*Annual Research & Review in Biology*

***12(5): 1-6, 2017; Article no.ARRB.33391***
***ISSN: 2347-565X, NLM ID: 101632869***

# Specific Activity of Cs-137 in Milk of Semey Region of East Kazakhstan Area

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors AK and YZ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IS and ZY managed the analyses of the study. Authors ZK, GM and MB managed the literature searches. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/ARRB/2017/33391
*Editor(s):*
(1) Paola Angelini, Department of Applied Biology, University of Perugia, Perugia, Italy.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
*Reviewers:*
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(4) José Martínez Reyes, University of the Ciénega of Michoacán State, México.
Complete Peer review History: http://www.sciencedomain.org/review-history/19092

***Original Research Article***

***Received 12th April 2017***
***Accepted 12th May 2017***
***Published 17th May 2017***

## ABSTRACT

Cesium-137 (Cs-137) activity concentration in cow milk samples, collected near the former Semipalatinsk nuclear test site (SNTS) in Kazakhstan were measured. Milk samples were obtained from 7 different locations within 2 administrative regions (Abai and Ayaguz). Abai and Ayaguz regions belong to different zones of radiation risk: zone of maximum radiation risk and zone of heightened radiation risk, respectively. Radionuclide activities concentrations were determined using a gamma-ray spectrometer with pure germanium detector. The highest activity concentration values in milk were found in Karaul of Abai region 8.60±0.16 Bq/l. In Zhidebai, Kaskabulak, Kokbai and Medeu the Cs-137 activity concentration were 5.30±0.21 Bq/l, 4.10±0.12 Bq/l, 7.10±0.22 Bq/l and 3.70±0.14 Bq/l, respectively. In Ayaguz region the average value was 3.60 Bq/L. In this zone, the highest activity concentration was measured in Akshatau 6.60±0.27 Bq/l. In Ayaguz Cs-137 content was lower 2.60±0.09 Bq/l.

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*Keywords: Cs-137; milk; nuclear test site; Semipalatinsk.*

## 1. INTRODUCTION

At present time with the development of nuclear science and technology, the radioecological problems in agriculture are gradually gaining increased visibility and attention. Radioecological problems arise as a result of controlled and uncontrolled radioactive contamination of the environment. Radionuclides migrate in biological chain through soil-water-plant-animal and accumulate in human body.

Food safety control is one of the major factors defining human health. In Kazakhstan, radiological considerations are an integral part of food safety due to the ecological situation, because of radionuclide transfer to food chain. Kazakhstan, therefore, has to manage potential risks associated with the legacies from the former Soviet nuclear bomb testing site and its mining industry [1]. In the East Kazakhstan region, the main risks are associated with the radioactive fallout from 40 years of nuclear bomb testing. These inputs were largely from atmospheric and aboveground nuclear tests carried out on the "Experimental Field" (also known as Ground Zero) test site and underground testing conducted at the "Degelen" site, the "Balapan" site and the "Sary Uzen" site [2].

The Semipalatinsk nuclear test site (SNTS) in the Republic of Kazakhstan is one of 16 sites in the world where nuclear devices were tested. The SNTS, covering an area about 18,000 sq. km, is located in north-eastern Kazakhstan (77° to 79° E and 49°–51° N). Between 1949 and 1989, 456 atomic bomb tests were performed at the SNTS [3]. SNTS activities can be divided in two periods. First, between 1949 and 1962, when above ground nuclear tests (surface and atmospheric) were conducted; and second, between 1963 1989, when underground nuclear tests were conducted.

SNTS settlements, including those found in Abai, Ayaguz and Urdzhar regions, received inputs from the radioactive fallout. In accordance with the law of the Republic of Kazakhstan (from the 18th of December, 1992) "About social protection of citizens suffering from the consequences of nuclear testing in the Semipalatinsk Nuclear Test Site" adjacent territories belong to the different zones of radiation risks. Abai, Ayaguz and Urdzhar regions belong to zone of maximum, high and minimum radiation risk, respectively (Fig. 1).

The Balapan area to the South-East of SNTS (780 km$^2$, site of 105 underground nuclear bomb tests) may be the receptor of much of the SNTS radionuclide contamination, including the "Experimental Field" where 86 atmospheric nuclear tests and 30 above ground tests were conducted [4]. This is because the dominant wind direction is from the West to the East and because the underground water also tends to run from West to East (from the "Experimental field" towards the Balapan area [5]. The chosen study sites are located along the axis of the prominent wind direction and groundwater flow.

High concentrations of radionuclides (for example: Cs-137, Pu-240/241, Am-241 and Sr-90) in the environment lead to irreparable damage to the health of people and the environment. This study assesses the presence of Cs-137 in milk produced by different settlements located to the South-East of SNTS. The levels measured were, therefore, compared to the Kazakh regulatory limit for Cs-137 in milk.

