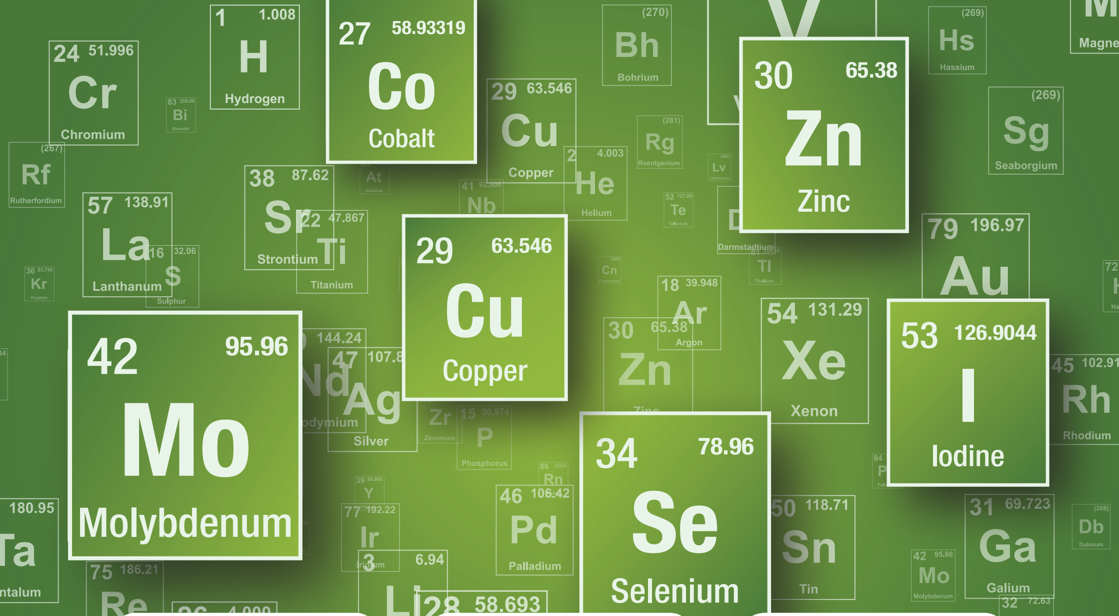


Use of Trace Elements in New Zealand Pastoral Farming

Fertiliser Association

Shaping profitable and sustainable farming

Acknowledgments

Contributing author (revised edition 2019)

J.D. Morton

Previous contributing authors

J.D. Morton, AgResearch

Dr N.D. Grace, AgResearch

M.B. O'Connor, AgResearch

This booklet is published by the Fertiliser Association of New Zealand:

PO Box 11519, Manners Street, Wellington, New Zealand

Phone: 04 473 6552

Email: info@fertiliser.org.nz

Website: www.fertiliser.org.nz

The fertiliser manufacturing companies (Ballance Agri-Nutrients Ltd and Ravensdown Ltd) have provided the funding for this revised edition.

Previous edition (1999) was published by the New Zealand Fertiliser Manufacturers' Research Association and created by Fert Research and AgResearch.

Published 2019

ISBN 978-0-9951151-2-5 (Print)

ISBN 978-0-9951151-3-2 (Electronic)

Use of Trace Elements in New Zealand Pastoral Farming

The principles and practice of meeting trace element requirements of pastures and animals

This second edition is created by the Fertiliser Association of New Zealand

Edited by J.D. Morton

Fertiliser Association
Shaping profitable and sustainable farming

Contents

	Page
Introduction	3
Major soils use for farming in New Zealand	4
Essential trace elements for plants and animals	5
Trace elements in soils	6
Trace elements in plants	7
Trace elements in animals	8
Cobalt/Vitamin B_{12}	8
Selenium	9
Copper	10
Iodine	11
Criteria to assess trace element status	12
Soil	12
Pasture	12
Animals	12
Reference ranges for criteria	13
Soil	13
Pasture	14
Animals	15
Monitoring of trace element status	16
Effect of trace element amended fertilisers on the trace element content of pastures	19
Rate of trace element required to correct deficiencies	21
Management strategies to prevent trace element deficiencies in animals	22
Cobalt/Vitamin B_{12}	22
Selenium	23
Copper	23
Iodine	24
Forms of trace elements in fertiliser	25

Introduction

New Zealand soils are inherently deficient in several trace elements that are required for pasture growth and animal health. Since the 1930s, trace element deficiencies of cobalt (Co), copper (Cu) and selenium (Se) in animals, boron (B) for brassicas, clover seed crops and lucerne and molybdenum (Mo) in clover have been identified. More recently, the requirement of iodine (I) for sheep and cattle and zinc (Zn) for treatment of facial eczema has also been established.

With the greater intensity of pastoral farming, soil reserves of some trace elements will become depleted. This has been shown by deficiencies in trace elements becoming evident across a wider range of soils than was earlier apparent. As many farmers are directly supplementing animals to maintain optimum animal performance, they may not be maintaining the trace element status of the soil.

The available information from research on trace element status and requirements of soils, pastures and animals has been used to compile this booklet. Because the trial results have been gained from a limited number of sites representing different soils and climatic conditions, the recommendations can only be regarded as guidelines. It is essential to monitor the trace element status of your own farm to give the most accurate picture.

This booklet has sections covering a brief description of (1) the major soil groups in New Zealand, (2) the trace elements required by plants and animals, (3) the role of trace elements in soils, pastures and animals, (4) assessing trace element status of soil, pasture and animals and (5) methods and practices to prevent trace element deficiencies from having adverse economic effects.

