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Radionuclide transfer from feed to camel milk

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ABSTRACT

The transfer of ^{137}Cs, ^{85}Sr, ^{131}I, ^{210}Po, ^{210}Pb and ^{238}U from feed to camel's milk was investigated in a pilot experiment with three lactating camels. For a period of 60 days, the animals were fed on spiked feed containing the studied radionuclides. They were subsequently returned to a contamination-free diet and monitored for another 90 days. The activity concentrations of ^{137}Cs, ^{85}Sr and ^{131}I in milk decreased with time and reached background levels after 20 days. Equilibrium transfer coefficients and biological half-lives were estimated and transfer coefficients were calculated as $(8.1 \pm 3.6) \times 10^{-4}$, $(4.4 \pm 1.6) \times 10^{-2}$, $(7.8 \pm 3.9) \times 10^{-4}$, $(2.7 \pm 3.5) \times 10^{-4}$, $(1.8 \pm 1.5) \times 10^{-4}$ and $(7.0 \pm 3.6) \times 10^{-3}$ d L^{-1} for ^{85}Sr, ^{131}I, ^{137}Cs, ^{210}Po, ^{210}Pb and ^{238}U, respectively. The biological half-lives were estimated to be 6.4, 4.2, 8.9, and 53.3 days for ^{85}Sr, ^{131}I, ^{137}Cs, and ^{238}U, respectively. Estimates of the half-lives were based on a one component model: it was found that the half-life values measured for artificial radionuclides were slightly shorter than those for natural radionuclides. The data obtained in the study are the first published experimental data on radionuclide transfer to camel milk.

1. Introduction

Following the contamination of the environment with radionuclides, the population is exposed through both external and internal irradiation pathways, the latter mainly due to contamination of food. In most cases, the contribution from internal irradiation is comparable with or may exceed that of external irradiation. For example, the total effective radiation dose of the global population as a result of nuclear weapon testing is 4.5×10^6 man-Sv, the share of internal and external irradiation are 2.0×10^6 and 2.5×10^6 man-Sv, respectively (UNSCEAR, 2000). A close relationship between internal and external doses was also obtained based on measurements and predictions carried out after the Chernobyl NPP accident in 1986 (IAEA, 2005).

For many contamination scenarios, especially for accidentally released radionuclides such as ^{90}Sr, ^{131}I and ^{137}Cs and radionuclides specific for nuclear testing, milk is a major contributor to the internal dose to the public (UNSCEAR, 2000). The consumption of foodstuffs containing ^{137}Cs in areas affected by the Chernobyl accident (especially milk) was and remains the main source of internal exposure. Many of these highly contaminated areas were and are used for the production of animal fodder or for grazing by cattle, with the result that the consumption of such milk represents one of the principal pathways giving rise to a radiation dose to man (Fesenko et al., 1997). In addition, there is an increasing interest in radiological assessments of the discharges of naturally occurring radionuclides (U, Ra, Pb and Po) into the terrestrial environment from current releases from industrial sites and from the radiation legacy activities. The release of natural radionuclides from uranium mining and milling activities, as well as production of naturally occurring radioactive material (NORM) such as phosphogypsum and oil and gas scales is permanently increasing. With the expected increase of NORM residues in the future, the radiological impact of U, Ra, Pb and Po is of increasing interest.

Data on radionuclide transfer to animals were extensively reviewed (Fesenko et al., 2007; Howard et al., 2009a, 2009b). Most of the data were generated between the 1960s and 1990s and refer to weapons testing, and the Kyshtym and Chernobyl accidents. Information and experimental results are published for sheep and goat and significant information is available on the transfer of radionuclides to milk of dairy cows (IAEA, 2010), however few data are available and address radionuclide transfer to some other dairy animals. Only one experimental study has been published on radionuclide transfer to horse milk (Semioshkina et al., 2005).

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In some arid and semiarid zones of tropical and subtropical Africa and Asia, camel milk is a key nutrient resource for the human diet and is believed to have curing and healing properties. Traditionally, camel nutrition is based on vegetable species they can browse or graze in natural pastures, often inaccessible to other domestic livestock, with little or no supplemental feeding. While camels are known to adapt well to low quality forage in a harsh environment, information on the influence of different feeding regimes on camel milk components is very scarce. Drinking water availability is the most important factor affecting the concentration of the various milk components. Differently from the milk of cows exposed to heat, milk from the dehydrated camel is more diluted, with decreased percentages of fat, protein and lactose (Cattaneo et al., 2005). Concentrations of the corresponding stable elements in the different compartments are generally used for deriving equilibrium transfer factors when no experimental data are available. Konuspayeva et al. (2011) reported data on concentration of metals and radionuclides in camel milk collected in Kazakhstan, but those data do not allow quantification of radionuclide transfer from feedstuffs to camel milk.

To address the deficiency in radioecological data for camels, the aim of the present study was to estimate both: (i) the equilibrium transfer coefficients of ^{85}Sr, ^{131}I, ^{137}Cs, ^{210}Pb, ^{210}Po and ^{238}U from feed to camel milk and (ii) biological-half-lives for these radionuclides.

