Fertiliser Association

Shaping profitable and sustainable farming

Uranium – in soil, plants and fertiliser

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Overview

- All soils and plants contain trace levels of uranium.
- Uranium is naturally occurring in soil. It enters plant tissue through absorption from soil and the atmosphere.
- All phosphate rock contains natural, low levels of uranium and the amount will vary in different sources of phosphate rock.
- Phosphate rock is used to produce mineral fertiliser in a processed form such as superphosphate, DAP, MAP or other compound fertilisers, and in an unprocessed form as Reactive Phosphate Rock (RPR).
- Relative to other heavy metal elements, uranium is not highly toxic.
- Uranium does not appear to bio-accumulate in plants to any significant degree.
- Research undertaken in many countries has shown that crops grown in soil fertilised with phosphate rock for more than than 50 years do not have higher concentrations of uranium than crops grown in non-fertilised soil.
- New Zealand soils contain low levels of uranium.
- New Zealand phosphate fertilisers have low levels of uranium.
- To reach levels matching Soil Quality Guideline Values set by the Canadian Council of Ministers for the Environment as remediation targets which are ‘safe and protective for human health and the environment’ would take between 500 and 1000 years, at current typical application rates of phosphate fertilisers to New Zealand soils.

Conclusion

Uranium at trace levels in soil and plants is a natural occurrence.

While the levels of uranium in soils are very gradually increasing due to phosphate fertiliser application, this represents no threat to human health or the environment.

The occurrence of uranium in soil

Uranium is a heavy metal that occurs naturally in soils. Background concentrations commonly found in surface soil range between 0.1 parts per million (ppm) and 11 ppm, with average levels of 2 or 3 ppm[1], while naturally occurring levels of uranium in parts of Canada are as high as 572 ppm[2].

Uranium is present in the Earth's crust to a greater extent than a number of other elements, including mercury and silver.[3] However, relative to other heavy metal elements, uranium is not highly toxic.[2]

In excessive quantities, uranium can produce toxicity effects through chemical toxicity and radiotoxicity. However, the very long half-life and slow rate of decay of uranium isotopes means the radiotoxicity is very low. Therefore, adverse effects observed in toxicity studies can be assumed to arise from chemical effects rather than radiation effects.[2]

Uranium tends to migrate through soils to at least a depth of 30 cm. It does not accumulate in only the top layer.[4] However, the mobility of uranium in soil may be limited due to the formation of slightly soluble precipitates (such as phosphates, oxide) and adsorption to clays and organic matter.[1]

Research undertaken in England reported little downward movement of uranium in soil below 23 cm.[5]

Uranium levels in soils can be increased from atmospheric deposition, volcanic activity and fertiliser use. In New Zealand the most common way the level of uranium in soil is increased is through the application of fertiliser and from volcanic activity.

The level of uranium in New Zealand soils is at the low end of the international scale. Taylor et al.[6] reports background levels at 0.7 ppm for the Waikato region, and Roberts et al. refers to 1.1 ppm as a background level for the Winchmore trial site, while Schipper et al. reports 1.1-1.3 ppm for the Whatawhata trial site.

TABLE 1 Mean content of uranium in surface soils[1]

Country	Parts Per Million
Russia	3.8
United States	3.7
Great Britain	2.6
Canada	1.2
Poland	0.8
Italy	3.2
New Zealand	1.1[4,8]
Average for the earth's crust	3.0 to 4.0[2]

The occurrence of uranium in plants

Plants take up uranium from the soil and atmosphere. All plant tissue contains background levels of uranium, and these have no significant adverse effect on human health.[2,7]

United States research[7] undertaken on field crops grown in plots that had received phosphatic fertiliser at the annual rate of 30 kg P/ha for more than 50 years established there was no difference in the uranium concentrations in corn leaves, grain, straw, soyabean leaves or timothy forage growth grown in the plots and control plots that had not been fertilised. The conclusion was that the annual application of phosphatic fertiliser did not appear to result in increased levels of uranium in field crops.

Canadian Soil Quality Guidelines report uranium does not appear to bioaccumulate in vegetation to a significant degree. Soil–plant bioaccumulation factors vary among plants and with different soil properties. They can range from 0.001 to 1.8, but are generally less than one, indicating no bioaccumulation.[2]

The occurrence of uranium in fertilisers

All phosphate rock contains uranium. The uranium found in phosphate fertiliser reflects the levels in the rock from which it is manufactured.

The uranium content of phosphate rock is dependent on the geographical area from which it is mined.

Before the mid 1990s the majority of phosphate rock used in the manufacture of New Zealand superphosphate came from Christmas Island (in the Indian Ocean), Nauru and North Carolina. More recently it has been sourced from the Middle East, China and North Africa.

TABLE 2 Typical concentration levels of uranium in these rocks [4,12]

Country	Parts Per Million
Algeria[12]	93 to 119
Brazil	42 to 212
Chatham Rise[13]	20 to 476
China	12 to 18
Christmas Island[4]	15 to 25
Egypt	59 to 119
Israel	42 to 127
Jordan	42 to 127
Middle East	45 to 80
Morocco	76 to 136
Nauru	54 to 64
North Africa	45 to 75
Saudi Arabia	21 to 72
Senegal	102 to 153
Syria	51 to 136
Togo	68 to 85
Tunisia	21 to 85
USA Florida	85 to 127
USA North Carolina	51 to 68

New Zealand situation

The level of uranium that will be added to soil is dependent on the quantity of phosphatic fertiliser applied at the location.

