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Improving the quantity, quality and transparency of data used to derive radionuclide transfer parameters for animal products. 1. Goat milk.

Howard, B.J., Wells, C., Barnett, C.L.

NERC Centre for Ecology and Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, LA1 4AP, UK

bjho@ceh.ac.uk

ABSTRACT

Under the MODARIA (Modelling and Data for Radiological Impact Assessments Programme of the International Atomic Energy Agency), there has been an initiative to improve the derivation, provenance and transparency of transfer parameter values for radionuclides. The approach taken for animal products is outlined here and the first revised table for goat milk is provided. Data from some references used in TRS 472 were removed and reasons given for removal. Particular efforts were made to improve the number of CR (concentration ratio) values which have some advantages over transfer coefficients. There is little difference in most of the new CR and F_m (transfer coefficient) values for goat milk compared with those in TRS 472. In TRS 472, 21 CR values were reported for goat milk. In the 2015 dataset for goat milk CR values for a further 14 elements are now included. The CR and F_m values for only one element (Co) were removed.

INTRODUCTION

The transfer coefficient, defined as the equilibrium ratio of the fresh weight activity concentration in milk or meat to the daily dietary radionuclide intake, has been widely adopted as the basis for quantifying transfer to milk (F_m, d l^{-1} or d kg^{-1}) and meat and eggs (F_f, d kg^{-1}) for all radionuclides (Howard et al. 2009a,b).

For many years it was generally accepted that transfer coefficients for smaller animals were higher than those for larger animals, so those for adults are lower than those for smaller livestock. Beresford et al. (2007a) and Ng et al. (1982) both suggested that much of this difference was because transfer coefficients incorporate daily dry matter intake (DMI, in kg d^{-1}) which increases with animal size. An alternative approach to quantifying transfer is to remove the dietary intake used in the estimation of F_m or F_f, and simply calculate the concentration ratio (CR) defined as the equilibrium ratio between the radionuclide activity concentration in the animal food product (Bq kg^{-1} fresh weight) divided by the radionuclide activity concentration in the feedstuff ingested (Bq kg^{-1} dry weight). Values for CR were first provided in TRS 472 and are now often reported for animal products.

TRS 364

The TRS 364 (IAEA, 1994) animal product tables for F_f and F_m were compiled by the end of 1992 and published in 1994. They were prepared initially by Ng who published many extensive reviews of transfer parameter values (Ng et al. 1968, 1977, 1978, 1979a, 1979b, 1982; Ng 1982). The work was finalized at short notice by Howard and Voigt, who completed the tables by focusing on review data complemented by only a few original source data. The literature used contained no original Russian data values, but instead relied upon values from a limited number of monographs and reviews. The animal product tables in TRS 364 gave 'Expected F_f

and F_m' values and ranges. 'Less than' values were included (i.e. values below detection limits) and the type of data was given in footnotes to the tables.

The importance of review sources in TRS 364 is shown in Table 1, which lists the most commonly cited reviews and those sources which were used for at least three elements in the animal products.

Table 1. Reviews and sources of data for three or more elements in animal products in TRS 364

Source	**Cow**		**Sheep**		**Goat**		**Pig**	**Poultry**	
	Meat	**Milk**	**Meat**	**Milk**	**Meat**	**Milk**	**Meat**	**Eggs**	**Meat**
Review source information									
Coughtrey (1990)	✓	✓	✓	✓		✓	✓	✓	✓
Ng (1982)		✓							
Ng et al. (1982)	✓		✓				✓	✓	✓
Commission of the EC (1987)			✓				✓		✓
Cramp et al. (1990)									✓
Bishop et al. (1989)	✓								
References supplying data for more than three elements in animal products									
Ennis et al. (1988)								✓	✓
Johnson et al. (1988)	✓	✓			✓	✓			
Johnson and Ward (1989)		✓				✓			
Voigt et al. (1988)		✓							
Van Bruwaene et al. (1984)		✓							

The use of review values has some advantages in that they utilise expert guidance from authors who have considerable experience and expertise in compiling and evaluating data such as Ng and Coughtrey. Also, for some reviews, the values are compiled by more than one expert in radionuclide transfer to agricultural animals (e.g. Commission of the EC 1987). Some reviews derive values using model predictions based on relevant data to fill gaps (e.g. Thorne 2003) by extrapolating in a consistent manner (e.g. Balkema series: Coughtrey and Thorne 1983; Coughtrey et al. 1984 etc.).

