Official Guidelines for Contaminant Levels Permitted in Mineral Feed Ingredients

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The Mineral Investigation Committee considered the matter of contaminants in mineral feed ingredients for several years before adopting an approach to the problem as reported in the 1978 AAFCO Official Publication~~*Official Publication*~~. The original approach was combined with toxicity data in the 1980 National Academy of Sciences (NAS), National Research Council (NRC) *Mineral Tolerance of Domestic Animals* [National Academy of Sciences, National Research Council. *Mineral Tolerance of Domestic Animals* (1980). National Academy Press, Washington, D.C. 20001] to produce the guidelines appearing in the AAFCO Official Publication~~*Official Publication*~~ through 2021. Updates to the AAFCO ~~Official~~ Mineral Guidelines in 2022 were derived from multiple sources including the 2005 National Academy of Sciences (NAS), National Research Council (NRC) *Mineral Tolerance of Animals*~~2005 NRC *Mineral Tolerance of Animals*~~ [National Academy of Sciences, National Research Council. *Mineral Tolerance of Animals Second Revised Edition*, (2005). National Academy Press, Washington, D.C. 20001]. The 2005 *Mineral Tolerance of Animals* indicates that the 2005 NRC Expert Subcommittee ~~expert subcommittee~~ did not consider tissue residues of mineral contaminants with regard to human food safety when setting the various maximum tolerable levels (MTL or tolerance) for minerals. Given the lack of consideration for human food safety by the 2005 NRC Expert Subcommittee~~NRC expert subcommittee~~, the AAFCO Mineral Guidelines Work Group that updated these ~~Official~~ AAFCO Mineral Guidelines took the approach that if a tolerance for a given mineral was reduced by the 2005 NRC Expert Subcommittee ~~2005 NRC expert subcommittee~~ from the tolerance stated in the 1980 *Mineral Tolerance of Domestic Animals*, the AAFCO Mineral Guidelines Work Group accepted the reduced amount in the 2005 *Mineral Tolerance of Animals*. If, however, the 2005 NRC Expert Subcommittee ~~2005 NRC expert subcommittee~~ increased a tolerance for a given mineral, the AAFCO Mineral Guidelines Work Group retained the lesser tolerance from the 1980 *Mineral Tolerance of Domestic Animals*.

The mineral products section (section #57) of the 2022 AAFCO Official Publication contains 142~~1~~ mineral ingredient definitions for sources of 15 elements to consider in drafting guidelines to limit contaminants. Variables considered and used in guideline development included:

(1) Differing nutrient requirements between species and within species, e.g., young vs. mature, lactating vs. non-lactating, and layers vs. broilers.

(2) Whether the toxicity of a contaminant varies between and within species.

(3) The concentration of a nutrient varies between several ingredient sources. For example, magnesium oxide (MgO) contains 6 times the magnesium (Mg) to an equivalent weight of magnesium sulfate heptahydrate ($MgSO_4$-$7H_2O$), and thus, could contain 6 times the contaminant level compared to magnesium sulfate for an equivalent contaminate burden in a finished product since only one-sixth as much magnesium oxide would be needed to meet a given amount of magnesium.

(4) The range between a nutrient requirement and toxicity for a given element varies greatly. Manganese, for example, is required at about 50 ppm but levels as high as 1,000 to 2,000 ppm can be tolerated.

(5) Knowledge of nutrient requirements and toxicities is incomplete and/or imprecise in many cases.

If the variables are acknowledged, it becomes apparent that precise contaminant limits, fixed at the very brink of toxicity, are impractical. Rather, we must work in much more general and conservative terms, using scientific data to limit, but not

exclude some subjective decisions based upon common sense. Safety factors, for example, would be included in the latter category.

With the above ~~factors~~ variables in mind, the following approach was used in developing the overall recommendations for handling contaminants in mineral feed ingredients proposed in this report.

(1) Determine the all-species average requirement for each of the 15 elements included in the AAFCO mineral product definitions if a requirement has been established. [Chromium is believed to be essential, but no minimum requirement has been established for any species, thus, chromium does not appear in Table 1.] These values (Table 1) were adapted from the NRC nutrient requirement recommendations for the species listed in Table 1.

(2) Determine the all-source average content for each element.

(3) Calculate, from the data in (1) and (2) above, the dilution factor needed to meet NRC recommended amounts for each element (Table 2). Example: If the average calcium content from all AAFCO sources is 32% and the NRC recommendation is 1.55%, the dilution factor is 21.