Once a “balanced” nutrient level has been achieved, as a rule of thumb, soil phosphorus requirements can be maintained on most farms, including a dairy farm, through the application of up to 40 kg P/ha/year.

New Zealand research

- Research on the accumulation of uranium in New Zealand soils was undertaken by AgResearch in 1999 on behalf of the New Zealand Fertiliser Manufacturers’ Research Association, which analysed archived soil samples covering field trials between 1952 and 1996.[4]
- The level of uranium in topsoil (top 7.5 cm) at the Winchmore Research Station in 1958 was 1.02 ppm. After 40 years of receiving superphosphate at the rate of 376 kg/ha each year, the level of uranium in the topsoil had increased to 1.45 ppm. This represents an increased presence of uranium of 0.43 ppm in 40 years, or 0.01 ppm/year.[4]
- In 1978 English research made use of soil samples from New Zealand field trials undertaken between 1954 and 1975.[5] The analysis of this soil was not undertaken in New Zealand or as part of any New Zealand research but did indicate that uranium applied as a trace component of phosphate fertiliser may accumulate in the top 15 cm of soil. Roberts reports this study demonstrated an increase of 0.45 ppm after 19 years of fertiliser application (giving an annual soil accumulation rate for uranium of 0.02 ppm/yr).[4]
- More recently, Schipper et al.[8] assessed annual accumulation of uranium in soils at the Whatawhata hill country research farm, on the North Island of New Zealand, covering the period of 1983-2006. Mean annual rates of soil accumulation ranging from 0.019, 0.042 and 0.067 ppm/yr were estimated for annual application rates of phosphate fertiliser of 30, 50 and 100 kg P/ha/yr respectively.
- If, at typical annual application rates of phosphorus fertiliser, the level of uranium in soil increases by 0.04 ppm per year, then over the next 100 years the levels in these New Zealand trial sites will be just above the range of average soil levels found internationally, for example Russia (3.8 ppm) or United States (3.7 ppm)[1] and close to the typical range found within the earth’s crust (3-4 ppm).[2]
- Taylor compared soil samples with samples archived 36–43 years previously and reports annual accumulation of 0.033 ppm.[9] It was concluded that all or nearly all the uranium in phosphate fertiliser remained in the soil and so did not significantly leach to groundwater and was not taken up in significant amounts by plants. Taylor et al.[6] reports elevated levels of uranium in Waikato soils, with averages at 2 or 3 ppm. Accumulation at the above rates on these soils will after 100 years result in soil uranium levels still within the range reported to occur naturally in parts of the world[1,2] and well within the Canadian Soil Quality Guideline values.[2]
- McDowell assessed uranium in archived soil samples from the Winchmore long-term fertiliser trial site.[10] With annual application of superphosphate at 376 kg/ha/yr the annual soil accumulation of uranium was 0.007 ppm. Assessment on effects of drainage and irrigation washout showed no significant difference between the dryland and irrigated treatments. This suggests that compared with cadmium, there was less influence of irrigation or phosphorus application rates on the downward movement of uranium.

International situation

Witterlind et al.[1] used archived soil samples in central France to evaluate the effect of 15 to 30 years of annual phosphate fertiliser applications at 26 and 52 kg P/ha/yr on soil uranium accumulation. Significant effects were observed with increase in soil uranium up to 0.18 and 0.34 ppm at two trial sites, which equate to an annual accumulation of 0.01 and 0.02 mg U/kg soil for the respective fertiliser rates.

There are almost no international guidelines covering the acceptable level of uranium in soil.

Canada[2] has developed guidelines for the protection of human and environmental health, and these soil quality guidelines for the following land uses are:

Agriculture, residential and parkland	**23 ppm**
Commercial land	**33 ppm**
Industrial land	**300 ppm**

These Soil Quality Guidelines were developed as remediation targets for contaminated land, so land cleaned down to these values is considered safe and suitable for that ongoing land use.

Accumulation projections

Based on the trials above soil accumulation rates associated with phosphate fertiliser are shown below.

TABLE 3 Estimated uranium accumulation rates associated with phosphate fertiliser applications

Trial Site	Duration of Fertiliser Application (years)	Phosphate Fertiliser Rate (Kg P/ha/yr)	Soil Depth (cm)	Uranium Accumulation Rate (ppm soil/yr)
Winchmore[4]	40	34	0-7.5	0.01
Papatoetoe[5]	19	37	0-5 5-10	0.02 0.01
Waikato[9]	36-43			0.033
Whatawhata[8]	23	30 50 100	0-7.5	0.019 0.042 0.067
France[11]	15-30	26 52	22	0.01 0.02

The following table estimates the number of years it would take for New Zealand soils to accumulate uranium to the Canadian Soil Quality Guideline Values for agricultural land use, if superphosphate fertiliser is applied at the following rates:

TABLE 4 Estimated accumulation rate at 30 kg P/ha/yr

Soil U at the Start ppm	Yearly Rate of Increase ppm	Years to Achieve 23 ppm
1.5	0.02	1075

TABLE 5 Estimated accumulation rate at 50 kg P/ha/yr

Soil U at the Start ppm	Yearly Rate of Increase ppm	Years to Achieve 23 ppm
1.5	0.04	537

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