The purpose of this study was to determine the specific content of cesium (Cs-137) in milk, depending on their migration in the soil and plant of Semipalatinsk region of the East Kazakhstan area.

## 2. MATERIALS AND METHODS

Samples of soil, vegetation and milk were collected from 7 locations within 2 administrative regions of Abai and Ayagoz. The region of Abai belongs to the zone of maximum radiation risk; the region of Ayagoz is within the zone of heightened radiation risk. The samples were collected from 5 settlements within the Abai region (Karaul, Zhidebay, Kaskabulak, Kokbai and Medeu) and 2 settlements within the Ayaguz region (Ayaguz and Akshatau) (Fig. 2). Milk samples (105 in total) were collected in May and June, 2016.

Vegetation was collected over an area that was not less than 6 m$^2$ (2 m x 3 m). Scissors sickle or knife was used to collect the top part of the vegetation leaving the bottom part of the plants (at least 3 cm from the ground). The vegetation cover on the studied areas is represented by feather grass (*Stipa capillata*, *S. sareptana,*

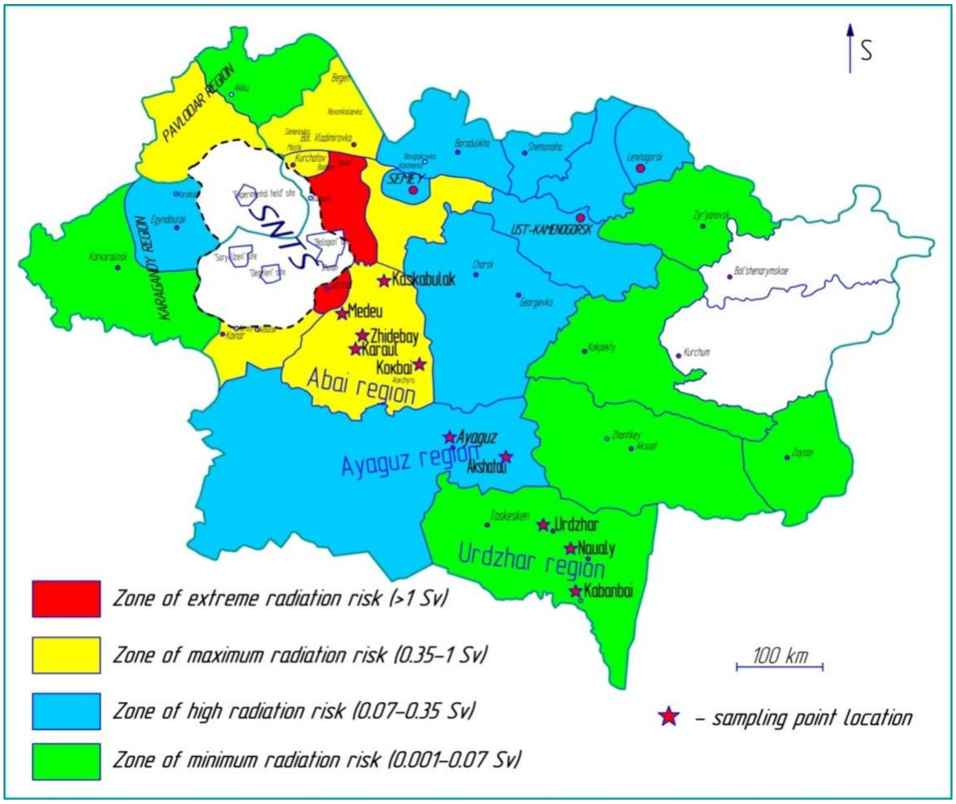


**Fig. 1. Zones of radiation risk in East Kazakhstan**

*S. lessingiana*) and fescue (*Fectuca valesiaca*). After collection, the vegetation was stored at room temperature in draught cupboard. Samples were milled to pieces 1 cm long pieces and dried at 70 to 80℃ for 15 to 18 hours.

Soil was collected using a special shovel to a depth of 5 cm (surface to 5 cm depth). For each grabs, the area sampled was 100 $cm^2$. To make up one sample, soil grabbed from 5 different places, within a 50 m perimeter, were mixed together in a large container. The soil samples were packed into polyethylene sack, labeled and transported to the laboratory.

For determination of the radionuclides in the soil and vegetation samples, the samples were left to dry for two weeks at room temperature. During that time, the soil was scattered on a rigid paper and mixed periodically. Next, the soil samples were milled and sifted through a 2 mm mesh sieve. The vegetation samples were milled using a blender. Then, the samples were transferred to a Marinelly vessel measuring container. For each analysis, the weight of the sample varied as the sample was prepared by volume (volume necessary to fill the Marinelly vessel). The vessel was then placed in the gamma-spectrometer.