In other words, the calcium source will be diluted by a factor of 21 on a complete feed basis. [Complete feed. A nutritionally adequate feed for animals other than man; by specific formula is compounded to be fed as the sole ration and is capable of maintaining life and/or promoting production without any additional substance being consumed except water.] ~~[A Complete Feed is a multi-ingredient product fed to an animal. Examples include, but are not necessarily limited to, total mixed rations, sweet feeds, pelleted feeds or grain mixes. It also can be the summation of the total amount of feedstuffs fed separately at various locations or times within a 24-hour period.]~~

(4) Come up with a safety factor, which is 2.5 in this report.

(5) Group contaminants according to toxicity following the general guidelines proposed in the 2021 report by the AAFCO Mineral Guidelines Work Group ~~2021 report of the Work Group~~ to this Committee. Five groups, labeled 1 through 5, ordered from least to greatest tolerance, were recommended by the AAFCO Mineral Guidelines Work Group ~~Work Group~~ based on the MTL in c~~C~~omplete f~~F~~eed (Table 3).

(6) Set limits *within each group* as follows:

a. Level for contaminants below which no declaration or labeling for the contaminants is required or deemed appropriate.

b. A range of contaminants' levels permitted in feed ingredients if, but only if, the product is labeled as to the contaminants' levels. "Labeling" here and elsewhere is considered in the broader sense, e.g., "Typical Analysis Specification Sheet" or similar information supplied by the manufacturer to customers.

c. Contaminants' levels above which the product's use as a feed ingredient is prohibited. This guidance does not apply to the primary nutritional element(s) of defined mineral ingredients. Definition 57.119 sodium selenite contains selenium at 460,000 ppm, but selenium from sodium selenite is a primary nutritional element.

(7) Select a dilution factor (see item (3) above) to be used in setting the maximum contaminant level permitted in a feed ingredient without labeling the amount present. A dilution factor of 21 is recommended and was used in arriving at the values in Table 3. This is the lowest value in Table 2 (for calcium) and thus provides the greatest margin of safety.

(8) Calculate the maximum level permitted in ingredients, without labeling, for each of the 5 groups, using the following equation:

$$MLP = (CFL \times DF)/SF,$$

where MLP is Maximum Level Permitted without labeling (on "Typical Composition Specification Sheets" for example)

CFL is NAS recommended maximum Continuous Feeding Level for the most toxic element in the group

Commented [KJ(1]: Replace with the defined term for complete feed in Chapter 6 of the OP:

Complete feed. A nutritionally adequate feed for animals other than man; by specific formula is compounded to be fed as the sole ration and is capable of maintaining life and/or promoting production without any additional substance being consumed except water.

DF is Dilution Factor SF is Safety Factor Example:

In Group 1 (Table 3) of inorganic mercury, cadmium, and selenium, inorganic mercury has the least daily tolerance in complete feed at 0.2 ppm. Therefore, if DF = 21 and SF = 2.5, MLP = (0.2 ppm × 21) / 2.5 = 1.7 ppm. Thus, ingredients containing 1.7 (~2) ppm or less of Group 1 contaminants will not raise the level in the total ration above the MTL for any of the contaminants in Group 1.

The MLP values for the other 4 groups were determined similarly.

(9) Determine range of contaminant levels permitted, **by group**, if levels are stated in the labeling. This is a judgment decision.

(10) Determine contaminant levels, **by group**, above which an ingredient would be excluded from use in a feed. This is also a judgment decision.

The procedure recommended above provides a systematic approach to establishing contaminant limits in feed ingredients based upon toxicity data in the NRC publications for mineral tolerances of animals and other publicly available information. The equation used to set the limits is designed to handle worst case situations, since it is based upon the most toxic element in each group and assumes the lowest dilution of the ingredient (dilution factor of 21). Thus, an additional margin of safety is provided automatically for all but the most toxic contaminants in each group and the greatest nutrient requirements. This margin of safety comes not just from focusing on the MTL for the most toxic element in the group, but also because the values in the last three columns of Table 3 represent the total amount, that is the sum of the content, of all elements within the Group. That these values represent the sum of the Group, and not just the amount of an individual element within the group, has been a source of confusion by users of the former versions of Table 3. However, a reading of the 1978 minutes of the former AAFCO Mineral Investigation Committee reveals that this is in fact the approach and intent of the group that originally established these guidelines. Table 3 has been reorganized to try and clarify this aspect of the guidelines. In addition, a new table (Table 4) has been created that contains species-specific MTLs for certain minerals that previously was found in the footnotes of Table 3.

