Colorectal cancer and nitrates: implications for health and the economy

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- **Integration of Multiple Uses of Water Resources in Inner Catchments/Reservoirs**
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Summary
Nitrate concentrations have been increasing steadily in New Zealand groundwater over the last two decades. This has coincided with an unprecedented increase in intensified dairy farming. Monitoring has demonstrated that increases in nitrate levels in the South Island province of Canterbury were initially mainly confined to shallower bores, but deeper, community supplies are increasingly threatened as nitrate permeates deeper aquifers. Modelling from the Canterbury Regional Council indicates that the Christchurch (population 400,000) urban supply is likely to experience a significant increase in nitrate contamination within 100 years. This is particularly concerning considering a recent population based Danish study which indicated that the risk of colorectal cancer from nitrate in drinking water begins well below the current maximum allowable value (MAV) of 50mg/L nitrate ion (nitrate measured as nitrate ion. This is equivalent to 11.3 mg/L nitrate as nitrogen). Although nitrate leaching is limited using the land-use consenting process, compliance, monitoring and enforcement of land-use rules is difficult. Moreover, such rules may be too little, too late, as nitrate in groundwater can take many years to build and conversely, many years to diminish – the nitrate levels in New Zealand groundwater today are a consequence of farming practices twenty or thirty years ago. If drinking water suppliers are to avoid the expense of nitrate removal, radical measures may be required more urgently, such as destocking intensified farming areas.

Key words
Nitrate, drinking water, ground water, colorectal cancer

Introduction

Increasing nitrate levels found in New Zealand ground water aquifers and drinking water are approaching or exceeding levels identified which cause colorectal cancer as identified by a recent Danish study [1.] The Danish study found statistically significant increased risks of colorectal cancer at drinking water levels above 3.87mg/L nitrate as nitrate ion. This has implications not only for drinking water providers, but also for agriculture and potentially national economies.

Farm intensification as a source of nitrate in groundwater

The Parliamentary Commissioner for the Environment in New Zealand identified the main source of nitrate in New Zealand's waterways (and by inference groundwater also) is from urine from farm animals [2]

The increase in nitrate nitrogen in New Zealand ground water has occurred due to the massive land-use transformation from the end of the 1990s where large irrigation schemes have permitted and promoted the conversion of sheep and mixed cropping farms to intensified, and profitable, dairy cattle farming with the addition of even more nitrate fertiliser allowing this increase in cattle density (Fig 1)

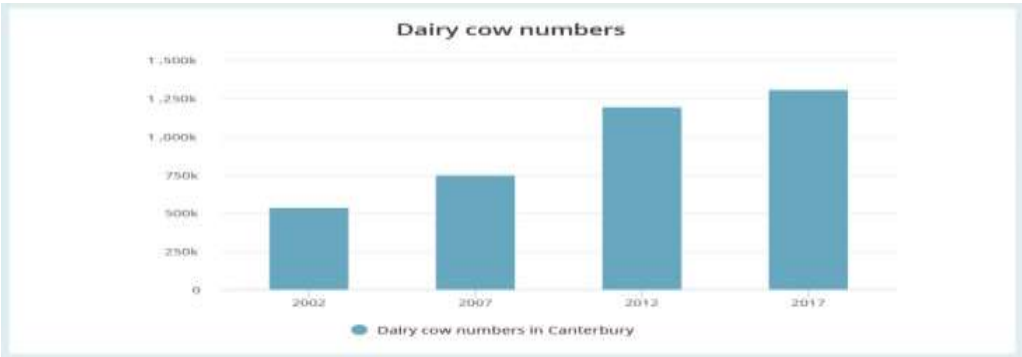

Figure 1: Dairy cow numbers in Canterbury since 2003 [3]

There are now more than 1.3 million head of dairy cattle in Canterbury (plus half a million beef cattle) in an area half the size of Ireland. Each cow produces up to seventy litres of effluent each day, which is not treated. Most dairy effluent runs straight onto paddocks thence to groundwater or waterways [2]

The poor quality of Canterbury's glacial soil requires additional application of nitrogen and phosphorus fertiliser to support intensified dairy farming. Nitrates in concentrated patches leach into subsoil and subsequently groundwater from cow urine and nitrate feriliser. Even the better performing farms with good management practices have seen inevitable increasing nitrogen loss from their soils into water as their milk production increases (see figure 2)).

