IMPACT OF 1986 CHERNOBYL ACCIDENTAL RADIOACTIVE RELEASE ON BIOMASS SUPPLY FOR INDUSTRIAL USE IN CENTRAL WESTERN BELARUS

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Abstract. The 1986 reactor accident at the Chernobyl nuclear power plant (NPP) in Ukraine had caused considerable radioactive fallouts throughout much of Belarus. It has been estimated that more than 20 % of Belarus would still remain contaminated with radionuclides 30 years after the NPP accident. Residual Cs-137 radionuclide is considered to be the most important. The physical half-life of Cs-137 is 30 years. Relatively high level of Cs-137 was identified to have been deposited in the top soil of several areas in the western region of Grodno oblast, during the first decade after the NPP accident. The mobility of Cs-137 in the soil is similar to that of K. In the 2004 survey data released by the United Nations, Cs-137 in the top soil of most of Belarus appeared to have dissipated largely into the natural cycle, including physical decay, high water solubility, and transference from the soil into the growing biomass (e.g., annual grain crops) which is exported from the affected region. The accumulation of Cs-137 in wood residues could be very problematic. Unlike annual cereal crops, trees are harvested typically in ~80-year cycles. Repeated exposure of workers to fugitive Cs-137 in wood wastes could pose a significant health hazard.

Keywords: biomass, Belarus, contamination, Chernobyl, radioactivity.

Introduction

On April 26, 1986, a catastrophic accident took place at the nuclear power plant (NPP) in Chernobyl, Ukraine, located about 10 kilometres from the Belarusian border. A large amount of radionuclides were released to the atmosphere over the next few days. Nearly 25 % of the Belarus territory with ~2 million citizens was affected by the radioactive fallout. The prevailing wind on the first day of the NPP accident was from Chernobyl towards Vilnius. Figure 1 shows the estimated trace of the radioactive plume during the first week after the NPP accident. Plumes 1 and 2 would be particularly troublesome for deposition of radionuclides in the Grodno oblast.

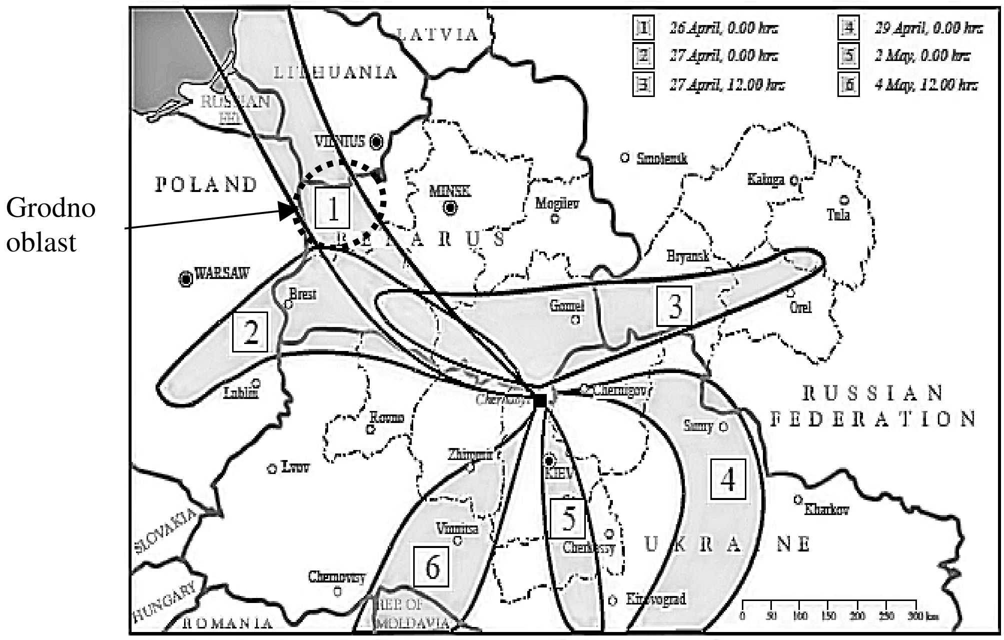

Fig. 1. **Estimated radioactive plume during the first week after the NPP accident [1]**

The three radioactive isotopes of particular public health concerns are I-131, Sr-90 and Cs-137. The essential data of the key radionuclides given in Table 1 indicated that Cs-137 would be the most problematic because of the continued emission of γ rays from long half-life Cs-137.

Table 1

Selected data of key radionuclides emitted from the NPP accident

Isotopes	Emissions	Half-life		Estimated amount released, PBq (a)	Remarks (b)
		Physical	Biological		
I-131	β particles, γ rays	8 days	138 days (c)	629 to 1,760	recorded to be <37 Bq·m^{-2} by about 1995 for most of Belarus
Sr-90	β particles	29 years	49 years (d)	8 to 10	deposition confined largely to Gomel and Mogilev oblasts
Cs-137	β particles, γ rays	30 years	110 days (e)	37 to 85	-

(a) Estimated reported in Ref. [2, 3].
(b) Strength of radioactive source is measured by units of Becquerel (Bq), viz. 1 Bq = one event of radiation emission (scintillation) per second. The total amount of radiation received by a mammalian subject is given in Sieverts (Sv), i.e., dose concentration x rate of exposure x exposure time.
(c) Depletion from human thyroid gland.
(d) Depletion from human bones.
(e) Continually excreted from the human body via urine and feces [1].

