 285 children in the pectin groups and 330 children in the placebo groups remained for statistical analysis, i.e. 615 out of the participating 729 children.

To investigate the potential impact of blocking uptake from the gastrointestinal tract theoretical calculations were performed with the Cs retention model of Leggett et al. [4]. The calculations were based on the assumption that at the beginning (t=0) the distribution of caesium in the different organs approximated to equilibrium conditions. Although the calculation of the retention functions within this model is strictly valid only for adults in a

good approximation results on whole-body retention for other age groups might be obtained by scaling according to the biological half-life. The system of coupled differential equations involved in the Cs retention model does not have an analytical solution. Therefore values of the retention functions have been calculated for selected points of time numerically.

Estimations of potential dose reduction were done for certain simplified scenarios. It turned out that with a sufficient accuracy the numerically calculated retention for the phase of removal of Cs from the body could be approximated by a single exponential function. In-growth of activity was calculated based on the biological half-lives of ICRP 56 [5].

RESULTS AND DISCUSSION

The statistical analysis results in a relative reduction of the specific activity for the pectin groups of 32.4 % (arithmetic mean) and 33.6 % (median), respectively, whereas the specific activity of the children who received a placebo decreased only by 14.2 % (arithmetic mean) and 13.1 % (median), respectively. This corresponds to a significant reduction of the observed mean effective half-life by a factor of 2.5 from 69 days for the placebo groups to 27 days for the pectin groups.

Table 1 : Statistical evaluation of the experimental data (values in parentheses are the standard deviations of the respective arithmetic mean value)

	pectin groups	placebo groups
Total number of children evaluated		
Male	149	170
Female	136	160
Total	285	330
Age of the children (arithmetic mean)	12.9 (± 0.2) years	12.6 (± 0.2) years
Specific activity of the children at the first measurement (arithmetic mean)	58.2 (± 3.4) Bq/kg	50.8 (± 2.0) Bq/kg
Relative reduction of the specific activity	32.4 (± 0.6) %	14.2 (± 0.5) %

Details about the sex and age and specific activity of the children are summarized together with the relative reduction of the specific activity in Table 1. The frequency distributions of the activity reduction are published elsewhere [2].

Two whole-body retention functions calculated according to the Cs retention model of Leggett et al. [4] and scaled to the effective biological half-life are shown in Figure 2 . The first curve represents the effect of replacing contaminated food by clean food effective from t=0. Since vitamins and minerals contained in the placebo are not expected to influence retention this curve can be considered to represent the case of additional placebo intake as well. The second curve corresponds to the case where in addition to using clean food the uptake of ^{137}Cs from the gastrointestinal tract is completely blocked, also effective from t=0. The result is a reduction of the effective half-life by a factor of 2.4 . Such a reduction has already been discussed by Legett et al. [4] in modelling the blocking effect of Prussian Blue.

Although the calculation of the retention functions is strictly valid for adults only this factor can be assumed to be widely independent of age, since in a good approximation results on whole-body retention for other age groups might be obtained by scaling according to the biological half-life [4]. The observed reduction of mean effective half-life (69 days → 27

days) corresponds to a factor of 2.5. This reduction is represented in Figure 2 by a yellow dot at the 0.4-fold of the biological half-life. It can be easily seen, that there is good agreement with the model calculation, which is based on the assumption of complete blocking of uptake from the GI-tract, i.e. the observed data are compatible with this assumption. Therefore it can be concluded qualitatively that Cs is blocked to a great degree. However data might not be precise enough to conclude quantitatively on the exact degree of blocking. To better clarify this point additional studies on the effect of pectin preparations in those environments where food is not clean would be advisable.

