TESTING THE WATER

Is nitrogen that drains from paddocks into aquifers and waterways contributing to New Zealand's high rate of colorectal cancer?

by ANDREA GRAVES

Boosting yields: the presence of nitrate in waterways and aquifers is generally attributed to agricultural intensification.

Michael Baker is hard to reach. He had to bump his interview with the *Listener* to be vaccinated on live television. He apologised: "This is a really important topic."

Covid-19 has shone a light on public health expertise, and Baker is a respected source of advice. He's professor of public health at the University of Otago, Wellington, and part of the Ministry of Health's Covid-19 Technical Advisory Group. He was this year made a member of the New Zealand Order of Merit for services to public health science.

It seems an opportune time to ask him about other issues that concern him – such as the apparent association between colorectal cancer and elevated nitrate in drinking water.

In New Zealand, he notes, the risk of colorectal cancer is much higher than in many other countries, which makes him wonder whether something in the environment is to blame. "The causes are probably multifactorial, but it's suggestive from a number of studies that there is an association with elevated nitrate in drinking water," he says. "It might only account for a small percentage of cases, but that's still important when applied to our second-biggest cause of cancer deaths."

The backbone of the nitrate compound is nitrogen, an abundant element in air needed by all plants and animals. But more isn't necessarily better. Carbon is vital for life, yet the effects of plumping up the atmosphere with it are becoming obvious. We also plump up soil with nitrogen, much of it extracted from air and turned into synthetic nitrogen fertiliser. This boosts crop yields and is recognised as a primary factor in the past century's population explosion. It helps produce half the world's food.

But there's a downside. Some of that nitrogen dissipates as greenhouse gas or washes into aquifers and waterways. It has contaminated streams and lakes around the world, fuelled algal growth that suffocates aquatic species, and caused coastal "dead zones". Its effects on human health are less clear.

BABIES AND BOWELS

Historically, waterways and aquifers contained little nitrate, and its presence is generally attributed to agricultural intensification. It's rare, though, to drink water that exceeds the safety levels in this country of 11.3 milligrams of nitrogen per litre, based on World Health Organisation (WHO) guidelines. That was set to avoid "blue baby syndrome" in babies fed infant formula mixed with tap water (see "Born too soon?", page 16).

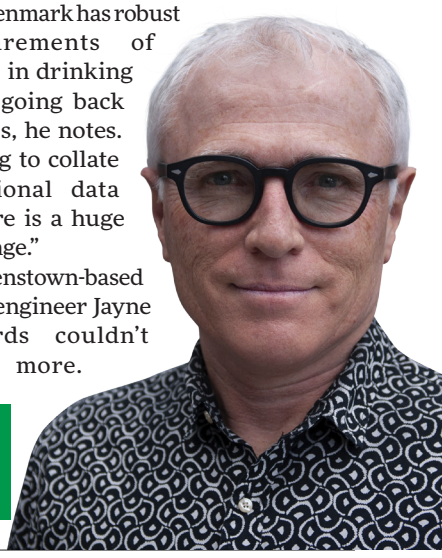
Baker says the "blue baby" maximum doesn't consider chronic exposure to lower levels. Dr Tim Chambers, a senior research fellow who works with Baker, agrees: "The perception is that if it's under 11.3mg, there's only a risk for infants under six months. So, for adults, there's essentially considered to be no risk, no matter how high the concentration. But if you read the studies on chronic exposure, especially the high-quality ones, that's not what's indicated."

Chambers knows of 11 studies showing an association between elevated nitrate in drinking water and colorectal cancer.

In a 2018 study comparing drinking water and cancer records in Denmark, water nitrate levels above only 0.87mg/l were linked with a higher incidence of colorectal cancer. The incidence jumped again at 2.1mg/l – about a fifth of the maximum acceptable level.

Chambers knows of 11 studies showing an association between elevated nitrate in drinking water and colorectal cancer. But for him, the Danish study was "a wake-up call". Denmark has robust measurements of nitrate in drinking water going back decades, he notes. "Trying to collate a national data set here is a huge challenge."

Queenstown-based water engineer Jayne Richards couldn't agree more.



Michael Baker: The colorectal cancer risk is much higher in NZ than in many other countries.

DAVE ALLEN PHOTOGRAPHY/NIWA; NZME

Born too soon?

Everyone wants babies to be healthy, so when a persuasive study came out in the United States this year showing that nitrate in drinking water was associated with preterm birth, it raised eyebrows.

The Stanford University study included 1.4 million births and found that at between 5-10mg of nitrate per litre of drinking water, the risk of very preterm birth increased by nearly 50%. That would translate in New Zealand to roughly one additional preterm birth for every 200 births from mothers drinking that level. For those drinking higher than the federal limit of 10mg per litre of water, a preterm birth was two and a half times as likely.

Other studies have also suggested a link with low birthweight and neural tube defects. But it was the scientific quality of the Stanford study that made it so convincing, says the University of Otago's Dr Tim Chambers.

The Ministry of Health recently commissioned the University of Auckland's Liggins Institute, which has a focus on pregnancy and birth, to review the data.