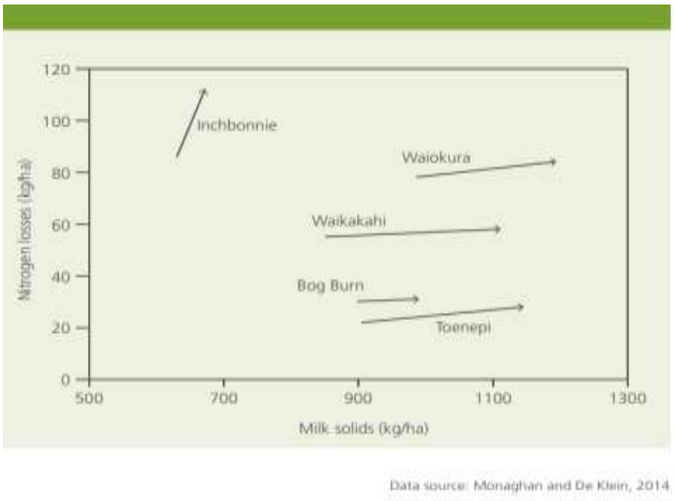

Figure 2. 'Standard' mitigation techniques on dairy farms struggle to keep nitrogen losses from rising as productivity rises.

Modelling by technical advisers of the Canterbury Regional Council (Environment Canterbury or ECAN), indicates that best farming practice can only reduce nitrate leaching by 30% so nitrates are likely continue to increase for decades. Although most nitrate contamination in Christchurch Aquifer System now occurs in shallow private bores (Table 1), nitrates are beginning to leach into deeper aquifers from which community water supplies are drawn.

Table 1: Nitrate Concentrations on Statistics for Christchurch Groundwater Depth range [4]

	Median	**Mean**	**95th percentile**	**Max (mg/L)**
< 30 m	2.5	3.4	7.6	27
30 – 80 m	2.4	2.3	6.1	7.3
>80 m	0.3	0.6	1.6	2.6

NB. Nitrate as nitrate ion. One off sampling set in 2016.

Without radical change to farming practices nitrates are expected to significantly increase in the City of Christchurch water supply within a century.

Levels of Nitrate in Water

ECAN manages an extensive database incorporating information on over 40,000 wells in Canterbury. From those where nitrate is measured, they have been able to build up risk maps of the province identifying where private bores are most likely to exceed the MAV for nitrate (50mg/L nitrate as nitrate ion)[5] This is based on the frequency and density of monitoring bores where the MAV is exceeded. Absolute or even average levels of nitrate are not useful because of wide variation in nitrate readings, which fluctuate widely depending on rainfall and seasonality. Large parts of Canterbury have relatively shallow bores which are considered moderate or high risk (Fig 3) High risk was defined as an area of several dozen bores where more than half exceeded the MAV some of the time; low risk was where no bore exceeded the MAV. As the map shows high and moderate risk shallow bores are found in most of the Canterbury and South Canterbury plains. Nitrate concentrations in the deepest aquifers which supply the City of Christchurch urban water supply are relatively low at present, with a maximum concentration of 1.3 mg/L recorded. However, modelling by ECAN predicts that groundwater nitrate concentrations beneath the city are likely to increase over the next few decades as nitrate leaches south and eastwards from areas north of the city where the aquifer is unconfined and intensified dairying is common. A report of ECAN's modelling suggests that within 100 years there is a 50% probability that nitrate concentrations will increase to over the 3.87 mg/L level [6] in the Christchurch urban drinking water supply - a level at which nitrate could present a significance health risk of colorectal cancer [1].