However, the use of review values also has some disadvantages, these include:

- Unclear provenance of data with some values now being impossible to verify as they refer to bibliographic numbers in an unobtainable reference system (e.g. Ng 1977)
- Variable or undocumented Quality Control (QC) and/or peer review
- Some reviews cite reviews which cite reviews which ultimately provide transfer parameter values for an element and animal product that were derived. For example, in SRS 19 (IAEA 2001), the source data for the F_m and F_f values is given as TRS 364 and, if data are not present in TRS 364, it refers to NCRP 123 (1996) as the secondary source of data. NCRP 123 includes citations from Ng et al. (1977, 1982) and Baes et al. (1984) as its source of F_m and F_f data. The latter utilises data from Ng references (1968, 1979a,b) and a theoretical approach based on the elemental variation in soil to plant and plant to milk. Similarly, although some values in Ng references are based on data for the element in both animal product and feed, many values were derived, or extrapolated, using a number of different approaches, some of which are still widely used in current assessments.
- Time, resource and expertise limitations mean that it is common for values taken from reports to be used without checking the validity or acceptability of the method used to derive or extrapolate data.

<u>TRS 472</u>

The F_f, F_m (and CR) values in TRS 472 were compiled up to 2007 under the EMRAS programme of the IAEA by CEH, IAEA and RIARAE and published in TECDOC 1616 in 2009, and TRS 472 in 2010. The dataset incorporates data for both radionuclides and stable elements. Compared with the TRS 364 data tables, more elements were included and some elements were removed after QC. Most of the values were based on original data, < values were excluded and the majority of review data were removed. Detailed information on the approach taken to derive the tables in TRS 472 and supplementary information can be found in the accompanying TECDOC 1616 (IAEA, 2009) and Howard et al. (2009a,b). In a substantial improvement, TRS 472 included original Russian literature data associated with a series of papers by Fesenko et al. (2007a,b; 2009a,b).

When the data for TRS 472 was collated up to the end of 2007, the primary focus was to report revised F_m and F_f values. The tables reported geometric mean (GM) and geometric standard deviation (GSD) when $n \geq 3$ otherwise the arithmetic mean (AM) was reported together with the minimum, maximum and n. Only values for adult animals were used to calculate F_f (or F_m) as the DMI of an animal varies with live-weight.

CR values were included in the TRS dataset when they were reported in the source data used for the F_m of F_f values for some elements. These CR values were supplemented with values based on stable element concentrations in animal products and feed. For feed, data were collated from agricultural review literature (Church 1980, NRC 2001, NRC 2005, MAFF 1990, Underwood 1977). The arithmetic mean of collated literature values of element concentrations in animal products were then divided by that of the feed concentrations to derive CR values. Ng et al. (1978) derived “unassociated” transfer coefficients using separate data sources for the element concentrations in animal products and feed. This approach was used to derive CR values for Se, Na, Zn and P in TRS 472 reported in the CR table (shaded values). Additional literature values for stable element concentrations were also collated for each of the animal products.

The number of F_f and F_m data available increased in TRS 472 compared with TRS 364. However, for many elements the number of data values was <10 and the quality and information for the data from different studies was variable.

THE NEED FOR IMPROVEMENTS

The widespread use of the review values discussed above can lead to a situation where new and valuable data are not incorporated into models at regular intervals when it becomes available. Instead, updating tends to follow that of the tables produced by the International Atomic Energy Agency at long intervals often exceeding a decade. Within the MODARIA programme, it was recognized that mechanisms to produce more frequent revisions of transfer parameter tables need to be explored. Any revisions of the datasets needs to be registered so that the version of the data used can be suitably referenced in assessments.

Current problems include the provenance of the data, transparency of changes made and how source data was used and the need for continual data quality checks. Those people carrying out assessments, or using the parameter values in models, need clear information on how and why the recommended values have changed. We therefore need to make such ancillary information available.