Major soils used for farming

From a practical agricultural point of view, there are two major groups of soils on which farming is carried out. These are:

Sedimentary soils: These soils have been derived from sedimentary material (greywacke, sandstone, mudstone) and include:

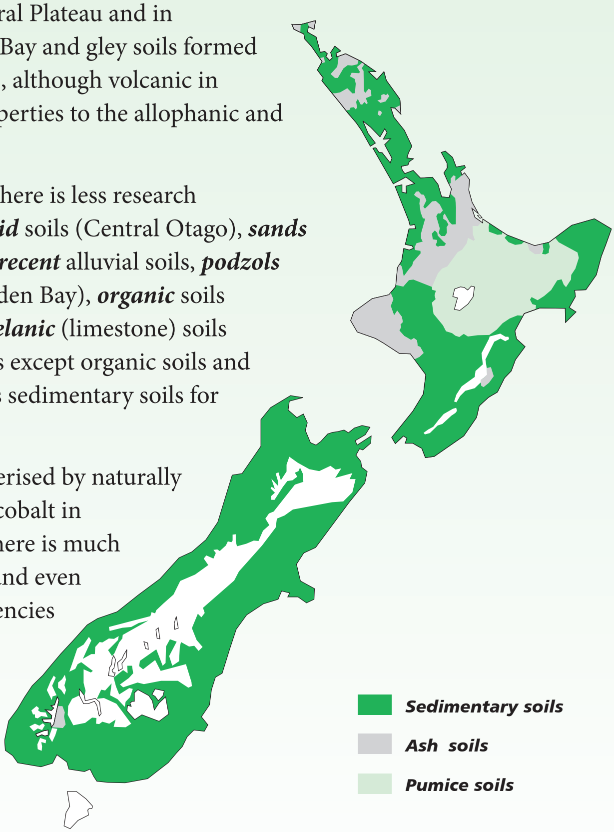
- ***Brown*** soils on terraces (eg. Southland) and in hill country (eg. Wairarapa). Generally, these are well drained soils under moderate rainfall.
- ***Pallic*** soils are either poorly drained soils on terrace or rolling lands under moderate rainfall (eg. Manawatu, South Otago) or under low rainfall (eg. Hawkes Bay, Marlborough, Canterbury).

Volcanic soils:

- ***Allophanic*** soils in Waikato and Taranaki and ***granular*** soils in Northland.
- ***Pumice*** soils on the Central Plateau and in Hawkes Bay and Poverty Bay and gley soils formed from pumice. These soils, although volcanic in origin, have different properties to the allophanic and pumice soils above.

Other soil groups for which there is less research information include ***Semi-arid*** soils (Central Otago), ***sands*** (Manawatu and Northland), ***recent*** alluvial soils, ***podzols*** (Northland, West Coast, Golden Bay), ***organic*** soils (Waikato, Southland) and ***Melanic*** (limestone) soils (North Otago). All these soils except organic soils and podzols can be categorised as sedimentary soils for the purposes of this booklet.

Some soil groups are characterised by naturally low trace element levels (eg. cobalt in pumice soils) but generally there is much variation within soil groups and even soil types. Some of the deficiencies associated with specific soil groups are outlined in the next section.



Essential trace elements in plants and animals

Trace elements are required in very small quantities as essential components of various enzyme systems of plants and animals, and for other biochemical and physiological functions in animals.

The essential trace elements:

Essential for plants	Essential for animals
Boron (B)	
	Cobalt (Co)
Copper (Cu)	Copper
	Iodine (I)
Iron (Fe)	Iron
Manganese (Mn)	Manganese
Molybdenum (Mo)	Molybdenum
Zinc (Zn)	Zinc
	Selenium (Se)

It is important to note that B is essential for plants but not animals while Co, I and Se are essential for animals but not plants, although Co is required by the N-fixing bacteria in clover nodules.

Trace elements in soils

All of the essential trace elements are found in soil. Plant availability of each trace element varies according to parent material, age of soil, soil pH, soil moisture, soil texture and organic matter content.

- *Pumice* soils formed from rhyolitic material and *Brown* soils from granite have a lower soil Co content than volcanic soils formed from andesitic material and sedimentary soils formed from schist.
- Old, very strongly weathered and leached *Podzols* formed under high rainfall have much lower levels of all trace elements in the soil than young, weakly weathered *Semi-arid* soils under low rainfall.
- As soil pH increases, the availability in the soil of trace elements except Mo is reduced. Mo availability is greater with higher pH.
- Lack of soil moisture encourages the formation of manganese oxides that reduce the availability of soil Co. The availability of B is also limited by low soil moisture.
- Soil organic matter binds and helps retain Cu, Zn, Fe and Mn in the soil.
- Over time, the trace element content of soils will fall unless the amounts lost from the grazing system are replaced by trace elements in fertiliser.

Trace elements in plants

The most common trace element deficiencies in forage plants in New Zealand are:

(a) Mo in white clover and lucerne. Mo deficiency in legumes is most commonly found on South Island soils formed on loess of schist and greywacke origin *pallic* and *brown* soils) in the rolling downlands and terraces in Otago and South Canterbury. In the North Island Mo deficiency occurs on *pallic* and *brown* soils formed from greywacke in Manawatu and Wairarapa, Northland soils formed from windblown sand, sandstone or andesitic rock, and some raw peats when first consolidated. Mo is essential for the fixation of N in legumes, and Mo deficiency is always associated with N deficiency in legumes. Mo concentrations are greater in grasses than legumes.

(b) B in brassicas, lucerne and clover seed crops. Brassica crops (swedes, kale), fodder beet, lucerne and clover seed crops have a greater requirement for B than grasses. B deficiency in these crops is more likely to occur on light textured soils with less organic matter to retain soil B from leaching. As with Mo, B concentrations are greater in grasses than legumes.

(c) Cu deficiency in clover and lucerne has been identified in peats and *Podzols*. Cu deficiency in pasture plants (< 5 ppm) is rare and has only been reported in legumes on peats, *podzols* and sands.