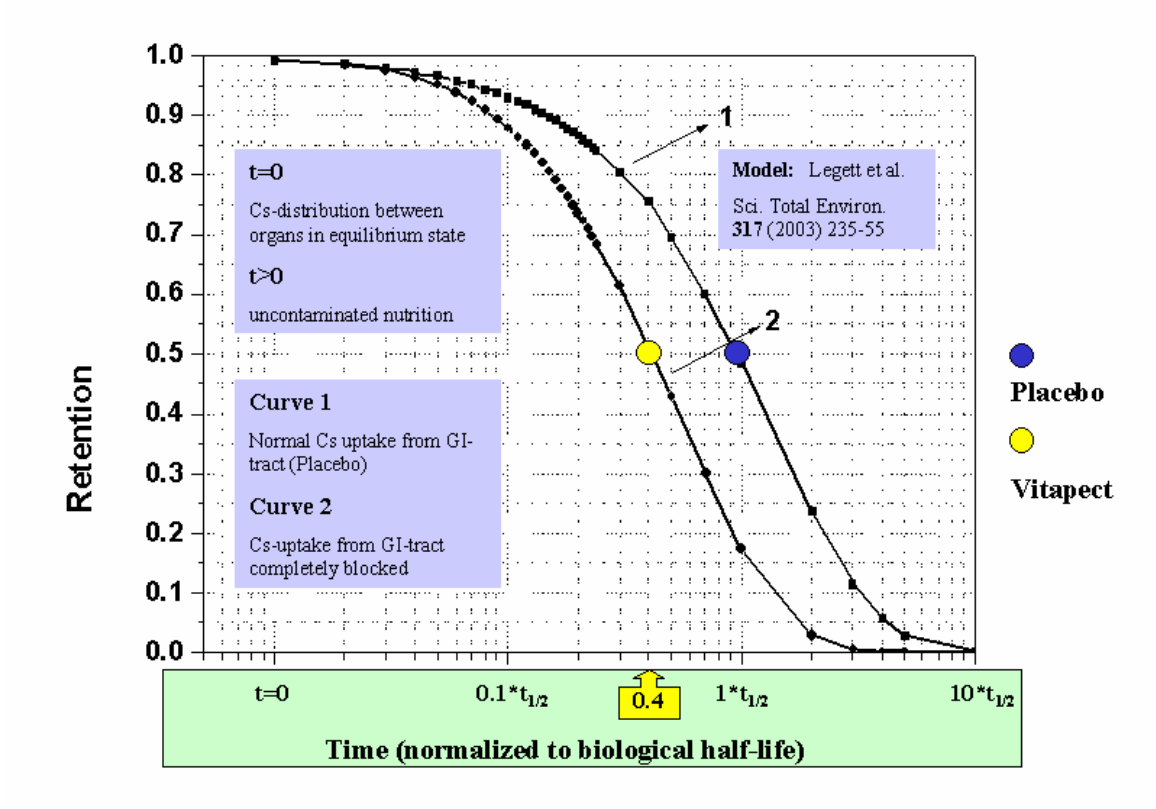

Fig. 2 : Theoretical whole-body retention of Cs according to the model of Legett et al. [4]. Small black dots indicate the points of time where numerical solutions were obtained. Lines are drawn to guide the eye.

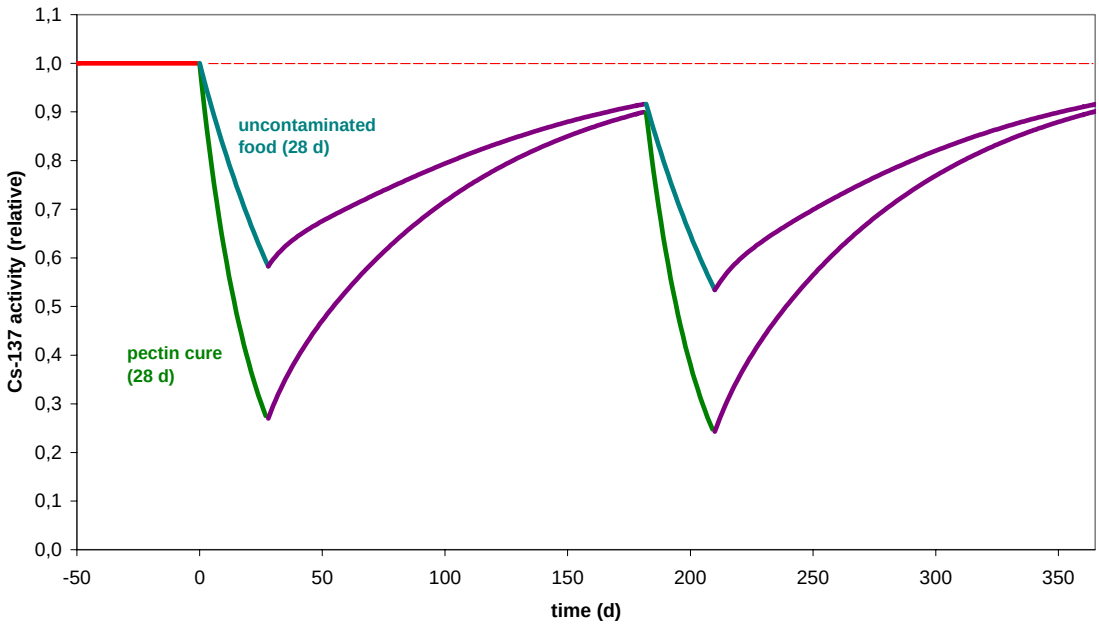

Fig. 3: Retention functions for the age-group of ten-year-olds in the case of cure-like pectin application for a period of four weeks followed up after half a year by a second four week treatment. See text for further details.

