Rare Earths

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Abstract

This page draws on evidence from EFSA, together with 26 peer-reviewed studies. The complete citation list is at the bottom of the page.

1 | Overview

This page covers two rare earth elements, cerium and lanthanum, and keeps every element-level finding labeled by element. Cerium is described as the most abundant rare earth element in the earth's crust 2, and lanthanum and cerium are among the more abundant rare earths, with average crustal values given as 39.0 mg/kg for lanthanum and 66.5 mg/kg for cerium 3.

Most of the cited evidence is experimental. It shows that both elements are applied to crops as growth stimulants or seed treatments, that crops take them up mainly into roots and leaves, and that lanthanum is used as an oral phosphate binder in people with kidney disease and in cat food 4 5 6 1. Direct measurements of either element in market food are limited to a single method-development study 7.

Neither element has an established oral reference dose in the cited evidence. One modeling study had to borrow surrogate values from nine other rare earth elements to interpret cerium intake from carrots 8.

2 | Toxicology

Lanthanum

In rats exposed to lanthanum chloride in drinking water at 0.25%, 0.5% or 1% from gestation through 28 days after weaning, offspring showed impaired spatial learning, dose-dependent lanthanum accumulation in the hippocampus, neuronal damage and increased apoptosis 9. These concentrations are far above any food exposure described in the cited evidence.

In rats with surgically reduced kidney function fed 0.5% lanthanum as lanthanum carbonate for four weeks, alanine transaminase was higher than in other groups 10. The European Food Safety Authority feed panel

confirmed lanthanum carbonate octahydrate as safe for cats at up to 7.5 g/kg of complete feed, based on post-market reports showing an adverse event incidence of 0.0003% in cats, mostly digestive signs in animals that already had kidney disease 1. The same opinion records that the additive was negative in genotoxicity tests and showed no systemic effects in a 90-day study, while inhalation caused some persistent lung effects in rats 1.

For aquatic life, the seven-day lethal concentration for half of Daphnia magna was 403.67 µg/L lanthanum, while delayed maturity responded at 0.26 µg/L (10% effect) 11. In catfish fed mycotoxin-contaminated diets, adding 200 or 400 mg/kg lanthanum chloride improved growth and blood measures rather than causing harm 12.

In plants, lanthanum at 0.5 mM and above raised reactive oxygen species and lipid peroxidation in rice roots, while lower concentrations raised antioxidant enzyme activity 13.

Cerium

Rats with reduced kidney function fed 1.31% cerium oxide for four weeks showed lower serum phosphate without a rise in liver enzymes; this study was funded by a pharmaceutical company and did not measure cerium in tissues 10. Zebrafish embryos exposed to a titanium dioxide nanocomposite containing 3% cerium oxide at up to 20 mg/L showed no developmental toxicity, although heart rate changed at 1 mg/L and above 14.

In a hospital case-control study in Fujian, China, oral cancer patients had lower serum cerium than controls (median 0.57 versus 2.27 µg/L), and serum cerium at or above the control median was associated with lower adjusted odds of oral cancer (odds ratio 0.60, 95% CI 0.43 to 0.84) 2. Blood was drawn after diagnosis, so the disease may have affected serum cerium; the study does not show a protective effect.

Plants show a low-dose stimulation and high-dose inhibition pattern. Foliar cerium at 5 mg/L promoted soybean growth and grain quality while 50 mg/L inhibited growth 5, and cerium oxide nanoparticles at 2000 mg/kg in sand reduced maize seedling biomass 15.

3 | Typical exposure routes

Soil to crop. Both elements are present in agricultural soils, and higher levels are reported near rare earth mining waste (see the soil table under Food sources) 3 16. Crops tend to hold cerium in roots: in two pot-grown species, root cerium rose up to about 16,000 µg/kg dry weight while leaf cerium stayed far lower 17. Barley grown in soil with 500 or 1000 mg/kg cerium oxide nanoparticles did not have significantly more kernel cerium than controls 18.

Agricultural inputs applied to crops. Lanthanum chloride has been applied to aromatic rice at 12 kg/ha in field trials 4, to konjac 19 and as an amino acid chelate to rice seedlings 20. Cerium nitrate has been sprayed on soybean leaves 5, cerium oxide nanoparticles used to prime rice seed 21, and a cerium-doped titanium dioxide spray applied to bok choy to break down an insecticide 22. None of these studies measured the element in the harvested food, except that foliar cerium on soybean moved to grain at less than 5% of the leaf concentration 5.

