3.5 Trace elements

For general management guidelines pertinent to all nutrients, see chapter 3.1 'Nutrient budgeting'. Trace elements in dairy effluent can reach concentrations that have adverse impacts on the dairy production system or on the environment, and for this reason require careful management. Although trace element deficiencies can occur in dairy production systems, they are related to agronomic management and are therefore not dealt with here.

Trace element and contaminant excess

Care is required in the application of dairy effluent to land, because trace elements (copper, zinc etc.), heavy metals (cadmium, arsenic, chromium, mercury etc.), therapeutic compounds and organic materials from pesticides can occur in dairy effluent (McBride and Spiers 2001, Wang *et al.* 2004). Although most dairy effluent is unlikely to have excess concentrations of these contaminants, an excess build-up can result in the over-application of these to land and a subsequent build-up in the soil. When trace element or contaminant levels in a soil become excessive, there is the potential for impacts on productivity and the environment, and the risk of plant and animal uptake to levels that can pose a threat to the health of stock or humans. Bolan *et al.* (2003) found that in New Zealand, metals, and especially Zn and Cu, in dairy effluent originated from feed or therapeutic treatments, especially from feed additives and growth promoters.

A study by McBride and Spiers (2001) of both liquid and solid dairy manures in New York state, USA, indicated that concentrations of heavy metals such as cadmium, lead and mercury were low and that those of Cu and Zn were elevated. They concluded that although a significant proportion of Cu and Zn could be attributed to feed additives, some could be attributed to contamination of the manure by soil or other wastes (feed, bedding, therapeutics etc).

Although the source is unclear, Anon. (2004) cites data on the composition of manures listing Zn concentrations in 'dairy shed solids' of 100 to 200 $mg{\cdot}kg^{-1}$ and in 'cattle' manure of 80 to 283 $mg{\cdot}kg^{-1}$, and Cu concentrations in 'cattle' manure of 14 to 71 $mg{\cdot}kg^{-1}$. These results compare with the data of McBride and Spiers (2001), who found Zn levels in New York dairy manures of 87 to 488 $mg{\cdot}kg^{-1}$ (average 191 $mg{\cdot}kg^{-1}$ dry weight), and Cu levels of 18 to 1100 $mg{\cdot}kg^{-1}$ (average 139 $mg{\cdot}kg^{-1}$). Although again the source is unclear, the maximum recommended limits for contaminants in animal manures applied to land as cited by Anon. (2004) are listed in Table 1.

Table 1. Maximum recommended limits of contaminants in animal manures applied to land (anon. 2004).

Contaminant	Limit ($mg{\cdot}kg^{-1}$)	Contaminant	Limit ($mg{\cdot}kg^{-1}$)
Arsenic	20	DDT group	0.5
Cadmium	1	Aldrin	0.05
Chromium	400	Dieldrin	0.05
Copper	100	Chlordane	0.05
Lead	150	Heptachlor	0.05
Mercury	1	Hexachlorobenzene	0.05
Nickel	60	Hexachlorocyclohexanes	0.05
Selenium	3	Polychlorinated biphenyls	0.05
Zinc	200		

Upper limits for contaminants in irrigation waters applied to soils, of relevance to dairy liquid effluent ANZECC and ARMCANZ (2000), are listed in Table 2.

3.5 Trace elements

Table 2. Long-term trigger values (LTV), short-term trigger values (STV) and soil cumulative contaminant loading limits (CCL) for heavy metals in agricultural irrigation water (ANZECC & ARMCANZ 2000).

Element	Suggested soil CCL ($kg \cdot ha^{-1}$)	LTV in irrigation water (long-term use—up to 100 y) ($mg \cdot L^{-1}$)	STV in irrigation water (short-term use—up to 20 y) ($mg \cdot L^{-1}$)
Aluminium	ND	5	20
Arsenic	20	0.1	2.0
Beryllium	ND	0.1	0.5
Boron	ND	0.5	
Cadmium	2	0.01	0.05
Chromium	ND	0.1	1
Cobalt	ND	0.05	0.1
Copper	140	0.2	5
Fluoride	ND	1	2
Iron	ND	0.2	10
Lead	260	2	5
Lithium	ND	2.5 (0.075 on citrus)	2.5 (0.075 on citrus)
Manganese	ND	0.2	10
Mercury	2	0.002	0.002
Molybdenum	ND	0.01	0.05
Nickel	85	0.2	2
Selenium	10	0.02	0.05
Uranium	ND	0.01	0.1
Vanadium	ND	0.1	0.5
Zinc	300	2	5

Trigger values should be used only in conjunction with information on each individual element and the potential for off-site transport of contaminants.
ND = not determined; insufficient background data to calculate CCL.