(d) Other trace element deficiencies such as Zn can be induced through over-liming and high soil pH (> 6.5).

Trace elements in animals

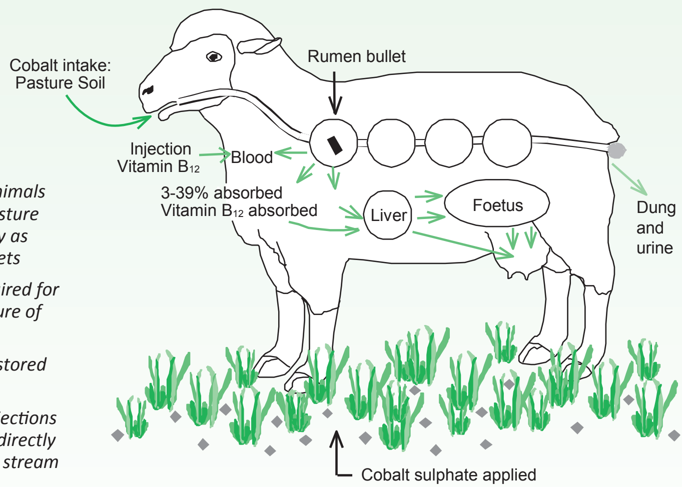
The function, distribution and signs of deficiency of each trace element are briefly described below.

Cobalt/Vitamin B_{12}

- A small part (13%) of the ingested cobalt (Co) is used by rumen micro-organisms for the synthesis of vitamin B_{12} which is then absorbed and stored mainly in the liver of the grazing animal. The remainder of the ingested Co is excreted.
- Vitamin B_{12} is an important cofactor for enzymes associated with energy and protein metabolism. Vitamin B_{12} crosses the placenta and is stored in the foetal liver. In the first weeks of life the lamb and calf are dependent on vitamin B_{12} stored in the liver during pregnancy and the vitamin B_{12} in milk.
- The most striking feature of subclinical vitamin B_{12} deficiency is loss of appetite and poor growth rates. Sheep have a greater requirement for Co than cattle or deer. The young lamb is the most sensitive to Co deficiency.
- Pasture Co concentration varies widely between seasons. Co concentrations are greater in clovers than grasses. Concentrations are lower when pasture growth rates are high during late spring and summer. This is caused by less clover from shading by grasses, dilution of pasture Co and less opportunity for animals to graze close to the ground and ingest soil Co.

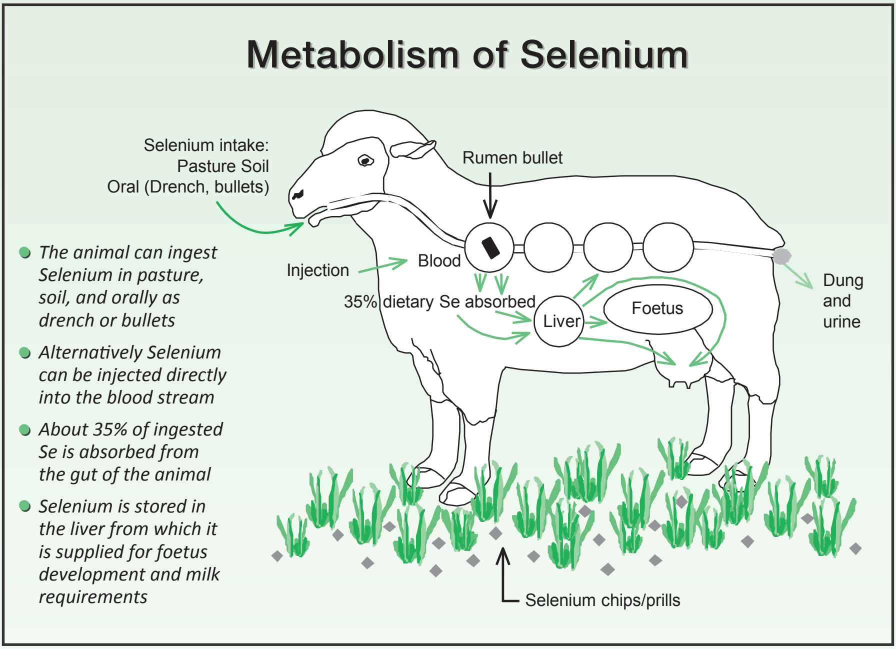
Metabolism of Cobalt

- *Cobalt can be ingested by animals consuming pasture or soil or orally as drench or bullets*
- *Colbalt is required for the manufacture of Vitamin B_{12}*
- *Vitamin B_{12} is stored in the liver*
- *Vitamin B_{12} injections are absorbed directly into the blood stream*



Selenium

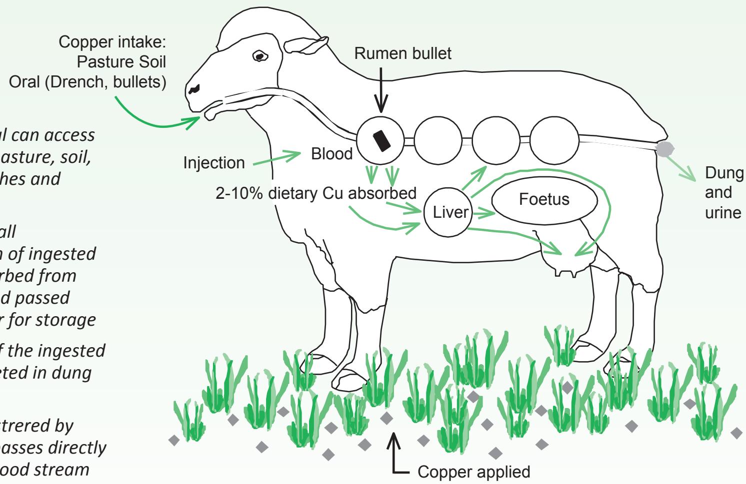
- Se is widely distributed throughout the body including the liver and the kidney. It is readily transferred across the placenta and secreted into the milk and therefore the Se status of the ewe and cow influences the Se status of the lamb and calf.
- Se has many roles including maintaining the integrity of cell membranes, the function of the immune system and promoting thyroid activity. Se deficiency is characterised by white muscle disease (clinical), infertility and ill thrift (sub clinical).
- The dietary Se requirements for sheep and cattle are similar while those for deer appear to be lower.