The decorporation effect of pectins seems to be similar to that of Prussian Blue, a proven and recommended decorporation agent for ^{137}Cs, which has been studied e.g. in connection with the radiological accident in Goiânia, Brazil [4,6]. Incorporated caesium is excreted into the intestine, partially reabsorbed from there and then excreted again into the gastrointestinal tract. Orally administered pectins probably chemically bind caesium in the gastrointestinal tract, prevent its reabsorption from the intestine and thereby increase faecal excretion. Thus, the biological half-life of ^{137}Cs is significantly reduced during a decorporation therapy.

A question of considerable interest is how much dose might be averted by the cure-like application of pectins. An estimation has been done for different simplified scenarios and children of about 10 years of age[2]. It is assumed that in the beginning the Cs-distribution in the different organs is in equilibrium. It is further assumed that the observed body burden did build up by ingesting constantly the same daily amount of Cs. The scenarios also have in common a build up of body burden after the end of treatment assuming the same constant daily intake as before the treatment. This corresponds to children returning into their original environments without taking further precautionary measures.

Table 2 : The percentage of effective dose possibly averted for 10-year-olds within one year after the start of a cure-like treatment with pectin compared to the effect of clean nutrition during the same periods of time. Pectin values are calculated assuming complete blocking in the GI-tract. Numbers are given with 2 significant digits.

Description	Pectin	Clean nutrition	Pectin/Clean nutr.
Scenario 1: *Single cure-like treatment for a period of two weeks*	12 %	--	--
Scenario 2: *Single cure-like treatment for a period of four weeks*	18 %	12 %	1.5
Scenario 3: *Cure-like treatment for a period of four weeks, repeated after half a year*	33 %	22 %	1.5

The percentage of effective dose possibly averted within one year after the start of a cure-like treatment with pectin is given in table 2 for three scenarios and compared with the effect of clean nutrition for a corresponding period of time. Scenario one is equivalent to the situation encountered in the double-blind study. Scenarios two and three could be possible scenarios for a cure-like treatment in villages. It should however be noted that if the blocking of Cs in the GI-tract is not complete as assumed in the calculation, the percentage of internal dose averted will be less than given in table 2.

The development of retention of Cs in the whole-body is visualized for the third scenario in Fig. 3. In the light of third party funding of cure-like applications as it has been practised in Belarus this scenario can be of special practical interest. It seems like up to one third of the annual dose might be repressible through two cure-like applications of pectin for a period of 4 weeks each.

[2] After one year of continuous intake children of this age can be viewed as having reached an equilibrium distribution of Cs-activity between the different organs.

All children were under medical control during the double blind study. It could be shown, that the use of the pectin preparation ‚Vitapect' during a period of a fortnight maintains a positive equilibrium for the trace elements potassium, copper, zinc and iron. It should be expected that this finding would not change very much for an application period of 4 weeks, but this still needs to be investigated.

Though in the investigated scenarios pectin preparations seem to be 50 % more effective in averting dose than clean nutrition it is also clear that for application periods, which are long compared to the biological half-life, this advantage of a pectin treatment compared to the use of clean food vanishes. Thus the most advisable way of averting dose remains the permanent use of clean food. In those cases where the use of clean food for any odd reason is not practicable the cure-like application of pectin preparations might be helpful in averting too high doses from incorporation of ^{137}Cs.

CONCLUSIONS

This study has shown that the ^{137}Cs body burden of highly contaminated children can be significantly reduced by a cure-like application of a pectin preparation such as Vitapect. For the age class of ten year old children a simplified scenario indicates that a repression of up to one third of the annual internal effective dose might be achievable by two 4-week long cure-like pectin applications.

Twenty years after the Chernobyl accident doses above the ICRP population dose limit of 1 mSv/a are no longer acceptable, especially not for children. Therefore, honest efforts must be performed to reach this goal.

On the long term the most advisable way of averting dose remains the permanent use of clean food. In those cases where the use of clean food for any odd reason is not practicable or only a limited reduction of food contamination can be achieved, the cure-like application of pectin preparations might be helpful in averting too high doses from incorporation of ^{137}Cs.

In the present stage of the work it is not yet proven that results on the effect of pectin preparations obtained under clean food conditions can be directly transfered to environments where food is still contaminated to some degree. Additional investigations would be necessary to clarify this point. In this sense conclusions drawn must be regarded as provisional.

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