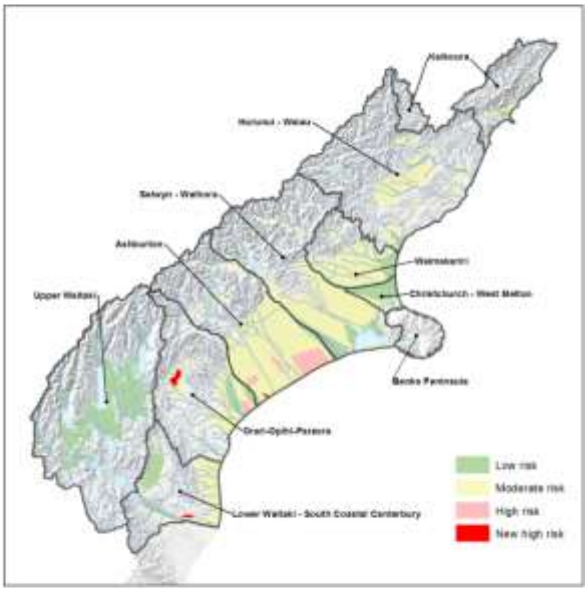

Figure 3: Map of the Canterbury region showing areas at low-, medium- and high-risk of nitrate concentrations exceeding the MAV in shallow groundwater (less than 40 m deep) (ECAN 2018)[5]

Health Implications

The current WHO maximum acceptable value (MAV) is 50mg/L nitrate-ion based on the risk of methaemaglobinaemia in bottle-fed new born infants, who lack the enzyme cytochrome b reductase (present in older children) which reduces methaemaglobin back to haemaglobin. Infants under four months of age who are exposed to nitrate contaminated water used to make up formula feed can consequently have the oxygen carrying capacity of their blood compromised leading to the eponymous and potentially life threatening "blue-baby syndrome". About half a dozen cases of this condition are reported in the US each year, nearly all related to exposure to nitrate contaminated well water used to make up infant formula. The MAV of 50mg/L nitrate ion or (11.3mg/L nitrate as nitrogen) was established in the early 1960s. This level, below which infants are safe and above which they can die, has stood the test of time despite efforts by the fertiliser industry to have the level relaxed.

More recently, a Danish population-based study of more than 2.7 million people found statistically significant increased risks of colorectal cancer at drinking water levels above 3.87mg/L nitrate ion, well below the current MAV of 50mg/L. While the study acknowledged that there are other causes of colorectal cancer, these confounders were accounted by stratifying according to income. Moreover, while individuals can avoid nitroso containing compounds in their diet, it is difficult and expensive to avoid drinking water contamination.

Cases of methaemaglobinaemia are relatively unknown in New Zealand. Figure 3 showed the high risk of nitrates exceeding the MAV in South Canterbury with this area having the highest rate of bowel cancer in NZ at 86.5/100,000 people. [7] With high levels of colorectal cancer and high and increasing levels of nitrates in New Zealand drinking water, further research is being commissioned to corroborate the Danish research. As the body of evidence builds linking nitrates in drinking water to colorectal cancer, the World Health Organisation (WHO) and the International Agency for Research on Cancer (IARC) could revise the MAV for nitrates downwards. This has serious implications for drinking water suppliers around the world, including New Zealand.

Conclusions

The effect of nitrates on human health was once considered to be limited to a small number of vulnerable infants. There is now increasing evidence that nitrate contaminated drinking water may have much wider human health implications at much lower levels of nitrates. Should this be confirmed, drinking water suppliers will have little choice in the long term but to remove nitrates. Current methods include expensive ion exchange or reverse osmosis technology which can add hundreds of dollars annually per person to the cost of providing safe water. Such costs, along with the problem of disposal of nitrate by-product, may be prohibitive to many communities around the world. The ecological, health and economic costs of intensified farming have led some European countries to pay dairy farmers to reduce their cattle numbers, in spite of short-term financial gains from farming intensification. The time has come for other countries, including New Zealand, to apply the precautionary approach to nitrate contamination and reduce stocking density accordingly.

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