The theoretical link between adverse birth outcomes and nitrate has the same basis as the drinking water limit to prevent blue-baby syndrome: nitrate initiates the conversion of haemoglobin, the blood's oxygen-carrying molecule, into a form that can't transport oxygen to tissues. Children and adults have an enzyme that converts it back again, but fetuses and young babies have very little of that enzyme.

Consuming too much nitrate can affect how blood carries oxygen, which can result in an imbalance in free radicals and antioxidants, says Dr Luling Lin, a Liggins post-doctoral fellow who conducted the review. In a pregnant woman, this process is a suspected cause of preterm birth.

Consuming too much nitrate can affect how blood carries oxygen.

Nitrate has also been shown to interfere with thyroid function in animals and humans and to cause developmental malformations, says Lin.

The Ministry of Health intends to release the review soon. It told the *Listener* that at this stage there was not a "convincing level of evidence" that established a causal link between adverse health outcomes and nitrate levels in drinking water lower than the maximum acceptable value. "However, we continue to review emerging evidence and research in this area."

Chambers and his colleagues have applied for funding to check for any relationship between their drinking water nitrate data and preterm births in New Zealand.

GETTY IMAGES

Luling Lin: nitrate has been shown to interfere with thyroid function in animals and humans.

Richards examined drinking water records for her master's thesis, which Chambers and Baker co-supervised. Because there is no central database in this country, she had to request data from 67 district councils and 119 private drinking water suppliers. She also measured nitrate in a sample of Southland homes with unregistered supplies.

A co-authored paper based on her thesis will soon be published in the journal *Environmental Research*. Although only a preliminary study, it suggests that nitrate in drinking water could be contributing to 0.8-5.6% of colorectal cancers here.

Richards and her co-authors believe that about 7-10% of the NZ population drink water that could increase their risk of colorectal cancer.

Richards and her co-authors believe that about 7-10% of the population drink water that could increase their risk of colorectal cancer. They found notably high nitrate levels in Canterbury and Southland, and in rural water supplies that serve small numbers of people. City supplies, which are generally well treated, did not have high levels.

OTHER FACTORS

At this stage, however, there is no cause for alarm, says public health physician Brian Cox, an associate professor and director of the Hugh Adam Cancer Epidemiology Unit at the University of Otago. Even for those drinking nitrate-rich water, the risk is small compared with eating a diet high in processed meat.

It can also be hard to deduce what else might be going on, Cox says. "The development of cancer typically requires regular exposure for at least a decade, so it's preferably the lifetime accumulation of exposure that needs to be measured, not current exposure. In this case, the relationships that have been found are weak enough that they may be explained by other things. We can't yet be confident that something else isn't at play."

Baker agrees. "We need a reasonable sense of proportion. The evidence is on the weaker end of the spectrum and association does not necessarily mean causation.

Tim Chambers: "The precautionary principle should apply to protect public health."

In rural areas, there are likely to be different dietary patterns, exercise patterns or other differences. They may be driving the association."

The Danish study attempted to account for known risk factors, such as eating meat, drinking alcohol and smoking, by including people's highest education level as a rough proxy for these habits. Other studies report that Danes with more education tend to have healthier, vegetable-rich diets and be non-smokers. More education dented the cancer's incidence, but the nitrate link persisted.

CHEMICAL REACTION

Nitrate's carcinogenic potential has long been contemplated. In 2010, the WHO's specialised cancer agency, the International Agency for Research on Cancer (IARC), considered multiple studies into many types of cancer and nitrate. Its verdict? No evidence from epidemiological studies of an increased risk from food, and inadequate evidence in humans that nitrate in drinking water is carcinogenic. But, it noted in its final conclusion, "ingested nitrate or nitrite under conditions that result in endogenous nitrosation is probably carcinogenic to humans".

Endogenous nitrosation, which is a chemical reaction inside the body, is the core of the suspicion cast on nitrate. Nobody suspects nitrate itself of causing cancer – our bodies need some of its nitrogen, and much of it exits swiftly in urine. Instead, concern lies with nitrate's transformation, with the aid of mouth bacteria and stomach acid, into nitrite and eventually nitrosamines. Many nitrosamines mutate DNA in a tumour-promoting fashion.

Nitrate intakes from all sources are well below the internationally agreed acceptable daily intake.

That's less alarming than it sounds, says Peter Cressey, a chemical risk assessor at the Institute of Environmental Science and Research (ESR) and a member of the United Nations' expert committee that looks at the safety of chemicals in food. That is because the IARC examines theoretical – rather than real-life – risk, says Cressey.

The European Food Safety Authority, which does take real-life factors into account, has stated that the acceptable daily intake might be exceeded for people with medium to high exposure if all sources, including environmental contamination, are taken into account.

Peter Cressey: satisfied that Kiwis aren't at higher risk of colorectal cancer from their drinking water.