2. Materials and methods

The study was carried out at the Division of Animal Production, at Der Al-Hajar area, 33 km south-east of Damascus. This is a dry area with an annual rainfall of about 114 mm, and, resembles the Syrian steppe region where the majority of the camel population is raised.

2.1. Animals

Three lactating female Damascus camels, 3–4 year old, originating from Sub Damascus and Syrian Desert were used in the study. Their approximate mean weights were 400 kg per camel. The animals were treated for external and internal parasites and were in good health during the whole study.

2.2. Design of experiment

During the whole study, each camel was kept in an individual pen and received a basal diet including 3 kg of feed containing concentrates (~0.9 kg) and wheat straw (~2.1 kg). Water was available *ad libitum*. After an adaptation period of 2 weeks, the experimental period consisted of three phases:

1. First period; a control period (days 1–15): During this stage, the animals received the basal diet.
2. Second period; a contamination period with supplementary feed containing the studied radionuclides (days 16–76): A radionuclides mixture with defined activities was prepared (Table 1) and supplied daily to each camel. The radionuclide mixture was mixed with 1 kg of the feed and distributed individually each morning. The complete consumption was verified.
3. Third period, a decontamination period (days 77–158): During this last period of the experiment camels received the basal diet only,

The radionuclides ^{131}I, ^{137}Cs and natural radionuclides such as ^{210}Pb, ^{210}Po and ^{238}U were used in our research. ^{85}Sr was included in this study as an analogue for ^{90}Sr, assuming that its behavior in camels is identical to that of ^{90}Sr.

Table 1
Radionuclide daily intake by camels during the experiment.

Date (Days)	Radionuclide intake[a] (Bq day^{-1})				
	^{137}Cs	^{131}I	^{85}Sr	^{210}Pb = ^{210}Po	^{238}U
Control period					
10–15	<0.5	<0.5	<0.5	<0.4	<0.16
Period of radionuclide administration					
16–22	1861	2000	3834	84	37
23–29	2485	2000	4700	112	49
30–36	4045	2000	7111	183	78
37–43	4043	2000	6599	183	78
44–50	3977	2000	6676	174	77
51–57	3591	2000	9392	122	72
58–64	3589	2000	8715	122	72
65–71	3588	2000	8086	122	72
72–75	3587	2000	7624	122	72

[a] Radionuclide activity concentrations were corrected to the sampling date.

^{85}Sr and ^{131}I were supplied by the Chemistry Department of the Atomic Energy Commission of Syria (AECS), ^{137}Cs was provided by Amersham Pharmacia Biotech UK Limited, ^{210}Pb was provided by Laboratoire de Metrologie des Rayonnements Ionisants, France, and uranium nitrate solution was provided by British Drug Houses BDH.

2.3. Sampling

Milk sampling was manually carried out in the morning before feeding throughout the study before the sucklings were allowed to the mothers. During the first period, milk samples were taken daily. 25 sampling campaigns were carried out in the second period, once a day for the first 10 days then twice a week for 50 days. In the last period, milk sampling was performed once a week. In average camel milk production was estimated to be 6 L per day.

2.4. Laboratory analysis

Milk samples were measured by gamma spectrometry (Eurysis Systems) using high resolution (1.85 keV at 1.33 MeV), high relative efficiency (80%), low background HPGe detectors to determine the gamma-ray emitters ^{40}K (1460 keV), ^{137}Cs (661.6 keV), ^{131}I (364.5 keV) and ^{85}Sr (513.99 keV). The lower limits of detection for the measured ^{137}Cs, ^{131}I and ^{85}Sr derived from the background measurements at 100,000 s are found to be 8 Bq L^{-1} for ^{40}K and 0.5 Bq L^{-1} for ^{137}Cs, ^{131}I and ^{85}Sr.

The ^{210}Po and ^{210}Pb activity concentrations were measured using a standard technique (the silver disc technique) (Flynn, 1968). Alpha counting of ^{208}Po (5.15 MeV) and ^{210}Po (5.3 MeV) was done using an alpha spectrometer (Oasis, Oxford) with a passive ion-implanted silicon detector (active area 300 mm^2, background counts per day 3.6 and the minimum depletion thickness 100 μm). The activity concentration of ^{210}Po was corrected for recovery and for radioactive decay since the time of start of experiment. The lower limit of detection of the method used was 4 mBq L^{-1}.

Since the activity concentrations of ^{238}U in milk samples were found to be low, liquid scintillation counting technique was used. A sequential radiochemical separation procedure was implemented using Dowex 1 × 4 and Dowex 1 × 8. The separated aliquots were evaporated and dissolved with 8 ml HNO_3 (pH = 1.5) and mixed with 12 ml of Hi Safe 3 cocktail. The samples were then measured using the LSC Wallac Winspectral type 1414 (Al-Masri et al., 2007). The limit of detections for ^{238}U was 0.18 Bq L^{-1}.