Because of the large area affected, precise monitoring of residual radionuclides since the NPP accident continues to be a formidable task. In the 2004 survey, Cs-137 contamination was found to be still significant in many regions. Contamination-density band for non-intervention radiation control in Belarus is designated to be 37 to 185 kBq·m^{-2}, at an effective dose <1 mSv per year [4]. Belarusian scientists have now projected that the level of Cs-137 in the top soil of northeastern Grodno oblast could return to the non-intervention threshold, i.e., <37 kBq·m^{-2}, by 2016 [4]. The background Cs-137 level should be zero as Cs-137 in the environment is anthropogenic, i.e., manifesting only from the by-production of intentional nuclear fission of heavier elements such as uranium through above-ground testing of nuclear weapons and/or accidental release to the environment from NPPs [1].

A new integrated pulp and paper manufacturing enterprise has been proposed for establishment in the western region of Grodno oblast. Cereal straw would be used for the fibrous feedstock. Processing wastes from local woodworking industries would be used as biomass for the co-generation of steam and power for in-plant uses. This paper aims to review the possible impact of the presence of Cs-137 in cereal straw and wood residues, on the health of mill workers and the safety of finished paper products.

Cesium-137 geochemistry

The high reactivity of elemental Cs is similar to that of K. Both elements are Group I alkali metals of the Periodic Table. Water-soluble compounds are typically formed beginning with CsOH and $CsCO_3$. Depending on prevailing chemistry of the receiving environment, other water-soluble compounds are formed subsequently. The mobility of Cs-137 has been noted to be low, depending on, among other things, the soil acidity and organic matter present. Cs-137 has also been noted to bind strongly to certain clay soil particles. Thus, any natural transport of such clay particles as run-offs could result in accumulation as sediment in lakes and topographic depressions such as shallow pools and gulleys [6-9]. Thus, mathematical modelling of Cs-137 in the circumstances of highly varied soil and hydraulic conditions is extremely difficult and can be highly unreliable, especially at the local scale.

Cs competes against K in its uptake by growing plants through roots. Indeed, intentional intensive K fertilization of crop soil has been cited as a practical means to suppress the uptake of Cs-137 into food crops [5]. The accumulation of Cs-137 in food crops has been studied extensively [10-13]. There is significant annual export of Cs-137 in the harvested grain (and straw) in addition to the natural decay of the radionuclide to non-radioactive Ba-134, during the initial 25 years after the NPP accident. On-purpose cropping of certain fibre crops such as flax and hemp has been assessed as a means to enhance and accelerate the depletion process from arable land [14]. The mobility of Cs-137 in the forest environment is complex and largely site-specific [15-20]. Because of the long growth period of trees, annual Cs-137 accumulation in stemwood is especially plausible under the conditions of K+ deficiency under acidic soil conditions. Depending on prevailing physical conditions, re-dispersion of Cs-137 from organic-bound biomass such as foliage and bark could manifest.

Implication for the proposed new enterprise

The estimated fall-out distribution of Cs-137 is shown in Figure 2. Note the "hot spots" in several northeastern areas of the Grodno oblast. The latest available data suggest that the supply of straw feedstock, especially from the southwest of the Grodno oblast, could be considered to be "essentially safe" from radioactive contamination after about 2016. However, an adverse situation could still emerge for classical sulphate pulp mills with dual (Na_2SO_4 and CaO) chemical recovery systems [21].

In a sulphate pulp mill, the fibrous feedstock is cooked routinely with a solution of NaOH and Na_2S, under elevated temperature and pressure conditions. The spent cooking solution contains mainly dissolved cellulosic components, lignin, Na_2CO_3 and Na_2SO_4. The inorganic chemicals are converted in a thermal reduction furnace to Na_2CO_3 and Na_2S. The combustion fuel is the dissolved organics in the spent cooking solution. Na_2CO_3 is causticized subsequently with CaO to form NaOH and $CaCO_3$. For re-use, CaO is re-formed thermally from $CaCO_3$. As incoming fibrous raw material contains typically much higher amount of K than Na, a steady significant bleed of process liquid from the pulp mill operation is required to maintain the integrity of the Na-based chemical system.

In a sulphate pulp mill, continued reduction in process water usage (resulting in less volume of effluent discharge) would typically afford the undesirable accumulation of K in the mill chemical system. It follows that the accumulation of Cs-137 would also be realized similarly. Because the proposed novel pulp manufacturing technology has no chemical recovery system, there is essentially no propensity for Cs-137 accumulation in the pulp mill chemical liquor system. There is thus low probability that any finished paper products would be substantially contaminated with fugitive Cs-137.