The aim of the current programme of activities, initiated under the IAEA’s MODARIA programme, is to substantially enhance each of the animal product datasets and associated tables for both F_m, F_f, and CR. Since this involves a substantial effort, the data tables will be reported individually to avoid delays in making them available.

Approaches for the 2015 onwards animal product transfer parameter tables

The new revised F_m, F_f and CR data tables use both radioiosotope and stable element data. For the stable data only control animals or those with stable element intakes below the maximum tolerable levels of elements in the feed were used (NRC 2005; EC 1991).

For all data, a more rigorous QC procedure has been performed, by consulting and reviewing the source data. A record has been retained of the last person who worked with each data row and when, and notes were inserted on any assumptions or decisions which were taken to derive the values. As part of the QC, when a value has been queried, it has been reviewed further by an independent person and if the value has then been removed the reason has been recorded within the dataset.

All Russian data were reviewed and modified if necessary to be consistent with the Fesenko series of papers (Fesenko et al. 2007b, 2009a,b).

CR values derived from agricultural stable element literature (discussed above) were added to the datasets for each element when the number of measurements for the animal product was equal to, or greater than, five.

It is often not possible to derive transfer coefficient values because the DMI of the animals was not reported. TRS 364 reported an “expected” range of DMI of the animals considered, but these have varied considerably over the past decades both within and between species. To enhance the number of F_m or F_f values in the datasets some assumptions were made, based on relevant agricultural literature, to estimate the liveweight of the animal, which can then make it possible to estimate DMI taking into account temporal changes in agricultural feeding regimes. However, DMI varies considerably within an animal species depending on many factors including the digestibility of the feed and there will always be uncertainity in making these assumptions.

THE GOAT MILK DATASET REVISION

A literature review for goat milk was undertaken to incorporate further reported F_m and CR values. Reference sources providing data which were added to the dataset were: Antunovic et al. (2012) for Cd, Hg and Pb; Dowdy et al. (1984) for Ca and Zn, Haenlein and Anke (2011) for As, Cd, Li, Mn, P, Se and Zn, Milhaud et al. (2000) for Cd, Nudda et al. (2009) for I and Perchova et al. (2009) for Zn.

Stable element data in agricultural reviews listed above were used to derive typical feed concentrations for goats. The elements for which there were N≥5 data for goat milk were Ca, Cu, Fe, Mg, Mn, Na, P, Se, and Zn. The reference sources are given as footnotes in Table 2 and 3.

Assumptions were made to estimate the liveweight of lactating goats, which then makes it possible to estimate their DMI. The approach is simple and does not reflect the considerable literature on variation in DMI for ruminants, but it allows a small, pragmatic refinement in current approaches used to produce the transfer parameter values. DMI for lactating goats were used because the transfer computed is for milk'?. The following approaches were adopted after reviewing the agricultural literature on liveweight and DMI of goats:

- where the DMI was not given in the source reference but the liveweight of the goat(s) was available, we used an assumption that the DMI for lactating goats is 4 % of liveweight (Clemson University (http://www.clemson.edu/).
- where no liveweight or DMI was given in the source reference, the data were sub divided into two different time periods. The liveweight of goats has assumed to have increased in recent years to reflect the impact of breeding programmes designed to increase milk yield.
    - for studies conducted in the 1960's, 1970's or 1980's, the liveweight of the goat was assumed to be 40 kg and the DMI was estimated to be ((40*4)/100)) = 1.6 kg d^{-1}.
    - For studies conducted from the 1990's onwards, the liveweight of the goat was assumed to be 50 kg and the DMI was estimated to be ((50*4)/100)) = 2.0 kg d^{-1}.

The adoption of these assumptions has enabled the conversion of previously reported F_m values to provide additional CR values which has considerably increased the number of CR data for some elements. In TRS 472, 21 CR values were reported including four values for stable elements; in the revised tables a further 14 elements are reported.

The QC procedure identified some discrepanices and outliers in some references. As a result data from some of these references were removed. Key examples of data removed include:

- Ward and Johnson (1983) – this reference is a major source of data for many elements for goat milk in TRS 472. All values reported for Ca, Cr, Fe, Mn, Na, Ni, Sr and Zn were based on data from an experiment with a single goat. The goat milk was centrifuged and only the liquid fraction measured and the F_m calculated. However, the exclusion of the fat content of the milk may lead to a loss of some elements that can be associated with the fat fraction. This means that the reported F_m values in TRS 472 for

Ca, Cu, Fe, Mn, Zn are probably too low (based on de la Fuente et al. 1997). Data for other elements reported in the paper were retained in the dataset as evidence for fat binding has not been identified and the F_m values were consistent with other data for those elements.