Copper

- Cu has an important role in the nervous system, bone growth, immune functions, metabolism of Fe, wool growth and colour of hair or wool. A Cu deficiency in animals will result in symptoms that are associated with those roles.
- Like Co, only a small proportion of ingested Cu (5%) is available and most of the Cu (40-70%) is stored in the liver. Cu is rapidly transferred across the placenta and stored in the liver of the young but only very small amounts are secreted into milk.
- Only on soils deficient in Cu (eg. peats, some pumice soils) does simple Cu deficiency occur. Most Cu deficiency situations are the result of induced Cu deficiency where dietary factors interfere with the absorption and utilisation of Cu. The most common interaction is the intake of Mo in the presence of S reducing the absorption of Cu from the gut. This interaction can occur at pasture Mo concentrations as low as 0.5 ppm. Increases in pasture S concentration from applying S fertiliser are small and pasture S concentration does not vary widely over the year so S fertiliser has little effect. Hence it can be the high pasture Mo concentration during late winter/early spring and the rapid increase in pasture Mo concentration after fertiliser Mo application that is the main cause. High Fe intakes caused by high pasture Fe concentrations (> 250 ppm in uncontaminated samples) rather than soil Fe ingestion will also reduce the absorption of Cu.
- Deer and cattle have greater Cu requirements than sheep and are more likely to become deficient. The use of zinc oxide boluses for treatment of facial eczema can reduce the absorption and storage of Cu in the liver and Cu supplementation may be required if liver Cu levels are in the low to marginal range.

Metabolism of Copper



- *The animal can access Cu from pasture, soil, oral drenches and bullets*
- *Only a small proportion of ingested Cu is absorbed from the gut and passed to the liver for storage*
- *The rest of the ingested Cu is excreted in dung and urine*
- *Cu adminstrered by injection passes directly into the blood stream*

Iodine

- Most of the I, that is 80% of the total body I, is associated with the thyroid because I is a component of the thyroid hormones. Iodine readily crosses the placenta and its uptake by the foetus increases markedly during the later stages of gestation. It is secreted into the milk.
- The functions of I can be accounted for by the effects of the thyroid hormones namely T4 and T3 which control basal metabolic rate and heat production as well as growth and cell differentiation of tissues. Iodine deficiency therefore has its greatest effect on the developing foetus. A characteristic sign of I deficiency is an enlarged thyroid, or goitre, while sub-clinical I deficiency in the ewe is associated with a decrease in the twinning rate, an increase in neonatal mortality, low birthweights and poorer wool production. Dietary factors, termed goitrogens reduce the I uptake by the thyroid.
- The important goitrogenic forages in New Zealand are the kales which contain cyanogenetic glucosides.

Adequate feeding of animals

If animals have inadequate feed intakes for growth and production, the intake of trace elements will also be inadequate and measured as deficient. In these situations, correcting the lack of trace element will not improve animal performance unless feeding levels are also increased. This means that if animal performance is poor, feed intake should also be checked when the trace element status of the animal is measured. The trace element content of some supplementary feeds may differ from pasture (eg. low Se in maize silage).

Criteria to assess trace element status

Soil

- In New Zealand, methods of measuring the level of plant available trace elements in soil have been developed but there has been limited calibration of these soil levels with responses in pasture or animal production. Relationships between soil trace element levels with pasture and animal tissue trace element levels are usually poor.
- Although a trace element deficiency in plants or animals is best identified by analysis of plant or animal tissue, a measure of soil trace element status can be used to monitor the effect of application of trace elements in fertiliser.

Pasture

- The concentration of trace elements in the plant give a measure of the amount of trace element taken up from the soil and an indication, depending on pasture intake, of the amount of trace element ingested by the animal.
- Possible trace element deficiencies in clovers (Mo, Cu), lucerne (Mo, Cu, B) and brassicas (B) can be identified by analysis of the plant tissue. Where the trace element is required by the animal (eg. Co, Se, Cu, I) a mixed herbage sample is appropriate.
- Sampling pasture under wet soil conditions can result in soil contamination which will elevate trace element levels. High pasture Fe gives an indication of this. A later section (page 16) will deal with timing and methods of pasture sampling.

Manganese

- Manganese toxicity in sheep or cattle will only occur if pasture Mn content is greater than 1200 ppm which is well above the levels measured in New Zealand pastures.

Animal

- The usual determinants of trace element status are blood, serum or liver trace element concentrations of Vitamin B_{12}, Se and Cu.
- Serum Vitamin B_{12} and blood Se reflect the immediate intakes of Co and Se while liver Vitamin B_{12} and Se stores become depleted if Co and Se intakes remain inadequate for several weeks.
- Serum Cu concentrations only decrease when liver Cu stores have become depleted.
- Tissue biochemical criteria for I have not been well established and an increase in the thyroid weight (g) liveweight (kg) ratio of new born animals is at present the best way to assess the I status of animals.

The sampling procedure will depend on the reason for sampling and is outlined on pages 16 to 18.

Reference ranges for criteria

Soil

Reference ranges for trace elements in soil have only been established from limited research. The ranges presented below are based on the best information available and should be treated with caution.