Finally, fluorine is not included in Table 3 because fluorine is closely associated with phosphate ingredients and has been handled successfully for many years by requiring the phosphorus:fluorine ratio to be not less than 100:1. It is recommended this policy continue unchanged.

Table 1. Approximate Mineral Requirements (Total Diet Basis–Greatest Concentration)[a]

Mineral	Swine	Dairy	Beef	Poultry	Aquaculture	Sheep	Goats	All-Species Average
Calcium (%)	0.85	0.8	0.71	5	2	0.67	0.79	1.55
Phosphorus (%)	0.7	0.44	0.34	0.6	2	0.45	0.45	0.71
Potassium (%)	0.3	1.35	0.7	1	1.2	0.59	0.78	0.85
Magnesium (%)	0.06	0.4	0.2	0.5	0.35	0.16	0.15	0.26
Sodium (%)	0.4	0.34	0.1	0.23	0.15	0.08	0.12	0.20
Chloride (%)	0.5	1.2	–	0.35	–	0.18	0.29	0.50
Sulfur (%)	–	0.4	0.15	–	–	0.18	0.26	0.25
Cobalt (ppm)	–	0.11	0.1	–	–	0.2	0.12	0.13
Copper (ppm)	10	18	10	16	53	6	26	19.86
Iron (ppm)	100	26	50	80	199	83	71	87.00
Iodine (ppm)	0.14	0.88	0.5	1.7	1.1	0.83	0.81	0.85
Manganese (ppm)	25	24	40	120	13	34	29	40.71
Selenium (ppm)	0.3[b]	0.3[b]	0.3[b]	0.3[b]	0.7[c]	0.3[b]	0.3[b]	0.30
Zinc (ppm)	100	73	30	100	200	55	71	89.86

[a]2005 National Academy of Sciences (NAS), National Research Council (NRC) Mineral Tolerance of Animals.~~Updated and adopted from National Academy of Sciences, Engineering, and Mathematics, National Research Council (NAS/NRC) recommendations as of 2015.~~

[b]FDA approved concentration.
[c]Aquaculture species are not included in the selenium food additive regulation.

Table 2. Approximate Dilution Factors and Typical Contaminate Levels of AAFCO Defined Mineral Feed Ingredients

Mineral Feed Ingredient	Recommended Level NAS/ NRC[a]	Approx.imate Dilution. to Meet RecRecommended. Level[b]	Typical Contamination Levels (ppm)[c]					
			Arsenic	Lead	Mercury	Cadmium	Nickel	Antimony
Calcium	1.55%	2.1×10^1	2.5	5–30	0.05	5–10	–	–
Phosphorus	0.71%	3.5×10^1	2–5	5–30	0.05	5–10	–	–
Potassium	0.85%	5.2×10^1	1	1	1	–	–	–
Magnesium	0.26%	1.1×10^2	1–10	1–20	0.1–5	1	–	–
Sodium	0.20%	1.6×10^2	–	–	0	–	–	–
Chloride	0.50%	8.9×10^1						
Sulfur	0.25%	1.8×10^2	1	1	1	–	–	–
Cobalt	0.13 ppm	2.8×10^6	2–20	1–20	1–20	2–200	800	–
Copper	19.86 ppm	2.5×10^4	3–100	9–600	1	2–100	100	0–20
Iron	87 ppm	2.3×10^3	1–50	1–90	1	–	–	–
Iodine	0.85 ppm	8.5×10^5	2	3	2	1	–	–
Manganese	40.71 ppm	5.1×10^3	1–10	1–90	–	1–20	–	70–200
Selenium	0.3 ppm	1.3×10^6	–	–	1	1–5	1–5	–
Zinc	89.86 ppm	6.0×10^3	10–800	100–2,000	1	80–500	–	10

[a] ~~Values from Table 1, including goats and aquaculture~~All-species average NAS/NRC nutrient requirement recommended levels from Table 1. NAS stands for National Academy of Sciences, Engineering and Mathematics, and NRC stands for National Research Council. ~~NAS/NRC stands for National Academy of Sciences, Engineering, and Mathematics, National Research Council~~.