ANZECC & ARMCANZ (2000) provide the following explanation of Table 2:

'The long-term trigger value (LTV) is the maximum concentration ($mg \cdot L^{-1}$) of contaminant in the irrigation water which can be tolerated assuming 100 years of irrigation.

The short-term trigger value (STV) is the maximum concentration ($mg \cdot L^{-1}$) of contaminant in the irrigation water which can be tolerated for a shorter period of time (20 years) assuming the same maximum annual irrigation loading to soil as for LTV.

The LTV and STV values have been developed: (1) to minimise the build-up of contaminants in surface soils during the period of irrigation; and (2) to prevent the direct toxicity of contaminants in irrigation waters to standing crops. Where LTV and STV have been set at the same value, the primary concern is the direct toxicity of irrigation water to the standing crop (e.g. for lithium and citrus crops), rather than a risk of contaminant accumulation in soils and plant uptake.

The trigger value for contaminant concentration in soil is defined as the cumulative contaminant loading limit (CCL). The CCL is the maximum contaminant loading in soil defined in gravimetric units ($kg \cdot ha^{-1}$) and indicates the cumulative amount of contaminant added, above which site-specific risk assessment is recommended if irrigation and contaminant addition is continued.

Once the CCL has been reached, it is recommended that a soil sampling and analysis program be initiated on the irrigated area, and an environmental impact assessment of continued contaminant addition be prepared. As background concentrations of contaminants in soil may vary with soil type, and contaminant behaviour is dependent on soil texture, pH, salinity, etc., it should be noted that CCLs may be overly protective in some situations and less protective in others. The CCL is designed for use in soils with no known history of contamination from other sources. When it is suspected that the soil is contaminated before commencement of irrigation, background levels of contaminants in the soil should be determined and the CCL adjusted accordingly.

The trigger values assume that irrigation water is applied to soils and that soils may reduce contaminant bioavailability by binding contaminants and reducing concentrations in solution.'

In reference to Cu and Zn levels and by comparison between Table 2 and the data on manure concentrations by Anon. (2004) and McBride and Spiers (2001), the levels of Cu and Zn typically found in dairy manures is considerably higher than ANZECC & ARMCANZ (2000) recommend should be applied in irrigation water. Bolan *et al.* (2003) state that the majority of Cu and Zn in dairy effluent resides in sludge, and that only a small fraction ends up in liquid effluent. However, they found that when both the solid and liquid portions of dairy effluent were applied at a rate to supply typical N requirements of pastures, Cu and Zn were applied at rates tens of times higher than the typical pasture requirements, and that these metals were likely to build up in the soil. McBride and Spiers (2001) in their New York study found that Cu and Zn concentrations in the dairy manures were at levels where, if the manure was applied at rates to supply typical P requirements, Cu and Zn would be applied at rates hundreds of times greater than recommended annual loadings.

Managing trace elements in dairy effluent

Apart from monitoring of dairy effluent trace element and containment levels before land application and adherence to the thresholds listed in Table 2, no guidelines were found for the management of trace elements and containments, especially Cu and Zn, in dairy effluent. Practices that minimise the addition or accumulation of these constituents to dairy effluent in the first place are probably the best course of action, but these may not always be practical. Dilution of effluent may be another option. More research is required to determine thresholds for trace elements and contaminants in dairy effluent that is to applied to land to avoid the development of adverse impacts.

References

anon. 2004, 'Guidelines for the application of nutrient-rich wastewater to land', Department of Agriculture and Food WA, Perth.

ANZECC & ARMCANZ 2000, 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality', Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Bolan, N.S., M.A. Khan, D.C. Donaldson, D.C. Adriano & C. Matthew 2003, 'Distribution and bioavailability of copper in farm effluent', *Science of the Total Environment,* 309**,** 225-236.

McBride, M. & G. Spiers 2001, 'Trace element content of selected fertilizers and dairy manures as determined by ICP-MS', *Communications in Soil Science and Plant Analysis,* 32(1 - 2)**,** 139-156.

Wang, H.L., G.N. Magesan & N.S. Bolan 2004, 'An overview of the environmental effects of land application of farm effluents', *New Zealand Journal of Agricultural Research,* 47(4)**,** 389-403.