- Coni et al. (1996) – the Sr F_m value in this paper was two orders of magnitude higher than other Sr studies and the milk activity concentration was higher than that of the feed. The Ni F_m value was also almost two orders of magnitude higher than the only other reported study (Ward and Johnson 1983). A possible cause for the higher Ni F_m is cross contamination of the milk from a Cu-Ni alloy that can be used in the manufacture of milk vats (http://drinc.ucdavis.edu/dairyp/dairyp3.htm). Also, the F_m data for Zn from this study was an order of magnitude higher than that from other studies possibly because (i) Zn can be combined with other metals to form alloys, mainly of nickel, that are used to make stainless steel milk vats and (ii) Zn present in galvanized metal is often present in barns and may be licked by animals. The F_m value for Ba was also two orders of magnitude higher than other two reported F_m values for this element retained in the dataset (Johnson et al. 1988 and Ward and Johnson 1983). As there were a range of discrepancies in data from the paper we removed all the data even though some values were consistent with other data sources (notably for Cu).
- Bondietti and Garten (1988) – this study presents concentrations of ^{131}I in milk and pasture from a field based study. The ^{131}I was sprayed onto a pasture and the activity concentration was measured in pasture and milk of goats over time and presented graphically. The data were excluded because the deposition method led to considerable temporal changes and the DMI for the goats was not measured. Furthermore, there were >10 F_m better quality values already included for I in the dataset.

REVISED GOAT MILK PARAMETER VALUES

For all elements an arithmetic mean and standard deviation were calculated (AM and ASD). Where $N \geq 3$ a geometric mean and standard deviation (GM and GSD) has also been calculated. The revised parameter values for F_m and CR are shown in Tables 2 and 3.

Fm

The revised dataset of F_m values for goat milk provides a total of 33 F_m values compared with 28 in TRS 472, with values reported for an additional 6 elements (As, Cu, Hg, Li, Mg, Ti). In TRS 472 the F_m values for Fe, Mn, Na, P, Zn were based on animal nutrition literature alone whereas they are now based on both stable element agricultural review sources and other data. The revision also had some data values removed as part of the QC for Ba, Cs, I and Ni. Despite these changes, the resulting F_m values for these elements are within an order of magnitude of those reported in TRS 472.

In TRS 472, an F_m value was reported for Mn based upon source data from Coni et al. (1996) and Ward and Johnson (1983). This datum has now been removed. However, new source material based on agricultural stable review sources and the study of Haenlein and Anke (2011) has now been included. The revised F_m value is lower by more than one order of magnitude than that given in TRS 472.

The F_m reported in TRS 472 for Am, had a calculation error which has now been corrected and did not significantly change the F_m value.

CR

The 2015 revision gives a total of 34 CR values for goat milk compared with 21 in TRS 472 with CR values now reported for an additional 14 elements (As, Am, Ce, Cu, Hg, Li, Mg, Np, Pm, Po, Tc, Ti, U and Y) with one deletion (Co). For the four stable elements included in TRS 472 (Na, P, Se and Zn), the CR value reported is now based on both stable element agricultural review sources and radioisotope data.

CR values reported in TRS 472 were based on limited data reported in journals and some agricultural stable element reviews. Using the assumptions described above, the numbers of data underpinning the CR values have increased for Ca, Cd, Cs, I, Mn, Mo, S and Sr. Despite the changes, the resulting CR values for these elements are within an order of magnitude of those reported in TRS 472.

In the revision, CR values for Ba and Ni decreased by over an order of magnitude compared with the reported values in TRS 472. For both elements Coni et al. (1996) data were removed and Ward and Johnson (1983) data added. However, the current values are now based on few data (n = 2 for Ba; n=1 for Ni).

The CR value reported for Te in TRS 472 had a calculation error which has been corrected; the modification and has not significantly changed the value.

