13. Decorporation of Chernobyl Radionuclides

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Tens of thousands of Chernobyl children (mostly from Belarus) annually leave to receive treatment and health care in other countries. Doctors from many countries gratuitously work in the Chernobyl contaminated territories, helping to minimize the consequences of this most terrible technologic catastrophe in history. But the scale and spectrum of the consequences are so high, that no country in the world can cope alone with the long-term consequences of such a catastrophe as Chernobyl. The countries that have suffered the most, especially Ukraine and Belarus, extend gratitude for the help that has come through the United Nations and other international organizations, as well as from private funds and initiatives. Twenty-two years after the Chernobyl releases, the annual individual dose limit in heavily contaminated territories of Belarus, Ukraine, and European Russia exceed 1 mSv/year just because of the unavoidable consumption of locally contaminated products. The 11-year experience of the BELRAD Institute shows that for effective radiation protection it is necessary to establish the interference level for children at 30% of the official dangerous limit (i.e., 15–20 Bq/kg). The direct whole body counting measurements of Cs-137 accumulation in the bodies of inhabitants of the heavily contaminated Belarussian region shows that the official Dose Catalogue underestimates the annual dose burdens by three to eight times. For practical reasons the curative-like use of apple-pectin food additives might be especially helpful for effective decorporation of Cs-137. From 1996 to 2007 a total of more than 160,000 Belarussian children received pectin food additives during 18 to 25 days of treatment (5 g twice a day). As a result, levels of Cs-137 in children's organs decreased after each course of pectin additives by an average of 30 to 40%. Manufacture and application of various pectin-based food additives and drinks (using apples, currants, grapes, sea seaweed, etc.) is one of the most effective ways for individual radioprotection (through decorporation) under circumstances where consumption of radioactively contaminated food is unavoidable.

There are three basic ways to decrease the radionuclide levels in the bodies of people living in contaminated territories: reduce the amount of radionuclides in the food consumed, accelerate removal of radionuclides from the body, and stimulate the body's immune and other protective systems.

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13.1. Reducing Radionuclides in Food

Soaking in water, scalding, salting, and pickling foods such as mushrooms and vegetables and processing the fats in milk and cheeses can reduce the amount of radionuclides in some foods severalfold.

Stimulation of the body's natural defenses through the use of food additives that raise one's resistance to irradiation is also useful. Among such additives are the antioxidant vitamins A and C and the microelements I, Cu, Zn, Se, and Co, which interfere with free-radical

formation. The additives prevent the oxidation of organic substances caused by irradiation (lipid peroxidation). Various food supplements can stimulate immunity: sprouts of plants, such as wheat, seaweed (e.g., *Spirulina*), pine needles, mycelium, and others.

Accelerating the removal of radionuclides is done in three ways (Rudnev *et al.*, 1995; Trakhtenberg, 1995; Leggett *et al.*, 2003; and many others):

- Increase the stable elements in food to impede the incorporation of radionuclides. For example, K and Rb interfere with the incorporation of Cs; Ca interferes with Sr; and trivalent Fe interferes with the uptake of Pu.
- Make use of the various food additives that can immobilize radionuclides.
- Increase consumption of liquids to "wash away" radionuclides—infusions, juices, and other liquids as well as enriched food with dietary fiber.

Decorporants (decontaminants) are preparations that promote the removal of incorporated radionuclides via excretion in feces and urine. Several effective decorporants specific for medical treatment of heavy radionuclide contamination are known (for Cs, Fe compounds; for Sr, alginates and barium sulfates; for Pu, ion-exchange resins, etc.). They are effective in cases of sudden contamination. In the heavily contaminated Belarussian, Ukrainian, and European Russian territories the situation is different. Daily exposure to small amounts of radionuclides (mostly Cs-137) is virtually unavoidable as they get into the body with food (up to 94%), with drinking water (up to 5%), and through the air (about 1%). Accumulation of radionuclides in the body is dangerous, primarily for children, and for those living in the contaminated territories where there are high levels of Cs-137 in local foodstuffs (see Chapter IV.12). The incorporation of radionuclides is now the primary cause of the deterioration of public health in the contaminated territories (see Chapter II for details), and all possible approaches should be employed to mitigate the consequences of that irradiation.