[b] Dilution factor calculated using mineral ingredient values from the NRC Nutrient Requirements for Dairy Cattle Seventh Revised Edition, 2001, NRC of the National Academes, Nutrient Requirements for Small Ruminants, Sheep, Goats, Cervids and New World Camelids, Animal Nutrition Series, 2007 ~~the NAS/NRC Nutrient Requirements of Dairy Cattle, Nutrient Requirements of Small Ruminants,~~ and information available to the work group.

[c] Typical contaminate levels found in mineral-based feed ingredients. Unchanged as a~~A~~dapted from "NFIA Mineral Ingredient Handbook," National Feed

Ingredient Association, 1979 edition, and from “AFIA Feed Ingredient Guide,” American Feed Industry Association Inc.

Table 3. Official Guidelines Suggested for Contaminants in Individual Mineral Feed Ingredients

Contaminant Group[a]	Maximum Tolerable Level in Complete Feed (ppm)	Total Level of Group Permitted Without Labeling (collectively, ppm)[b,c]	Labeling Required Between Indicated Range (collectively, ppm)[b]	Use Prohibited at Levels Above (collectively ppm)[b]
Group 1[d]	**0 to less than–<5**	**2**	**2–500**	**500**
Mercury (inorganic)	0.2			
Cadmium	0.5			
Selenium	2			
Group 2	**5 to less than–<15**	**42**	**42–1,000**	**1,000**
Arsenic	5[e]			
Iodine	5[f]			
Molybdenum	5[g]			
Cobalt	10			
Lead	10			
Vanadium	10			
Group 3	**15 to less than–<50**	**126**	**126–1,500**	**1,500**
Copper	15[h]			
Barium	20			
Tungsten	20			
Lithium	25			
Group 4	**50 to less than–<150**	**420**	**420–2,000**	**2,000**
Nickel	50[i]			
Antimony	70[j]			
Chromium	100[c,k]			
Tin	100			
Group 5	**150 or greater than 150>**	**1,260**	**>1,260**	**No Limit**
Boron	150			
Aluminum	200			
Bromine	200			
Zinc	250[l]			
Bismuth	400			
Manganese	400[m]			
Iron	500			

[a]Ordered from most to least toxic within Group.

[b]Values in column represent the total (i.e., the sum) of the content of all elements in the Group.

[c]Calculated as (NRC MTL for most toxic element in the Group × dilution factor of 21)/ safety factor of 2.5.

[d]Fluorine is not included in Table 32 because fluorine is closely associated with phosphate ingredients and has been handled successfully for many years by requiring the phosphorus:fluorine ratio to be not less than 100:1.

~~[e]Arsenic 5 for fish, 30 for all other species.~~

~~[f]Iodine 5 for horses, 50 for cattle and sheep.~~

~~[g]Molybdenum 5 for horse, cattle, and sheep.~~

~~[h]Copper MTL's are species dependent. MTL's are: 15 for sheep, 40 for cattle, 100 for fish and ducks, 250 for other poultry species, horses, and swine.~~

~~[i]Nickel MTL for horse, rodent, and fish, unchanged from previous.~~

~~[j]Antimony MTL for rodents only, unchanged from previous.~~

[ck]Values for chromium III (Cr^{+3}). Chromium VI (Cr^{+6}) is carcinogenic and typically not incorporated or found in mineral ingredients.

~~[l]Zinc 250 for fish, 500 for horse, cattle, poultry, rodents.~~

~~[m]Manganese 400 for horse, 1,000 for swine.~~

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Table 4. Species-specific Maximum Tolerable Levels of Minerals, including Contaminants, in Complete Feed (ppm dry matter)[ab]

Mineral	Cattle	Horse	Swine	Fish	Sheep	Poultry	Rodents
Antimony	---	---	---	---	---	---	70-150
Arsenic	30	30	30	5	30	30	30
Copper	40[c]	250	250	100	15[c]	250; 100 for ducks	500
Iodine	50	5	400	---	50	300	---
Molybdenum	5	5	150	10	5	100	7
Manganese	2,000	400	1,000	---	2,000	2,000	2,000
Nickel	100	50	250	50	100	250	50
Zinc	500	500	1,000	250	300	500	500

[a]2005 National Academy of Sciences (NAS), National Research Council (NRC) Mineral Tolerance of Animals

[b]If there is no MTL, use the most sensitive species (lowest MTL) for that mineral.

[c]Assuming normal concentrations of molybdenum (1–2 mg/kg diet) and sulfur (0.15–0.25%). At molybdenum and sulfur concentrations below these, copper may become toxic at lower levels.

Dashes indicate that data were insufficient to set a MTL.