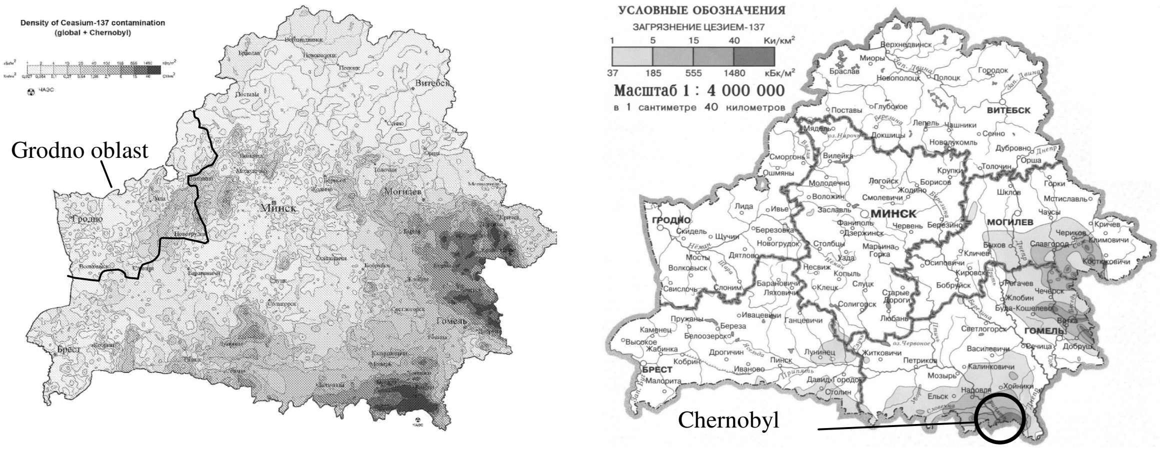

Fig. 2. **Distribution of Cs-137 in Belarus territory after the Chernobyl NPP accident:** 1986 estimate shortly after the NPP accident 2016 projection; the highest contamination is depicted by the darkest area [4; 22]

It may be noted that these projections do not reveal any possible highly localized "hot spots" in which the radiation level might exceed 37 $Bq \cdot m^{-2}$ substantially. This situation is especially problematic for the handling of wood waste (for energy production) from trees harvested in "localized "hot spots". The potential danger lies in the possible repetitious contact of the factory workers to highly contaminated supply of biomass. Figure 3 illustrates significant morbidity (rate of incidence of cancer) and mortality risks of exposure to a ground surface contaminated with Cs-137, within the non-intervention threshold band. It is generally recognized that "safety" is dependent on, among other things, human genetics, the exposure time and weight of tissue exposed. However, there may be no safe limit of radioactive contamination.

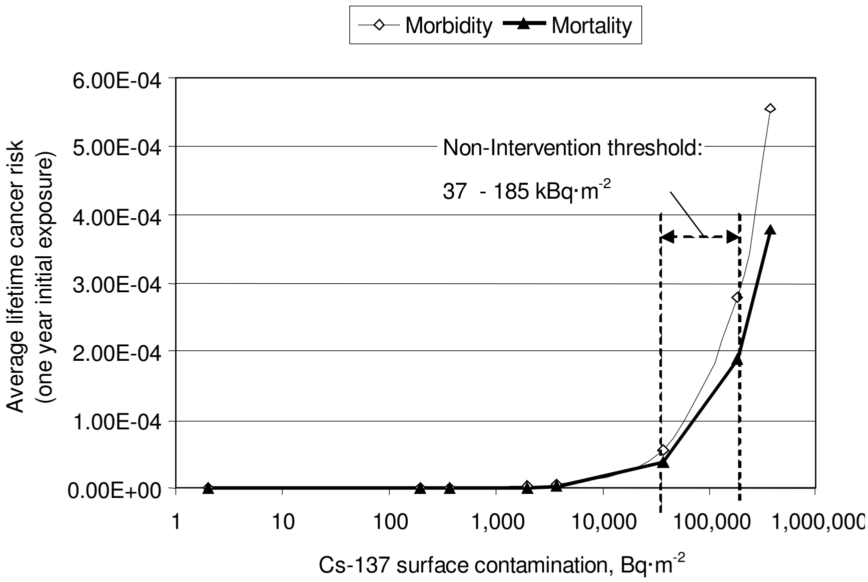

Fig. 3. **Example estimate of average lifetime cancer risk (morbidity and mortality) from one-year exposure following deposition of Cs-137 on a ground surface:** calculation made with the use of assumptions and methodology given in [23]

Concluding remarks

In view of the projected return to the intervention threshold contamination of 37 Bq·m^{-2} in the Grodno oblast territory by 2016, the procurement of agricultural biomass (e.g., straw) could be deemed to be generally safe from radioactive contamination. Because of the possibility of wood biomass supplying from "undetected hot spots" in the Grodno oblast, vigilant monitoring of radioactivity of all incoming biomass is highly desirable for the safety of the factory workers.

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