There is evidence that incorporation of 50 Bq/kg of Cs-137 into a child's body can produce pathological changes in vital organ systems (cardiovascular, nervous, endocrine, and immune), as well as in the kidneys, liver, eyes, and other organs (Bandazhevskaya *et al.*, 2004). Such levels of radioisotope incorporation are not unusual in the Chernobyl-contaminated areas of Belarus, Ukraine, and European Russia nowadays (see Chapter III.11 for details), which is why it is necessary to use any and all possible measures to decrease the level of radionuclide incorporation in people living in those territories. When children have the same menu as adults, they get up to five times higher dose burdens from locally produced foodstuffs because of their lower weight and more active processes of metabolism. Children living in rural villages have a dose burden five to six times higher than city children of the same age.

13.2. Results of Decontamination by the Pectin Enterosorbents

It is known that pectin chemically binds cations such as Cs in the gastrointestinal tract and thereby increases fecal excretion. Research and development by the Ukrainian Center of Radiation Medicine (Porokhnyak-Ganovska, 1998) and the Belarussian Institute of Radiation Medicine and Endocrinology (Gres' *et al.*, 1997) have led to the conclusion that adding pectin preparations to the food of inhabitants of the Chernobyl-contaminated regions promotes an effective excretion of incorporated radionuclides.

1. In 1981, based on 2-year clinical tests, the Joint Committee of the World Health Organization (WHO) and the U.N. Food and Agriculture Organization (FAO) on Food Additives declared the pectinaceous enterosorbents effective and harmless for everyday use (WHO, 1981).

2. In Ukraine and Belarus various pectin-based preparations have been studied as agents to promote the excretion of incorporated radionuclides (Gres', 1997; Ostapenko, 2002; Ukrainian Institute, 1997). The product based on the pectin from an aquatic plant (*Zostera*), known commercially as Zosterin-Ultra® is a mass prophylaxis agent used in the Russian nuclear industry. As it is a nonassimilated pectin, the injection of zosterine into the bloodstream does not harm nutrition, metabolism, or other functions. Zosterin-Ultra® in liquid form for oral administration was approved by the Ukrainian Ministry of Health (1998) and the Russian Ministry of Health (1999) as a biologically active (or therapeutic) food additive endowed with enterosorption and hemosorption properties.

3. In 1996, the BELRAD Institute initiated enterosorbent treatments based on pectin food additives (Medetopect®, France; Yablopect®, Ukraine) to accelerate the excretion of Cs-137. In 1999 BELRAD together with "Hermes" Hmbh (Munich, Germany) developed a composition of apple pectin additives known as Vitapect® powder, made up of pectin (concentration 18–20%) supplemented with vitamins B1, B2, B6, B12, C, E, beta-carotene, folic acid; the trace elements K, Zn, Fe, and Ca; and flavoring. BELRAD has been producing this food additive, which has been approved by the Belarussian Ministry of Health, since 2000.

4. In June–July 2001 BELRAD together with the association "Children of Chernobyl of Belarus" (France) in the Silver Springs sanatorium (Svetlogorsk City, Gomel Province) conducted a placebo-controlled double-blind study of 615 children with internal contamination who were treated with Vitapect (5 g twice a day) for a 3-week period. In children taking the Vitapect (together with clean food) Cs-137 levels were lowered much more effectively than in the control group, who had clean food combined with a placebo (Table 13.1 and Figure 13.1).

5. In another group of children the relative reduction in the specific activity of Cs-137 in the Vitapect-intake group was 32.4 ± 0.6%, and that of the placebo group was 14.2 ± 0.5% ($p > 0.001$), with a mean effective half-life for Cs-137 in a body of 27 days for the pectin group, as compared with 69 days without pectin. This was a reduction of the effective half-life by a factor of 2.4. These results mean that the pectin additive Vitapect with clean nutrition appears to be 50% more effective in decreasing the levels of Cs-137 than clean nutrition alone (Nesterenko *et al.*, 2004).

TABLE 13.1. Decreased Cs-137 Concentration after Using Vitapect for 21 Days (Total 615 Children) in 2001 in the Silver Springs Belarussian Sanatorium (BELRAD Institute Data)

	Concentration of Cs-137, Bq/kg		
Group	Before	In 21 days	Decrease,%
Vitapect	30.1 ± 0.7	10.4 ± 1.0	63.6*
Placebo	30.0 ± 0.9	25.8 ± 0.8	13.9

*$p < 0.01$.