Trace element	Soil group	Adequate range/level (ppm)	Comments
Animal requirements			
Co (EDTA extraction)	*Brown* and *pallic* soils	1-2	Needed for 80% probability of achieving adequate pasture Co (> 0.1 ppm). Higher level required if the soil Mn >200 ppm
	Pumice soils	1.7	Based on probability approach as above
	Allophanic soils	2.0	As above
Se	All soils	0.5	
Cu (EDTA)	All soils	1.0	
Plant requirements			
Zn (EDTA)	Brown soils	0.8	Glasshouse trial results with wheat
B (hot water soluble)	Pumice soils	0.8	Glasshouse trial results with pasture

Pasture

Reference ranges in pasture have been more accurately defined than for soil. In the deficient range, there is a high probability of a production response, in the marginal range a response may or may not occur and in the adequate range a response is unlikely. High pasture Fe concentration (> 250 ppm) can indicate that the sample is contaminated with soil and trace element concentrations are elevated.

Trace element	Animal species	Pasture species	Deficient	Marginal (ppm)	Adequate
Animal requirements					
Co	Sheep	Mixed	< 0.08	0.08-0.10	> 0.10
	Cattle/deer	Mixed	< 0.04	0.04-0.06	> 0.06
Se	All	Mixed	< 0.03		> 0.03
Cu		Clover	< 5	5-7	> 7
	Sheep	Mixed	< 5	5-10[1]	> 10
	Cattle/deer	Mixed	< 7	7-10[1]	> 10
I	All	Mixed	< 0.15	0.15-0.25	> 0.25
Pasture requirements					
Mo		Clover	< 0.1[2]		> 0.1
B		Clover	< 13	13-14	> 14
Zn		Clover	< 12	12-15	> 15
Mn		Clover	< 20	20-24	> 24
Fe		Clover	< 45	45-49	> 49

1 depends on pasture Mo and Fe
2 clover N must be below 4.5%

The lower level of toxic concentrations for sheep and cattle are Co 35ppm, Se 5 ppm, Cu 20 ppm, Zn 900 ppm, Mn 400 ppm and Fe 500 ppm (contained in pasture tissue).

Animal

The reference ranges to assess the Co, Se and Cu status in terms of serum and liver vitamin B_{12}, Se and Cu have been established from animal supplementation response studies. The animal ranges should be interpreted in the same manner as the pasture ranges. In the low reference range, the response in animal production will be greater at the upper compared with the lower end of the range. Reference ranges to assess I status of animals in terms of serum iodine T4 are not as well defined as the other trace elements.

Trace element	Animal species	Low	Marginal	Adequate
Serum				
Vitamin B_{12}	Sheep	< 220	220-370	> 370
(pmol /L)	Cattle		not recommended	liver preferred
Se (nmol /L)	Sheep	< 52	52-100	> 100
	Cattle (blood)	< 130	130-250	> 250
Cu (µmol /L)	Sheep		not recommended	liver preferred
	Cattle	< 4.5	4.5-8	> 8
	Deer	< 5	5-8	8-22
	Goats			11-25
I (nmol /L)[1]	Sheep and cattle	< 4.0		> 40
Liver				
Vitamin B_{12}	Lambs[2]	< 110	110-120	> 120
(nmol /kg)	Cattle	< 75	75-220	> 220
Se (nmol /kg)[3]	Sheep	< 250	250-450	> 450
	Cattle	< 600	600-850	> 850
	Goats	< 500	500-1100	> 1100
Cu (µmol /kg)[3]	Sheep	< 65		> 95
	Cattle[4]	< 45	45-95	> 95
	Deer	< 60	60-100	> 100
	Goats			> 160

[1] I status is best assessed from thyroid weight(g) / liveweight (kg) ratio which should be <0.4.

[2] Low range indicates an 80% probability of achieving a liveweight gain of at least 10 g / lamb / day.

[3] If liver Se and Cu concentrations are greater than 25,000 nmol /kg and 3130 µmol /kg respectively then this indicates excessive supplementation and livers will be rejected for human consumption. But liver Se levels of greater than 13,000 nmol /kg and Cu levels of greater than 7000 µmol /kg also indicate toxicity.

[4] > 300 µmol /kg liver Cu is recommended at the onset of winter.

Monitoring of trace element status

The best time to sample pasture or liver for trace element status is shown in the following table.

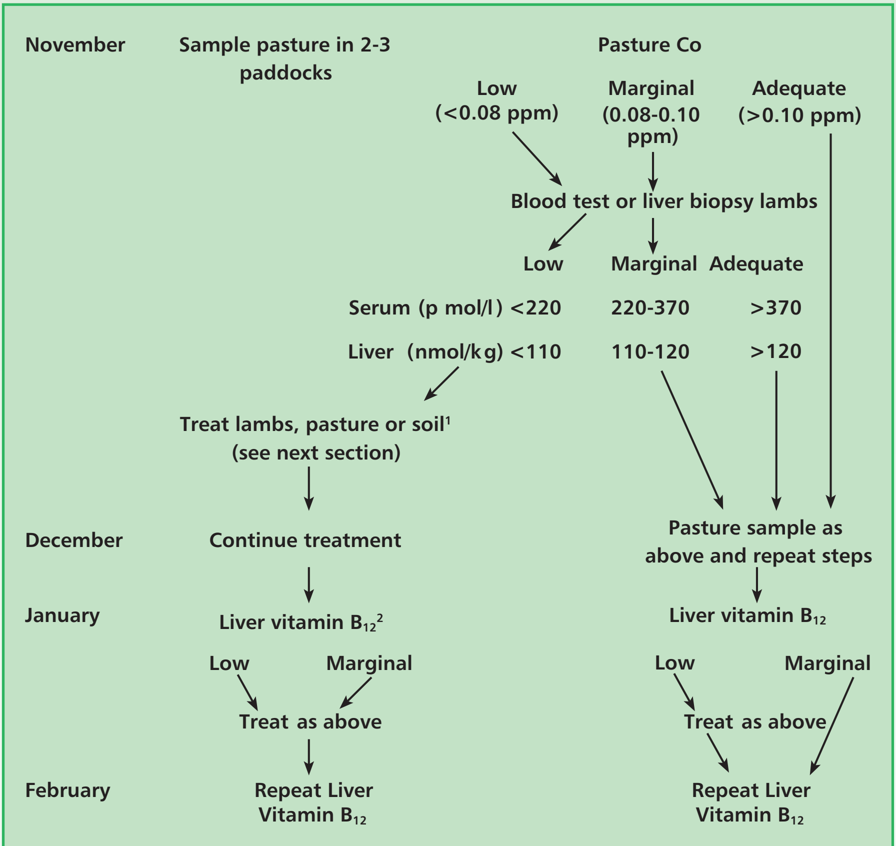
Trace element	Pasture	Liver
Co/Vitamin B_{12}	Late spring	Early summer
Se	Late spring	Summer
Cu	Early spring	Late autumn
I	Early autumn	
Mo/B	Summer (clover)	