Deliberate oral use. Lanthanum carbonate is taken as a phosphate binder by people with chronic kidney disease, at 500 mg three times daily in one Indian trial 6. Cerium oxide has been tested in rats as an alternative binder 10. In animal feed, lanthanum carbonate is authorized in the EU for cats 1, and lanthanum chloride has been tested in catfish diets 12.

Water treatment materials. Cerium- and lanthanum-based sorbents can release small amounts of the element into treated water: 0.015 to 0.062 mg/L cerium from a cerium oxide lignin sorbent across pH 4 to 9 23, and

about 3% of the lanthanum from a lanthanum-modified activated carbon 24. These are laboratory tests, not measurements of drinking water.

4 | Food sources

The only market food measurements in the cited evidence come from one method-development study in Bangladesh, which analyzed one sample of each food five times 7. Its cerium values (7.5 to 21.8 mg/kg, basis not stated) are far higher than the 0.50 mg/kg dry weight measured in control barley kernels in Italy 18, and they have not been reproduced in the cited evidence. Foods covered include carrot, wheat, corn, rice, potatoes, spinach, cabbage and mango.

Experimental studies show that carrots grown with cerium can carry most of it in the peel, so that peeling cut projected intake roughly 10-fold to 100-fold 8. Lanthanum accumulates in tea plant leaves, the harvested part of Camellia sinensis, with clear differences between cultivars 25; leaf values are shown only graphically. Foliar cerium on soybean moved little into the grain 5, and cerium oxide in soil did not raise cerium in barley, a cereal grain 18.

Measured results: food and human samples

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
7 Chittagong and Rajshahi, Bangladesh	Market foods; fluorescence method checked against ICP-OES	Ce (total)	Carrot 21.8; mango 16.8; wheat 12.8; potato 11.5; rice 10.1; spinach 9.8; corn 9.5; cabbage 7.5 mg/kg (basis not stated)	1 sample each, 5 analyses	Method demonstration; single samples; not representative
18 Udine, Italy	Barley kernels, pot trial; control and soil with 500 or 1000 mg/kg cerium oxide nanoparticles	Ce (total)	0.50, 1.03 and 0.70 mg/kg dry weight (means)	5 per treatment	No significant difference from control; high variability
8 USA, greenhouse	Carrots in sand culture with cerium oxide nanoparticles or ionic cerium up to 500 mg/kg	Ce (nanoparticle or ionic)	Maximum 65.8 (nanoparticle) and 126.9 (ionic) mg/kg fresh weight	4 to 5 per treatment	Deliberately extreme exposures; not market food
17 Udine, Italy	Diplotaxis tenuifolia leaves, pot trial with 200 mg/kg cerium oxide nanoparticles	Ce (total)	Control 145; 50 nm particles 1,044 µg/kg dry weight	4	Wild species; leaf values highly variable

2 Fujian, China	Serum, hospital case-control study	Ce (total)	Controls median 2.27 µg/L; oral cancer cases 0.57 µg/L	650 controls; 324 cases	Post-diagnosis sampling; source of cerium unknown
7 Chittagong, Bangladesh	Human blood, urine and milk from individual patients and one mother	Ce (total)	Blood 152.5 to 430.0; urine 42.8 to 110.8; milk 58.6 ng/L	1 per person	Single patient samples; not a population survey

Measured results: soils

STUDY / LOCATION	MATERIAL / DESIGN	METAL SPECIES	VALUE (UNITS AND BASIS)	N	INTERPRETATION / LIMITATION
3 Sichuan, China	Farmland topsoil near the Maoniuping rare earth tailings	La and Ce (total)	La about 29.0; Ce about 67.6 mg/kg	Composite sample	One site; values reported as approximate
16 Jiangsu, China	Rice field topsoils from three cities	La (total)	46.93, 47.37 and 32.78 mg/kg dry soil	1 per site	Background values for a microcosm study
5 Shenyang, China	Experimental field topsoil	Ce (total)	41.22 plus or minus 3.65 mg/kg	Not stated	Pot experiment soil
7 Chittagong, Bangladesh	Industrial, agricultural, roadside and marine surface soils	Ce (total)	21.8 to 135.8 mg/kg	10 sites	Method demonstration

5 | Regulatory limits

The cited evidence contains no food or drinking water limit for cerium or lanthanum. No oral reference dose for cerium was available to the authors of the carrot modeling study, who used the median of nine other rare earth elements (5 µg/kg body weight per day) as a surrogate; against that value, carrot cerium of 1.0 mg/kg fresh weight in one serving would reach the surrogate for a 13 kg child 8.