6. A clinical study of 94 children, 7 to 17 years of age, divided into two groups according to their initial level of Cs-137 contamination determined by whole body counting (WBC) and given Vitapect orally for 16 days (5 g twice a day) revealed both a significant decrease in incorporated Cs-137 and marked

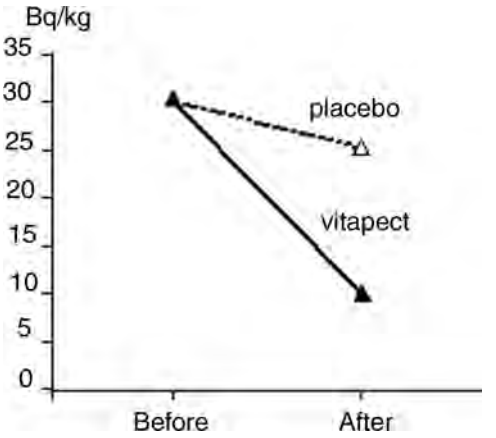

Figure 13.1. Decrease in levels of specific activity of Cs-137 in children's bodies after Vitapect intake (5 g twice a day) for 21 days (Nesterenko *et al.*, 2004).

TABLE 13.2. EKG Normalization Results in the Two Groups of Children Contaminated with Cs-137 Treated with Vitapect (Bandazevskaya *et al.*, 2004)

	Before		After 16 days	
Group	Normal EKG,%	Bq/kg	Normal EKG,%	Bq/kg
1	72	38 ± 2.4	87	23
2	79	122 ± 18.5	93	88

TABLE 13.3. Results of Treatment of 46 Children for 30 Days in France in 2004 (BELRAD Institute Data)

	Concentration, Bq/kg		Decrease, %
	Before	After	
Vitapect	39.0 ± 4.4	24.6 ± 3.4	37*
Placebo	29.6 ± 2.7	24.6 ± 2.1	17

*$p < 0.05$.

improvement in their electrocardiograms (EKG; Table 13.2).

7. From 2001 to 2003 the association "Children of Chernobyl in Belarus" (France), Mitterand's Fund (France), the Fund for Children of Chernobyl (Belgium), and the BELRAD Institute treated 1,400 children (10 schools serving 13 villages) in the Narovlyansky District, Gomel Province, in cycles in which the children received the pectin preparation Vitapect five times over the course of a year. The results demonstrated a three- to fivefold annual decrease in radioactive contamination in children who took the Vitapect. The results for one village can be seen in Figure 13.2.

8. There was concern that pectin enterosorbents remove not only Cs-137, but also vital microelements. Special studies were carried out in 2003 and 2004 within the framework of the project "Highly-Irradiated Belarus Children" with the support of the German Federal Office of Radiation Protection (BfS). Tests carried out in three Belarus sanatoriums (Timberland, Silver Springs, and Belarussian Girls) showed that Vitapect does not impair the positive balance of the K, Zn, Cu, and Fe in children's blood (Nesterenko *et al.*, 2004).

9. At the request of the "Chernobyl's Children" NGOs initiatives in Germany, France, England, and Ireland, the BELRAD Institute conducted measurements of Cs-137 in children before departure to and after their return from health programs in these countries. Children who only ate clean food during the 25–30 days showed a decrease in Cs-137 levels of some 20 to 22%, whereas children who also received a course of treatment with Vitapect showed an even further decrease in the level of Cs-137 incorporation (Tables 13.3 and 13.4).

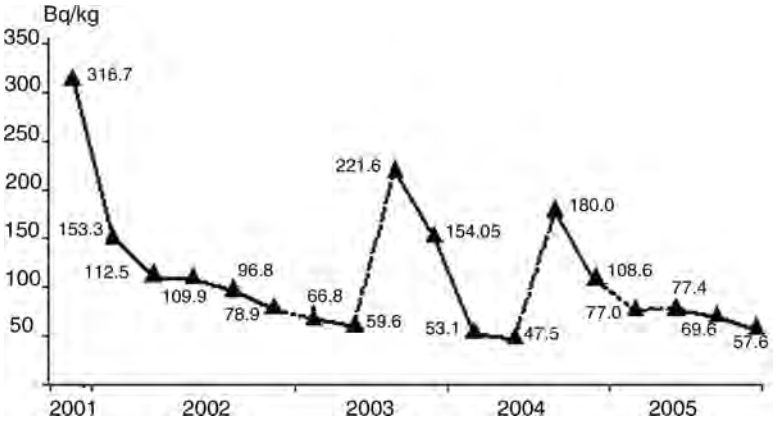

Figure 13.2. Changes in average specific activity of Cs-137 (Bq/kg) in the bodies of children of Verbovichi Village, Narovlyansky District, Gomel Province. Averages for these data are shown. Dotted line indicates the periods of Vitapect intake (Nesterenko *et al.*, 2004).