- The trace element status of livestock can be assessed from the collection of representative pasture samples, usually 3 or 4 per farm, and determining their Co, Se and Cu concentrations. In each paddock, at least 20 subsamples that represent what the animal is grazing, should be taken. If the amount of soil on the pasture is typical of normal grazing conditions, then the sample should not be washed.
- Likewise, suitable blood and liver samples usually 5 to 10 per flock or herd can be collected from sheep, cattle and deer and their Vitamin B_{12}, Se and Cu concentration determined.
- The trace element concentrations are then compared to the established criteria, outlined earlier, and the trace element status of the herd or flock assessed. For example, if the mean pasture Se concentrations are < 0.03 mg /kg DM and the mean blood Se concentrations of lambs grazing the pasture is < 130 nmol /L then the lambs are Se deficient and they will respond in terms of growth to Se supplementation. However, if the mean pasture Se are > 0.03 mg /kg DM and mean blood Se of the lambs is > 300 nmol /L the lambs are Se adequate and they will not respond to Se supplementation.
- In the case of Cu deficiency, pasture Mo and Fe concentrations are needed to assess the severity of the Cu deficiency as increased intakes of Mo and Fe decrease Cu absorption. The information from pasture samples should always be linked to the collection of blood or liver samples.
- The adequacy of Mo for pasture growth is assessed from a sample of actively growing clover taken during summer when clover Mo levels are at a seasonal low. If a Mo deficiency is suspected, a clover sample can be taken at any time and analysed. If clover Mo is less than 0.1 mg /kg DM and clover N less than 4.5% then the clover is Mo deficient and Mo should be applied. To check if the Mo status is adequate another sampling of clover should be carried out during the next summer to determine if the Mo concentrations have been elevated.

- The B status of the pasture should also be determined in a summer clover sample.

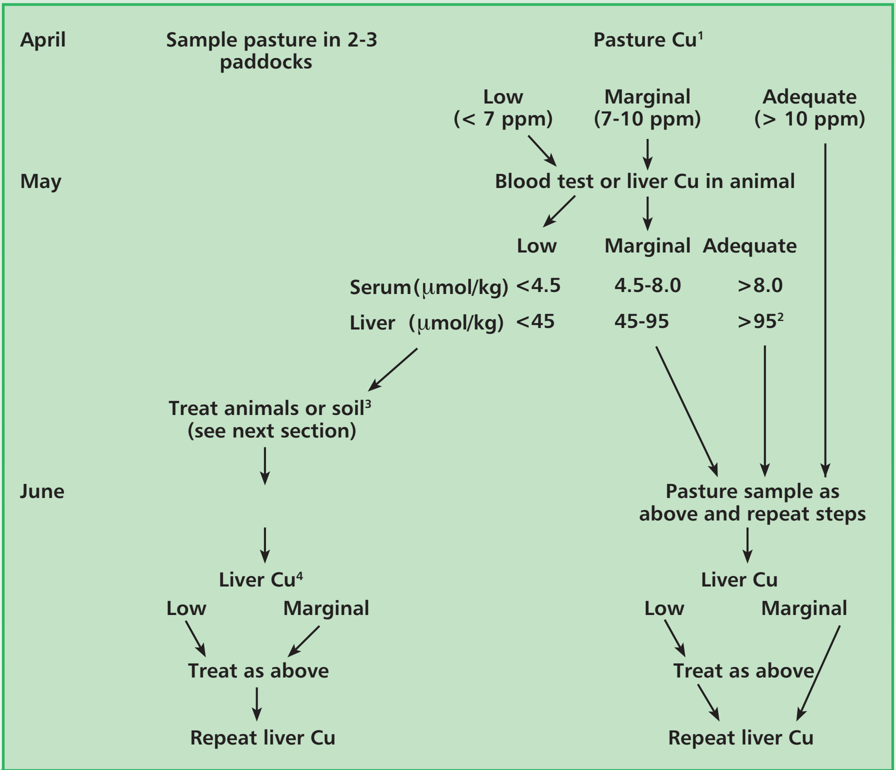
The next two diagrams show monitoring checklists that can be used to assess Co/ Vitamin B_{12} in lambs and Cu in cattle. Pasture Co concentrations in late spring and Cu in early autumn are used as indicators of the need to carry out animal tissue sampling.

Checklist for monitoring of Co/ vitamin B_{12} in lambs



[1] Consult your veterinarian and other advisors.
[2] These can be collected at the meat processing plant and sent to the laboratory.