The milk samples, collected from cows of local farmers, were poured into clean glass airtight containers. Milk samples were preserved with a 40% formalin solution (1-2 ml/l). Milk samples were poured into a Marinelly beaker and radionuclide content was determined by gamma-ray spectrometry.

The gamma-ray spectrometer used for Cs-137 determination was a pure Ge detector GC-2019 (55 cm3), Canberra Company (USA). The calibration of the detector was done using standard solution of gamma emitting isotopes. Standard source of Eu-152, Am-241, Cs-137 were from Khlopin Radium Institute, St. Petersburg, Russia. The limit of detection for the determination of radionuclide by γ-ray spectrometry under the prevailing experimental conditions is 0.1 Bq for 0.5 kg of environmental samples. The Marinelly beaker characteristics were as follows: volume of 1l, diameter of 15 cm and height of 11 cm. The sample weights placed in the Marinelly beaker were measured using a ±0.01 g balance.

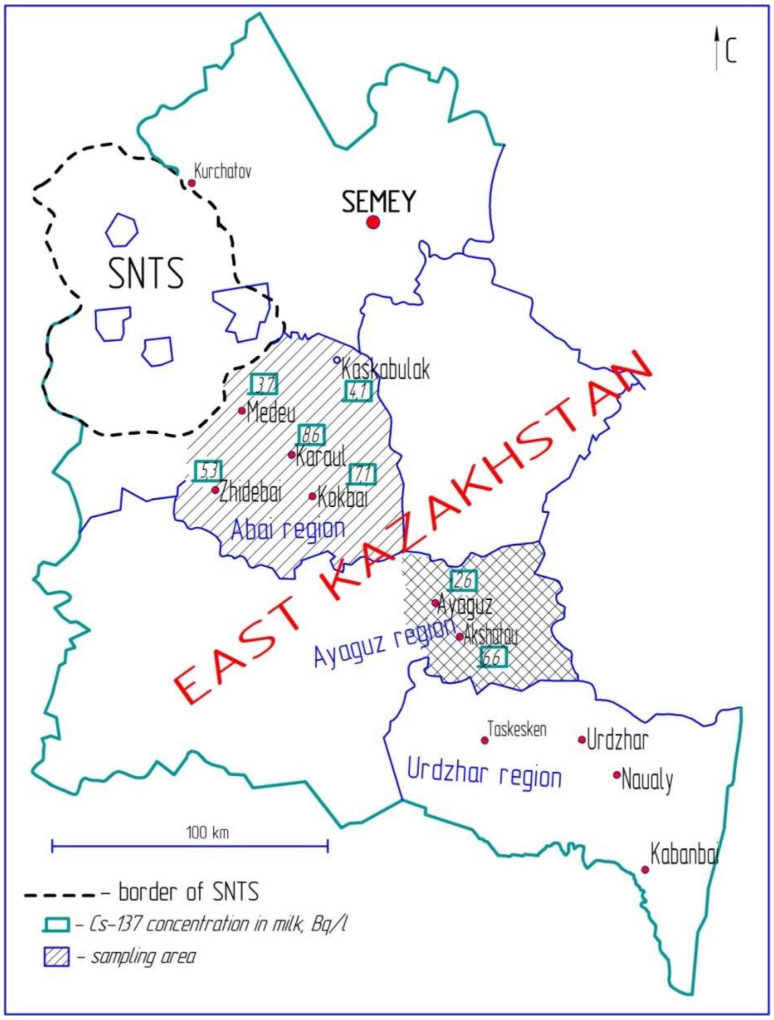


**Fig. 2. Sampling locations and Cs-137 concentration in milk**

## 3. RESULTS AND DISCUSSION

### 3.1 Soil

From the Table 1 the specific activity of Cs-137 in soil from the Abai region varies from 11.0±0.42 Bq/kg to 18.0±0.34 Bq/kg. Within the Abai region the highest level was determined in Karaul settlement, whereas the lowest in Medeu settlement. Soil analysis from Kokbai, Zhidebai and Kaskabulak showed the concentration of Cs-137 17.0±0.83, 14.0±0.59 and 12.5±0.36, respectively.

In Ayaguz region the concentration of Cs-137 in Akshatau settlement was 15.0±0.44 Bq/kg, while in Ayaguz 9.7±0.27 Bq/kg.

### 3.2 Vegetation

Radionuclides are input to living organisms through soil-water-plant biological chain. At the same time, Cs-137 is accumulated in the herb of plants in large quantities, entering the plant through the roots. The other isotopes are concentrated mainly in the roots of plants during the growing season [6].