TABLE 13.4. Several Results of Vitapect Treatment of Belarussian Children (BELRAD Institute Data)

Concentration, Bq/kg		Decreasing, %	Group data
Before	After		
30.0 ± 1.5	19.2 ± 1.4*	36	Germany, $n = 43$; Jul. 7 to Aug. 29, 2007
42.1 ± 5.1	19.6 ± 2.5*	53	Spain, $n = 30$; Jul. 2 to Aug. 30, 2007
26.4 ± 1.5	13.2 ± 0.8*	50	Canada, $n = 22$; Jun. 26 to Aug. 22, 2007
23.4 ± 2.0	11.8 ± 0.7*	49	Canada, $n = 15$; Jun. 24 to Aug. 22, 2007

*$p < 0.01$.

10. The frequency distribution of the activity reduction in one experiment is shown in Figure 13.3. The relative reduction of the specific activity for the pectin groups was 32.4% (arithmetic mean) and 33.6% (median), respectively, whereas the specific activity in the children who received placebos decreased only by 14.2% (arithmetic mean) and 13.1% (median), respectively. This corresponds to a reduction in the mean effective half-life of 27 days for the pectin groups, as compared with 69 days for the placebo groups.

11. The two calculated whole-body retention functions are shown in Figure 13.4 (for adults). The first curve represents the effect of replacing contaminated food by clean food effective from $t = 0$ and the second corresponds to clean food plus Vitapect, also effective from $t = 0$. The observed reduction of mean effective half-life (69→27 days) corresponds to a factor of 2.5.

12. From 1996 to 2007 a total of more than 160,000 Belarussian children received oral Vitapect (5 g twice a day) for an 18- to 25-day course of treatment. The results showed a decrease in Cs-137 levels after each course of treatment by an average of 30–40%.

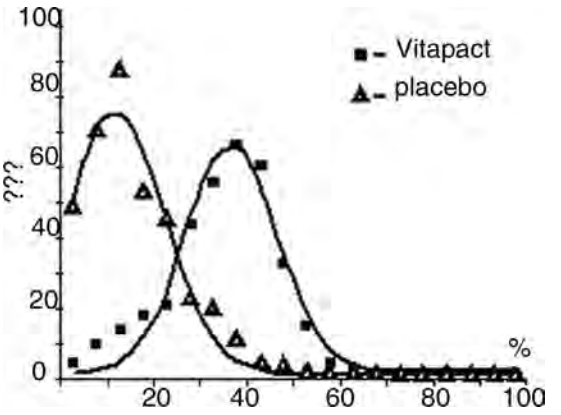

Figure 13.3. Frequency of occurrence of observed relative reduction of the Cs-137 body burden with Vitapect treatment in Belarussian children (Hill *et al.,* 2007).

Based on long-term experience, the BELRAD Institute recommends that all children living in radioactive contaminated territories receive a quadruple course of oral pectin food additives annually along with their conventional food ration. Eleven years of BELRAD's activities in controlling levels of incorporated Cs-137 in more than 327,000 children has not caused alarm in the population or radiophobia and has led to the spread of knowledge concerning radiation protection and an

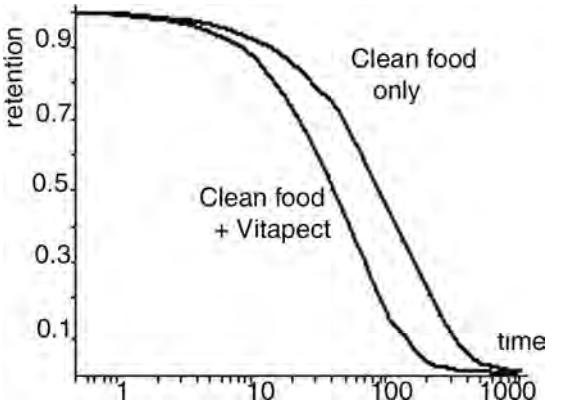

Figure 13.4. Theoretical retention functions for adults based on the model of Leggett *et al.* (2003). The upper curve shows the effect of clean food and the lower one illustrates the additional effect of blocking adsorption using Vitapect (Hill *et al.,* 2007).

increased sense of personal responsibility for one's health.

13.3. New Principles of Radiation Protection Based on Direct Measurements

The BELRAD Institute's 11 years of experience shows that for effective radiation protection in the contaminated territories, an intervention level—30% of the official dangerous limit (i.e., 15–20 Bq/kg)—must be established for children.