In TRS 472, a CR value was reported for Co based upon a single value in Coni et al. (1996), this value has now been removed as part of the QC. No further CR values were identified for Co.

SUMMARY

The goat milk transfer parameter tables were revised and supplemented for both F_m and CR values. Nevertheless, data gaps still remain for elements with isotopes relevant to radiation protection.

In the case of Co, the removal of data from Coni et al. (1996) means that no value is now reported in the revised tables. When a transfer value is required which is not included in the revised tables for goat milk, CR values could be used for other milk products if available, as there is evidence that there is no difference in CR between species (Howard et al. 2009b). Alternatively, extrapolation methods could be used such as those outlined in Beresford et al. (2016). Also, the use of removed data discussed here could be considered after further analysis of the possible validity of the reported value for that element.

This paper provides the first set of revised and improved parameter values for goat milk. We intend to continue to revise the tables as relevant data becomes available. Other mechanisms to revise and report such tables are being explored and further work is being finalised in MODARIA WG4 to establish suitable metadata and online reporting approaches for such datasets.

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Table 2. Goat milk Fm values for TRS 472 and 2015 Revision

	TRS 472						2015 Revision							
Element	**GM**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
As							1.5E-2						1	Haenlein and Anke 2011
Am	6.9E-6		3.7E-6	1.0E-5	2	Sutton et al. (1978)	2.8E-5				3.7E-6	5.2E-5	2	
Ba	1.1E-2	9.9	2.1E-3	1.5E-1	3	Ward and Johnson (1973); Johnson et al. (1988); Coni et al. (1996)	3.3E-3				2.1E-3	4.6E-3	2	Removed (Coni et al. 1996)
Ca[a]	7.3E-2	1.9	1.2E-2	1.4E-1	12	Sirotkin et al. (1978); Comar et al. (1966); Wasserman et al. (1958); Twardock et al. (1960); Comar, Wasserman and Twardock (1961); Twardock and Comar (1961); Ward and Johnson (1983)	1.5E-1	2.1E-1	9.3E-2	2.7	1.2E-2	7.6E-1	11	Agricultural review
Cd	1.6E-2				1	Coni et al. (1996)	2.1E-3	2.4E-3	9.6E-4	4.9	1.7E-4	5.4E-3	4	Antunovic et al. (2012); Haenlein and Anke 2011; Milhaud et al. (2000) Removed (Coni et al. 1996)
Ce	4.0E-5				1	Ekman and Aberg (1961)	4.0E-5						1	
Co	5.0E-3				1	Coni et al. (1996)								Removed (Coni et al. 1996)
Cr	1.5E-2				2	Coni et al. (1996); Ward and Johnson (1983)	2.9E-3						1	Removed (Coni et al. 1996)

	TRS 472						2015 Revision							
Element	**GM**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
Cs	1.1E-1	2.2	7.0E-3	3.3E-1	28	Assimakopoulos et al. (1994b); Bonsembiante et al. (1991); Burov et al. (1978); Daburon et al. (1991); Ekman (1961); Hansen and Hove (1991); Hove et al. (1990); Hove and Hansen (1993); Johnson and Ward (1989); Sirotkin (1991); Wasserman et al. (1961); Ward et al. (1989)	1.4E-1	7.9E-2	1.1E-1	2.1	9.0E-3	3.3E-1	27	Removed (Ward et al. 1989)
Cu[b]							3.1E-2	2.8E-2	2.3E-2	2.3	9.7E-3	7.8E-2	5	Agricultural review; Dowdy et al. (1984); Haenlein and Anke 2011
Fe[c]	5.2E-2					Animal nutrition literature	4.0E-2						1	Agricultural review
Hg							2.3E-2	4.6E-2	4.8E-4	38.6	2.2E-5	9.3E-2	4	Howe et al. (1972); Antunovic et al. (2012)
I	2.2E-1	2.9	2.7E-2	7.7E-1	24	Binnerts et al. (1962); Bondietti and Garten (1988); Bonka et al. (1988); Comar (1963); Comar et al. (1966); Lengemann (1964); Lengemann (1969); Lengemann (1970); Lengemann and Wentworth (1979);	3.2E-1	2.3E-1	2.1E-1	3.0	2.7E-2	7.7E-1	23	Nudda et al. (2009);