The results of Cs-137 determination showed that the most contaminated samples were detected in Abai region: particularly, the highest in Karaul 3.90±0.17 Bq/kg, in Kokbai and Zhidebai 3.60±0.11 Bq/kg and 3.20±0.09 Bq/kg, respectively. The lowest concentration was quantified in Kaskabulak 2.40±0.06 Bq/kg and Medeu 2.00±0.04 Bq/kg.

**Table 1. Activity concentrations of Cs-137 in soil, vegetation and milk**

| Settlement | Soil (Bq/kg) | Vegetation (Bq/kg) | Milk (Bq/l) |
|---|---|---|---|
| Karaul | 18.0±0.34 | 3.90±0.17 | 8.60±0.16 |
| Kokbai | 17.0±0.83 | 3.60±0.11 | 7.10±0.22 |
| Akshatau | 15.0±0.44 | 3.40±0.14 | 6.60±0.27 |
| Zhidebai | 14.0±0.59 | 3.20±0.09 | 5.30±0.21 |
| Kaskaulak | 12.5±0.36 | 2.40±0.06 | 4.10±0.12 |
| Medeu | 11.0±0.42 | 2.00±0.04 | 3.70±0.14 |
| Ayaguz | 9.7±0.27 | 1.40±0.03 | 2.60±0.09 |

In Ayaguz region Cs-137 concentration in Akshatau was 3.40±0.14 Bq/kg and in Ayaguz 1.40±0.03 Bq/kg.

### 3.3 Milk

Food and drinking water are considered the main sources of radionuclides intake by human beings although inhalation can also be a contributor [7]. The Kazakh regulatory limit for Cs-137 in milk is currently 100 Bq/l [8]. The same limit is approved in Russia, Belarus and Ukraine, however in Japan the national limit for Cs-137 in milk is 50 Bq/l, in United States – 1200 Bq/l and in European Union – 1000 Bq/l [9].

According to the results reported in Table 1 and Fig. 2, the highest activity concentration values in milk were found in the Abai region (zone of maximum radiation risk). In this region, the highest measured value was obtained from the samples collected in Karaul 8.60±0.16 Bq/l while the second highest measured value was from Zhidebai 5.30±0.21 Bq/l. In Kaskabulak, Kokbai and Medeu the Cs-137 activity concentration were 4.10±0.12 Bq/l, 7.10±0.22 Bq/l and 3.70±0.14 Bq/l, respectively.

The region of Ayagoz is within the zone of heightened radiation risk. The average value for the region was 3.60 Bq/L. In this zone, the highest activity concentration was measured in Akshatau 6.60±0.27 Bq/l. In Ayaguz Cs-137 content was lower 2.60±0.09 Bq/l.

The results, obtained in this study were compared with other data reported in different sources. Activity concentration of Cs-137 in milk from New Zealand [10] ranged from 0.05 to 0.11 Bq/l, from Chile [11] 0.013 to 0.09 Bq/l. In Argentinean cow milk Cs-137 level was below 0.06 Bq/l [12]. In Poland mean activity amounted to 0.8 Bq/l in 2003 [13]. Lettner et al. [14] studied the concentration of Cs-137 and Sr-90 in milk in Austrian alpine agriculture area, which was contaminated after the Chernobyl accident. Activity concentrations of Cs-137 between 6.8 Bq/l and 139.3 Bq/l. Radioactive contamination of private sector milk from Ukraine after effect of Chernobyl accident was studied by Borul [15], where the levels of Cs-137 ranged from 109 Bq/l (Village of Myliachi) to 286 Bq/l (Village of Budymlia).

Similar to this study was done by Dyussembayev et al. [16] where different settlements located near the SNTS was studied. The most contaminated milk samples in comparison with other settlements were from Sarzhal: Cs-137 – 1.8 Bq/kg; less contaminated in Karkaraly: Cs-137 – 0.2 Bq/kg. Cs-137 activity concentration in cow milk measured by Semioshkina et al. [17] was 6.5±0.6 in Zavety Iljicha Farm (near the south-east of the SNTS) and 0.9±0.1 in Akzhar Farm (near the north part of the SNTS).

## 4. CONCLUSION

Cs-137 is the most hazard radionuclides having long half-life and high radiation energy. At the same time, by its chemical properties can be the analogues of potassium and included in metabolic processes and are able to accumulate in living organisms. In this research, the measured activity concentration levels were not found to exceed the national maximum allowable limit for milk of 100 Bq/l. The milk produced in this region is, therefore, below regulatory limits. However, the results obtained in this study show that the Cs-137 most contaminated milk was from the Abai region. The region, according to legislation of Kazakhstan, belongs to the zone of maximum radiation risk. These data show that the current radiation hazard zoning in the country is reasonable. It also validates the location of the Cs-137 source since the levels were found to decrease with increasing distance from the SNTS.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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*Peer-review history:*
*The peer review history for this paper can be accessed here:*
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