1. The direct whole body counting (WBC) measurements of Cs-137 accumulation in individuals in the heavily contaminated Belarussian regions showed that the official Dose Catalogue prepared on the basis of the Cs-137 concentrations in 10 milk samples and 10 potato samples underestimates the annual personal dose burden three- to eightfold and cannot be relied on for effective radiation protection.

2. It is obvious that a true dose catalogue of the contaminated population should be developed on the basis of the data obtained from the direct WBC measurements of Cs-137, which reflect the accumulated internal dose burden. This should be done via reliable sampling of inhabitants from each area of Belarus affected by Chernobyl.

3. Only by combining WBC measurements of Cs-137 accumulation in the body with medical evaluations can the causal relationship (dose dependence) between the increase in morbidity and incorporated radionuclides in the population be known. At this time, these data can only be obtained in the Chernobyl-contaminated regions of Belarus, Ukraine, and European Russia. This information can be an important factor in designing radiation protection and treating people, in persuading the world community of the need to help Belarus minimize radiation exposures, and in understanding the dimensions of the consequences of the Chernobyl catastrophe.

13.4. Where International Help for Chernobyl's Children Would Be Especially Effective

No country in the world is able to cope alone with the long-term consequences of a catastrophe of the magnitude of the meltdown in Chernobyl. The countries most severely affected, especially Ukraine and Belarus, which suffered greatly, are grateful for the help they get from the United Nations and other international organizations, as well as from private funds and initiatives.

Annually, tens of thousands of Chernobyl children go to other countries for treatment to improve their health. Doctors from many countries work pro bono in the Chernobyl-contaminated territories to help minimize the consequences of this most terrible technologic catastrophe in history. The scale and the range of the consequences are so great that there is always the question of how to make such help even more effective.

Experience from large-scale long-term programs to monitor foodstuffs and the levels of incorporated radionuclides in the bodies of those living in the contaminated territories is the basis for the following proposals to increase the efficacy of the international and national programs:

- Joint studies to determine the frequency and intensity of various diseases, especially in children, correlated with levels of incorporated radionuclides.
- Regular individual radiometric evaluation of the populations, especially children, in all contaminated territories. To accomplish this, Belarus will have to increase the number of mobile laboratories from eight to twelve or fifteen. Similar to the Belarussian system, independent, practical, science/clinical centers must be established in Ukraine and European Russia to use the results of such regular radiometric monitoring to identify critical groups with high radionuclide incorporation.

- Manufacture and administer various pectin-based food additives and drinks (based on apples, currants, grapes, seaweed, etc.) as one of the most effective ways of providing individual radiation protection (through decorporation) when circumstances make using contaminated food unavoidable.
- Independent radiation monitoring and radiation control of local foodstuffs, making use of the BELRAD Institute's experience in organizing local centers for radioactive control. This does not replace, but can add to the existing official system.
- Regular courses of oral pectin food additives for preventive maintenance.

Twenty-two years after the catastrophe the true situation in Chernobyl's heavily contaminated territories shows that the internationally accepted individual dose limit is in excess of 1 mSv/year because of the unavoidable consumption of local radioactively contaminated products. Thus the most advisable way to lower the levels of incorporated radionuclides is to consume only clean food. In those situations where clean food is not available, decorporant and sorbent additives should be used to remove as much as possible of the absorbed and incorporated radionuclides.

There are many more-or-less effective decorporants and sorbents: a wide spectrum of products with alginic acid-alginates (mostly from brown seaweed) promotes the reduction of Sr, iron and copper cyanides (e.g., ferrocyanide blue) promote the reduction of Cs. Activated charcoal, cellulose, and various pectins are also effective sorbents for incorporated radionuclides. For practical reasons the curative-like application of apple-pectin food additives may be especially helpful to effectively decorporate Cs-137.

What can be done:

- Reduce Cs-137 concentration in the main dose-forming product—milk—by feeding cows with mixed fodder containing sorbents and by separating the milk to produce cream and butter.
- Provide children and pregnant women with clean foodstuffs and with food additives to increase the elimination of radionuclides and heavy metals from their bodies.
- Inform the population about the levels of radionuclide contamination of the local foodstuffs and the radionuclide concentration in the bodies of the inhabitants (especially children), taking into consideration the existing available foods and the local way of life.
- Institute the practice of regular decorporation of radionuclides into the lifestyle as an effective measure of radiation protection for the population of the Chernobyl-contaminated regions.

The use of food additives, pectin preparations with a complex of vitamins and microelements, demonstrated a high efficiency in eliminating incorporated radionuclides.

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