	TRS 472						2015 Revision							
Element	**GM**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
						Lengemann (1979); Reike (1961); Sirotkin (1991); Wright et al. (1955)								
Li							3.0E-2						1	Haenlein and Anke (2011)
Mg[d]							3.8E-2				2.9E-2	4.7E-2	2	Agricultural review; Ward and Johnson (1983)
Mn[e]	1.0E-3					Animal nutrition literature	3.4E-2				1.5E-3	6.6E-2	2	Agricultural review; Haenlein and Anke (2011)
Mo	8.2E-3	1.4	5.0E-3	1.1E-2	4	Hart et al. (1967); Johnson et al. (1988); Ward and Johnson (1983)	1.1E-2	5.1E-3	1.1E-2	1.6	5.4E-3	1.9E-2	5	Haenlein and Anke (2011)
Na[d]	1.2E-1					Animal nutrition literature	2.4E-1	2.4E-1	1.8E-1	2.5	1.0E-1	5.1E-1	3	Agricultural review; Shilov and Kulakova (1984); Ward and Johnson (1983)
Nb	6.4E-6				1	Johnson et al. (1988)	6.4E-6						1	
Ni	8.3E-2		3.2E-3	1.6E-1	2	Coni et al. (1996); Ward and Johnson (1983)	3.2E-3						1	Removed (Coni et al. 1996)
Np	5.3E-5				1	Mullen et al. (1977)	5.3E-5						1	
P[f]	2.9E-1					Animal nutrition literature	1.6E-1				5.5E-2	2.6E-1	2	Agricultural review; Haenlein and Anke (2011)
Pb	6.0E-3				1	Coni et al. (1996)	3.7E-2						1	Antunovic et al. (2012) Removed (Coni et al. 1996)

	TRS 472						2015 Revision							
Element	**GM**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
Pm	2.7E-5				1	Ekman and Aberg (1961)	2.7E-5						1	
Po	2.3E-3		1.8E-3	2.7E-3	2	Johnson and Watters (1972); Schreckhise and Walters (1969)	2.3E-3				1.8E-3	2.7E-3	2	
S	3.8E-2	1.7	1.6E-2	6.8E-2	12	Howard et al. (2007)	4.7E-2	1.9E-2	3.8E-2	1.7	1.6E-2	6.8E-2	12	
Se[g]	6.9E-2		5.9E-2	7.9E-2	2	Aspila (1991)	7.2E-2	2.9E-2	6.8E-2	1.5	4.1E-2	1.1E-1	4	Agricultural review; Haenlein and Anke (2011)
Sr	1.6E-2	2.0	5.8E-3	8.1E-2	21	Beresford (1998); Beresford et al. (1999); Burov (1974); Comar et al. (1966); Comar, Wasserman and Twardock (1961); Johnson and Ward (1989); Twardock et al. (1960); Twardock and Comar (1961); Wasserman, Lengemann and Comar (1958); Ward and Johnson 1983	2.0E-2	1.9E-2	1.5E-2	2.0	5.8E-3	8.1E-2	21	
Te	4.4E-3				1	Johnson et al. (1988)	4.4E-3						1	
Ti							1.5E-4						1	Ward and Johnson (1983)
U	1.4E-3				1	Sirotkin et al. (1978)	1.4E-3						1	
Y	2.0E-5				1	Ekman and Aberg (1961)	2.0E-5						1	

			TRS 472							2015 Revision				
Element	**GM**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
Zn[h]	6.4E-2					Animal nutrition literature	4.8E-2	2.3E-2	4.3E-2	1.6	2.6E-2	8.6E-2	7	Agricultural review; Dowdy et al. (1984); Haenlein and Anke 2011; Johnson and Ward (1989); Pechova et al. (2009)
Zr	5.5E-6				1	Johnson et al. (1988)	5.5E-6						1	

AM: arithmetic mean; ASD: arithmetic standard deviation; GM: geometric mean; GSD: geometric standard deviation

Authors for stable milk concentration values used in agricultural review:

[a] NRC mineral tolerance of animals (2005); NRC nutrient requirements of ruminants (2007); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[b] NRC nutrient requirements of ruminants (2007); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Benemariya et al. (1993); Jenness (1980); Lopez et al. (1985)