For lanthanum, the European Food Safety Authority confirmed the EU feed authorization of lanthanum carbonate octahydrate for adult cats at 1.5 to 7.5 g/kg of complete feed. The opinion excluded consumer and environmental safety from its scope, and recorded additive impurity results of arsenic below 2, cadmium below 1, lead below 1 and mercury below 0.2 mg/kg 1.

6 | Testing

Total cerium and lanthanum in serum, grain, plant tissue and soil were measured by ICP-MS in the cited studies. The Fujian serum study reported a detection limit of 0.0003 µg/L for cerium with recovery of 89.1% to 92%

for rare earth standards 2, and the barley study a detection limit of 1 µg/L in digest solution with 97% average recovery on a tomato leaves reference material 18. Single-particle ICP-MS distinguished cerium oxide particles from dissolved cerium in plant tissue 17.

A spectrofluorimetric method for cerium reported a detection limit of 0.1 ng/L in solution and gave food results close to ICP-OES 7; see also fluorescence methods. Sequential extraction separates exchangeable, carbonate-bound, oxide-bound, organic and residual soil fractions of both elements 3.

None of the human or food studies determined cerium oxidation state; the Fujian authors note their method could not distinguish cerium valence 2. In marine sediment, X-ray absorption spectroscopy showed cerium held as cerium-phosphate clusters around fish-bone apatite 26.

7 | Microbiome effects

The cited evidence does not address the human gut microbiome. In rice field soils from Jiangsu, China, adding lanthanum chloride inhibited methane consumption to a degree that depended on soil pH and origin, and methane-oxidizing communities shifted toward Methylobacter, Methylosarcina and Methylocystis while keeping function over time 16. This is soil ecology evidence and does not support statements about gut effects.

8 | Vulnerable populations

People with chronic kidney disease taking lanthanum carbonate receive deliberate, sustained oral lanthanum doses (500 mg three times daily in one trial), which is a distinct exposure from food 6; the cited trial did not measure lanthanum in the body. In a rat model of reduced kidney function, lanthanum carbonate raised alanine transaminase 10.

Young children have the highest projected cerium intake per unit body weight from a given carrot concentration, because the same serving is divided by a smaller body mass 8. Developmental exposure through gestation and nursing affected learning in rat offspring at high drinking-water doses of lanthanum chloride 9. The cited evidence does not establish effects at dietary exposure levels for any population.

9 | Mitigation

Peeling root vegetables. Peeling carrots grown with cerium reduced projected cerium intake roughly 10-fold to 100-fold, because most cerium stayed in the peel 8.

Soil amendment. Mixing compost from kiwifruit branches and sheep manure into farmland soil near rare earth tailings lowered the mobile fraction of lanthanum from 13.8% to 4.3% of the total and of cerium from 8.1% to 2.9% at the highest compost ratio after 28 days, with a 10% ratio suggested as practical 3. Part of the decline reflected dilution, and crop uptake was not tested.

Material design for water treatment. Coating lanthanum nanorods with carbon greatly reduced lanthanum leakage into water compared with uncoated material 27.

Food processing steps other than peeling are not established in the cited evidence.

10 | Open questions

- No survey of cerium or lanthanum in market foods with a stated moisture basis and adequate sample numbers; the only market values are single samples from one method paper.
- No lanthanum measurements in any harvested food, including rice, konjac and tea from fields treated with lanthanum.
- No oral reference dose, tolerable intake or food limit for cerium or lanthanum in the cited evidence; Regulatory limits could cite only a cat feed authorization.
- No population dietary intake estimate for either element.
- No human absorption, distribution or excretion data for dietary cerium or lanthanum, and no measurement of body lanthanum in people taking lanthanum carbonate.
- No evidence on cerium oxidation state or nanoparticle form in foods.
- No study of either element on the human gut microbiome.
- No evidence on whether soil amendment lowers crop uptake, or on processing steps other than peeling.

11 | What remains uncertain

The cited evidence is dominated by experiments that add cerium or lanthanum at high concentrations to plants, soils, animals or water. These show where the elements go and what high doses do, but they do not describe ordinary dietary exposure. The single set of market food values comes from a method paper with one sample per food and much higher values than control grain measured elsewhere, so the typical cerium content of foods remains unknown.

Human data are limited to one case-control study of serum cerium, in which the inverse association with oral cancer may reflect the disease itself, and one clinical trial of lanthanum carbonate that did not measure lanthanum. Animal toxicity findings come from drinking water or diet concentrations far above food levels, and one of the rat feeding studies was industry funded.

Cerium oxide nanoparticles, dissolved cerium and lanthanum salts behaved differently in the studies cited, and results for one form or element should not be transferred to another.

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