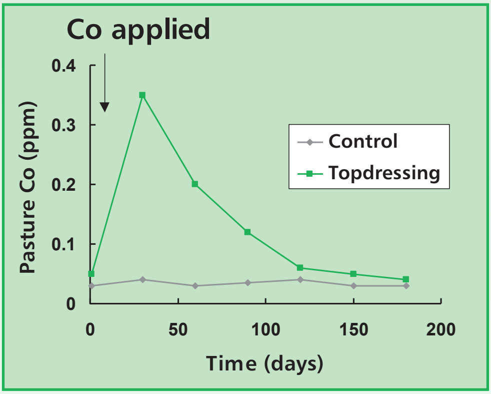
Monitoring checklist for Cu in cattle



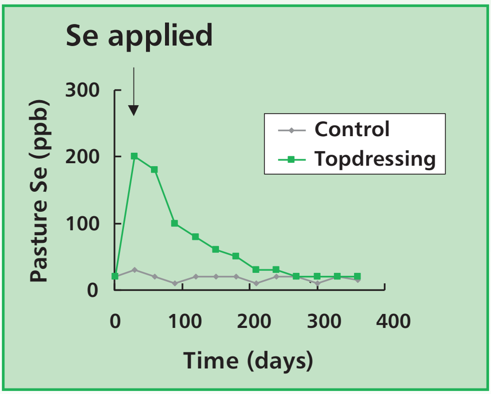
1. Assumes pasture Mo < 1 ppm.
2. It is recommended that in known Cu deficient areas liver Cu is greater than 300 µmol /kg in late autumn so that there is adequate Cu in early spring.
3. Consult your veterinarian and other advisors.
4. These can be collected at the meat processing plant and sent to the laboratory.

Effect of trace element amended fertilisers on the trace element content of pastures

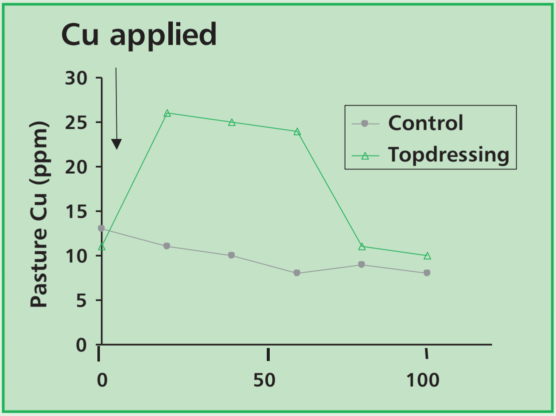
A generalised pattern of trace element uptake by the plants after an application of Co, Se and Cu amended fertiliser is a marked increase in the initial pasture trace element concentrations of some 5 to 20-fold for a period of up to 8 weeks then a marked decrease for up to 8 weeks followed by a slower decrease in pasture trace element concentrations over the next 8 to 12 months.



Effect of cobalt sulphate applied in late spring on a sedimentary soil on pasture Co concentration



Effect of 0.83 kg/ha of sodium selenate prills on a sedimentary soil



Effect of 6.4 kg /ha of copper sulphate applied in May on a sedimentary soil

- The uptake of trace elements by the plant is dependent on factors such as soil type, season, amounts applied and botanical composition.
- As the initial Co, Se and Cu intakes of the animals exceed their daily requirements several fold the Vitamin B_{12}, Se and Cu concentrations of the liver and other storage tissues will increase. These stores will then become depleted when pasture trace elements decrease and intakes are again low.
- This carry over effect means that the effective use of trace element in fertilisers is extended because of the ability of trace elements to be stored in tissues.
- Ideally most of the farm should be top-dressed with the trace element amended fertiliser to ensure all animals receive increased trace element intakes.
- If only a quarter or third of the farm is top-dressed then the animals must be regularly rotationally grazed over the trace element treated pastures. This reduced grazing time on high trace element pastures will decrease the effectiveness of the animals to increase their Vitamin B_{12} and Cu stores in the liver and other tissues.
- With Cu topdressing on areas grazed by cattle and deer, care must be taken to ensure that pasture Cu concentrations are not excessive for sheep.

Rate of trace element required to correct deficiency

Fertilisers containing trace elements can be used to elevate pasture trace element concentrations into the adequate range and maintain them. The recommended rates of each fertiliser trace elements are given in the table below:

Trace element material	Rate of application	Time of application	Frequency
Cobalt sulphate	350 g/ha[1]	Late spring	Annually for 5-10 years
	240 g/ha	Summer	
	60-100 g/ha	Spring	Annually
Sodium selenate (fast release)	1 kg/ha	Autumn	Annually
Sodium/barium selenate (fast and slow release)	0.5 kg/ha[2]	Spring or autumn	Annually
	1 kg/ha	Spring or autumn	Every 2 years
Copper sulphate	5-10 kg/ha	Autumn	Initially
	5 kg/ha	Autumn	Every 4-5 years
Sodium molybdate	50-100g/ha	Spring	Initially and re-test clover
	50 g/ha	Spring	Every 4-5 years
Sodium borate	5-10 kg/ha	Spring	Initially and re-test clover
	5 k /ha	Spring	Every 4-5 years

[1] Depends on soil Mn levels.
[2] If wish to elevate Se in dairy cows apply 1 kg /ha annually.

These rates should be regarded as guidelines and monitoring of pastures and animals should be carried out to determine the appropriate rate for an individual farm.

Application as liquids

If it is required to apply trace elements at times other than when it can be added to fertiliser (Co) or the solid fertiliser is not readily taken up (eg. I), mixing with water and spraying pasture can be a convenient method. With spraying some of the trace element will adhere to the leaf until washed off with rain but the majority will be taken up through the roots.

Spraying Co on to pasture needs to be carried out 2-3 weeks before each grazing by lambs at rates of 50-100 g $CoSO_4$/ha.

Spraying of I needs to be carried out just before grazing ewes on pasture at mating and 4 weeks prior to lambing at a rate of 0.5 g potassium iodide or potassium iodate/ewe.