[c] Underwood (1977); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[d] Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[e] Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[f] Nutrient requirements of ruminants (2007); Kondyli et al. (2007); Park (2000); Jenness (1980); Lopez et al. (1985)

[g] Rodriguez et al. (1999); Khan et al. (2006); Debski et al. (1987); Benemariya et al. (1993)

[h] Underwood (1977); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Benemariya et al. (1993); Jenness (1980); Lopez et al. (1985)

Table 3. Goat milk CR values for TRS 472 and 2015 Revision

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
As							9.6E-3						1	Haenlein and Anke (2011)
Am							4.4E-5				4.4E-6	8.4E-5	2	Sutton et al. (1978)
Ba	1.2E-1		1.4E-2	2.3E-1	2	Johnson et al. (1988); Coni et al. (1996)	8.5E-3				3.3E-3	1.4E-2	2	Ward and Johnson (1983) Removed (Coni et al. 1996)
Ca[a]	2.0E-1	8.3E-2	1.3E-1	2.9E-1	4	Comar, Wasserman and Twardock (1961)	2.6E-1	3.3E-1	1.7E-1	2.6	1.9E-2	1.2E+00	11	Sirotkin et al. (1978); Comar et al. (1966); Twardock & Comar (1961); Wasserman et al. (1958); Twardock et al. (1960); Agricultural review
Cd	2.4E-2				1	Coni et al. (1996)	4.0E-3	4.8E-3	1.9E-3	4.4	3.9E-4	1.1E-2	4	Antunovic et al. (2012); Haenlein and Anke (2011); Milhaud et al. (2000)

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
														Removed (Coni et al. 1996)
Ce							6.4E-5						1	Ekman and Aberg (1961)
Co	7.6E-1				1	Coni et al. (1996)								Removed (Coni et al. 1996)
Cr	4.1E-2				1	Coni et al. (1996)	4.6E-3						1	Ward and Johnson (1983)
														Removed (Coni et al. 1996)
Cs	1.8E-1	6.5E-2	6.3E-2	3.0E-1	12	Assimakopoulos et al. (1994b); Hansen and Hove (1991); Hove et al. (1990); Ward et al. (1989)	2.2E-2	9.8E-2	2.0E-1	1.7	4.9E-2	4.3E-1	26	Bonsembiante et al. (1991); Burov et al. (1978); Daburon et al. (1991); Ekman (1961); Hove and Hansen (1993); Johnson and Ward (1989); Sirotkin (1991); Wasserman et al. (1961)
														Removed Ward et al. 1989

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
Cu[b]							4.6E-2	4.7E-2	3.2E-2	2.6	1.2E-2	1.3E-1	5	Agricultural review; Dowdy et al. (1984); Haenlein and Anke (2011)
Fe[c]	3.4E-2				1	Coni et al. (1996)	7.8E-2						1	Agricultural review Removed (Coni et al. 1996)
Hg							4.7E-2	9.3E-2	7.3E-4	45.8	3.0E-5	1.9E-1	4	Howe et al. (1972); Antunovic et al. (2012)
I	5.0E-1	5.8E-1	8.4E-2	1.2E+00	3	Bonka et al. (1988); Bondietti and Garten (1988)	5.3E-1	4.0E-1	3.2E-1	3.1	4.4E-2	1.2E+00	21	Binnerts et al. (1962); Comar (1963); Comar et al. (1966); Lengemann (1964); Lengemann (1969); Lengemann (1970); Lengemann and Wentworth (1979); Lengemann (1979); Reike (1961); Sirotkin (1991); Wright et al. (1955); Nudda et al. (2009)

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
														Removed (Bondietti and Garten 1988)
Li							4.8E-2						1	Haenlein and Anke (2011)
Mg[d]							6.1E-2	2.1E-2			4.6E-2	7.5E-2		Ward and Johnson (1983); Agricultural review
Mn[e]	1.5E-3				1	Coni et al. (1996)	5.4E-2				2.3E-3	1.1E-1	2	Haenlein and Anke 2011; Agricultural review Removed (Coni et al. 1996)
Mo	2.7E-2				1	Johnson et al. (1988)	2.0E-2	9.0E-3	1.8E-2	1.7	8.6E-3	3.0E-2	5	Hart et al. (1967); Haenlein and Anke (2011); Ward and Johnson (1983)
Na[d]	1.8E-1					Stable element review	3.9E-1	3.8E-1	2.9E-1	2.5	1.6E-1	8.2E-1	3	Agricultural review; Shilov and Kulakova (1984);

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
														Ward and Johnson (1983)
Nb	1.9E-5				1	Johnson et al. (1988)	1.9E-5						1	
Ni	2.5E-1				1	Coni et al. (1996)	5.2E-3						1	Ward and Johnson (1983)
														Removed (Coni et al. 1996)
Np							8.4E-5						1	Mullen et al. (1977)
P[f]	4.3E-1					Stable element review	2.2E-1				2.1E-2	4.2E-1	2	Agricultural review; Haenlein and Anke (2011)
Pb	9.0E-3				1	Coni et al. (1996)	4.8E-2						1	Antunovic et al. (2012)
														Removed (Coni et al. 1996)
Pm							4.3E-5						1	Ekman and Aberg (1961)
Po							3.6E-3				2.9E-3	4.3E-3	2	Johnson and Watters (1972);

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
														Schreckhise and Walters (1969)
S	6.1E-2	3.0E-2	3.5E-2	1.0E-1	4	Howard et al. (2007)	8.3E-2	3.9E-2	7.3E-2	1.7	3.4E-2	1.3E-1	12	
Sb														
Se[g]	3.5E-2					Stable element review	1.1E-1	3.8E-2	1.0E-1	1.4	6.6E-2	1.5E-1	4	Aspila (1991); Haenlein and Anke 2011; Agricultural review
Sr	4.4E-2	4.4E-2	1.6E-2	1.2E-1	5	Comar, Wasserman and Twardock (1961); Comar et al. (1966)	3.4E-2	3.2E-2	2.6E-2	2.1	9.3E-3	1.3E-1	21	Beresford (1998); Beresford et al. (1999); Burov (1974); Johnson and Ward (1989); Twardock et al. (1960); Twardock and Comar (1961); Wasserman, Lengemann and Comar (1958); Ward and Johnson 1983

	TRS 472						2015 Revision							
Element	**Mean**	**GSD**	**Min**	**Max**	**N**	**References**	**AM**	**ASD**	**GM**	**GSD**	**Min**	**Max**	**N**	**Changes to references; new references and removed references)**
Tc							1.0E-1						1	Johnson et al. (1988)
Te	1.2E-2				1	Johnson et al. (1988)	1.3E-2						1	
Ti							2.3E-4						1	Ward and Johnson (1983)
U							4.8E-4						1	Sirotkin et al. (1978)
Y							3.2E-5						1	Ekman and Aberg (1961)
Zn[h]	9.6E-2					Stable element review	7.4E-2	3.9E-2	6.5E-2	1.8	2.9E-2	1.4E-1	7	Agricultural review; Dowdy et al. (1984); Haenlein and Anke 2011; Johnson and Ward (1989); Pechova et al. (2009)
Zr	1.7E-5				1	Johnson et al. (1988)	1.7E-5						1	

AM: arithmetic mean; ASD: arithmetic standard deviation; GM: geometric mean; GSD: geometric standard deviation

Authors for stable milk concentration values used in agricultural review:

[a] NRC mineral tolerance of animals (2005); NRC nutrient requirements of ruminants (2007); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[b] NRC nutrient requirements of ruminants (2007); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Benemariya et al. (1993); Jenness (1980); Lopez et al. (1985)

[c] Underwood (1977); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[d] Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[e] Kondyli et al. (2007); Khan et al. (2006); Park (2000); Jenness (1980); Lopez et al. (1985)

[f] Nutrient requirements of ruminants (2007); Kondyli et al. (2007); Park (2000); Jenness (1980); Lopez et al. (1985)

[g] Rodriguez et al. (1999); Khan et al. (2006); Debski et al. (1987); Benemariya et al. (1993)

[h] Underwood (1977); Rodriguez et al. (1999); Kondyli et al. (2007); Khan et al. (2006); Park (2000); Benemariya et al. (1993); Jenness (1980); Lopez et al. (1985)

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