Management strategies to prevent or treat trace element deficiencies in animals

- As many considerations are involved in making an on-farm decision regarding the most cost-effective method to prevent or treat a trace element deficiency in animals, only general principles rather than specific recommendations will be presented.
- For all trace elements, low trace element status of the animal or an impending deficiency (eg. marginal liver vitamin B_{12} in lambs at the first draft) has to be identified before treatment can be economically justified. However, there can be a case made for annual application of trace element in fertiliser to replace that lost in transfer to non-productive areas and removal in animal products.

Cobalt/vitamin B_{12}

- Correction of a Co deficiency in animals can be carried out by treating the soil (application of $CoSO_4$), pasture (spraying with $CoSO_4$) or the animal (vitamin B_{12} injection or drenching with Co).
- Where Co deficiency is caused by low soil Co levels and occurs in all years across all classes of sheep, an effective long-term programme of $CoSO_4$ application is required to increase soil Co levels. The time required for this programme to achieve adequate animal vitamin B_{12} will range from 5-10 years. Application of Co in fertiliser is not as effective where soil Mn levels are high. Alternatively, annual application of trace elements in fertiliser to maintain adequate soil levels can prevent an animal deficiency.
- If soil Co levels are adequate and lambs are Co deficient only in seasons with high pasture growth rates, animal or pasture treatment may be the most cost-effective method in the short term. Animal treatment will be more cost-effective in extensive farming systems and should be used initially to alleviate a deficiency. Methods include:
    - Injections of the water-soluble Vitamin B_{12} at 4-6 week intervals (1-2 mg for lambs and 2-3 mg for calves).
    - An intra-ruminal Co bullet. It is effective for a year if it is not regurgitated or becomes partially coated with a calcium phosphate.

- A long acting encapsulated injectable Vitamin B_{12} which is effective for up to 8 months in lambs and 4 months in calves (6 mg for lambs and 12 mg for ewes).

- Spray pasture with $CoSO_4$ at the rate of 50 to 100 g /ha 2-3 weeks before the pasture is grazed.

Whichever method of supplementation is used, it must be carried out as recommended to be effective. For example, $CoSO_4$ needs to be annually applied at the correct rate for 5-10 years until animal vitamin B_{12} status becomes adequate. Vitamin B_{12} needs to be injected at 4-6 weekly intervals.

Selenium

Se can be applied as prills with fertiliser, orally drenched, injected or given intra-ruminally as a bolus or pellets.

Se topdressing is a relatively cheap form of supplementation that is suited to farms where young growing animals are not drenched monthly with anthelmintics. In extensive farming systems animal treatment boluses or pellets may be the best method. Animal treatments include:

- Inject or drench with soluble sodium selenate. Lambs and calves at rate of 0.1 mg Se/kg liveweight, that is 2.5 mg for 25 kg lamb, every 6 to 8 weeks. Ewes 5 mg/head 3 to 4 week prior to mating and lambing.

- Inject sheep, cattle and deer with barium selenate at the rate of 1 mg Se/kg liveweight annually.

- An intra-ruminal Se bullet annually. One 10 g bullet for sheep and two 30 g bullets for cows.

Copper

Cu can be applied with fertiliser (usually as $CuSO_4$) or administered to the animal as an injection or intra-ruminally as slow release Cu needles or boluses.

Animal Cu treatment will be more applicable to remedy an immediate deficiency or in extensive farming systems. Animal treatments include:

- Dosing with copper oxide (CuO) needles at the rate of 0.1 g /kg liveweight. The product is administered as a capsule. Typical doses are 5 g for ewes and 30 to 40 g for cows. This will increase liver Cu concentrations for 250 days.

- Drenching hoggets with 67 mg Cu /kg liveweight has a short tem effect of 6-8 weeks on liver Cu.
- Injections with Cu. Cattle are injected (0.2 to 0.5 mg Cu/kg liveweight) at about 6 monthly intervals. A reaction at the site of injection can occur. Copper-Ca edetate injections (0.5-1.0 mg Cu /kg liveweight) will maintain elevated liver concentrations for 250 days sheep and cattle.

  Other potential treatments include:

  - Spraying copper sulphate at up to 3 kg /ha on to silage and hay paddocks pre-cut or when in the windrow. Feeding the fortified supplement should result in elevated animal Cu during winter when liver reserves are declining.
  - For deer, spraying 7 kg /ha of copper sulphate on to saved autumn pasture and immediately break grazing the animals so that they ingest large amounts of Cu that have adhered to the leaves.

Iodine

Iodine can be injected into animals or sprayed on pastures. Spraying will be less expensive but all animals may not ingest sufficient I. Methods of treatment include:

- Drenching pregnant ewes with 200 mg I at 8 and 4 weeks prior to lambing.
- Inject with iodised oil containing 400 mg I /ml. Dose rates are 1 ml for ewes annually and 5 ml for cows at 6 monthly intervals.

Methods using water troughs and salt blocks as carriers to supplement stock with trace elements are not very effective because the intakes are highly variable.

Forms of trace elements in fertiliser

All the commonly used forms of trace element are very soluble and quickly available to the plant.

Element	Trace element additive	% of element in additive
Co	Cobalt sulphate	21
	Granular cobalt[1]	10
Se	Sodium selenate (1 yr prill)	1.0
	Sodium/barium selenate (2 yr prill)	1.0
Cu	Copper sulphate	25
Mo	Sodium molybdate	40
	Granular molybdenum[2]	20
B	Sodium borate	15

[1] Cobalt sulphate/bentonite
[2] Sodium molybdate/bentonite

Some seaweed and fish based liquid fertilisers contain trace elements but concentrations and fertiliser rates applied can be very low, resulting in an inadequate application of trace element for pasture or animal requirements.

Fertiliser Association

Shaping profitable and sustainable farming