HAGEN HOPKINS

LOCAL ASSESSMENT

That accounting has been done for New Zealanders. Commissioned by the New Zealand Food Safety Science & Research Centre, Cressey and ESR toxicologist Dr Belinda Cridge recently assessed dietary and drinking water exposure to nitrate. Fonterra and the Ministry of Business, Innovation

Cecile de Klein: "Cattle or sheep urine deposits are the origin of most nitrous oxide from farming systems."

DAVE ALLEN PHOTOGRAPHY

Climate cost

Another consequence of the use of nitrogen in agriculture is its contribution to climate change. Although synthetic fertiliser and clover contribute to nitrate leaching into water, some nitrogen escapes as nitrous oxide gas. It does so after passing through the digestive system of livestock, which cannot use most of the nitrogen in the pasture they eat.

"Cattle or sheep urine deposits are the origin of most nitrous oxide from farming systems, because the nitrogen in these patches is very concentrated," says Dr Cecile de Klein, a principal scientist at AgResearch and science leader at the New Zealand Agricultural Greenhouse Gas Research Centre.

Unlike nitrogen that is naturally abundant in air, nitrous oxide is a potent, long-lived greenhouse gas. It is also the main cause of ozone depletion, increasing the risk of skin cancer.

Human-induced nitrous oxide emissions, which mostly come from adding nitrogen to soil for cropping and agriculture, have grown by 30% globally over the past 40 years. About 6% of New Zealand's greenhouse gas emissions come from agricultural nitrous oxide. According to the Potsdam Institute for Climate Impact Research, New Zealand "exceeds its national share of both the phosphorus and nitrogen boundaries, placing it far beyond the guardrail in terms of biogeochemical flows". This is because our food exports are outsized in proportion to our population and land area.

Associate Professor Alex Macmillan, a public health physician at the University of Otago, points out that more than 90% of our synthetic nitrogen fertiliser is used to produce milk solids and meat, which on the whole feed people who are already well fed.

"We've come to rely on it economically, but now we must transform the way we produce food if we are serious about ending hunger locally and globally," she says. "Climate change is already hitting essential food production internationally, so for that and other reasons – including the role of nitrate in ocean acidification affecting the ability of Māori and Pasifika peoples to access mahinga kai and kaimoana – continuing down this path is an own goal for food security."

The planet-warming impact of livestock urine was a key reason the New Zealand College of Public Health Medicine requested a stringently reduced level of nitrate in waterways when it submitted on the Ministry for the Environment's 2019 "Action for Healthy Waterways" discussion document.

The industrial manufacture of synthetic nitrogen fertiliser is also a climate problem: it relies mostly on heating natural gas to 1000°C and accounts for about 2% of the world's energy use. One of its by-products is large quantities of carbon dioxide.

& Employment requested and co-funded the study, which has been reviewed by a toxicologist at the Ministry for Primary Industries and submitted to the journal *Food Additives & Contaminants*.

Cressey says their findings are reassuring. By combining food and drinking water nitrate data with national surveys of food consumption, they show that nitrate intakes from all sources are well below the internationally agreed acceptable daily intake. Averaged across water supplies, water contributed less than 10% of nitrate intake.

Most water is drunk near mealtimes or in beverages, they report. This matters because vitamin C and polyphenols from fruit and vegetables, and possibly tea and coffee, inhibit nitrosamines being formed.

"It would be easier for countries to lower the nitrate standard if the WHO re-evaluated its guideline first."

Children, the study found, mostly drink water between meals as fruit-based drinks containing vitamin C. But do they really? "That's one area where trends have probably changed," Cressey admits. "Unfortunately, the most recent national nutrition survey is from 2008-09.

"Most of the nitrate we eat is from lettuce and potatoes," he says. It's plentiful in watercress, celery, spinach and kūmara – as are compounds that protect against nitrosamine formation. Water contains no such compounds, but if it reaches the gut near mealtimes, Cressey says that food's protective compounds should be sufficient.

Chambers and other epidemiologists have questioned that and other assumptions in the study. But Cressey rejects the criticisms and says he is satisfied that Kiwis aren't at higher risk of colorectal cancer from their drinking water. He also points out that no other country has reduced its nitrate limit.

PRECAUTIONARY PRINCIPLE

Jörg Schullehner, who led the Danish study, says any change would be a political decision. "Denmark and the EU align their water standards with WHO guideline values. It would be easier for countries to lower the nitrate standard if the WHO

re-evaluated its guideline first."

The Ministry of Health asked the WHO if it had plans to review the guideline, or to commission further research. The response noted that although it is plausible that ingested nitrate could potentially cause colorectal cancer, other epidemiological studies have shown mixed associations and the Danish study did not establish a causal relationship.

Others remain curious. "The IARC says it's a probable carcinogen in certain conditions, and the more robust epidemiological evidence supports that," says Chambers. "You cannot conclusively rule it out without sufficient evidence to do so. The precautionary principle should apply to protect public health."

Fitting together all the pieces of a cancer puzzle is often a protracted process.

Doubt has also been cast on how the cancer could form at the end of the digestive tract, given that nitrosamines mostly form in the stomach and are absorbed in the small intestine. But Chambers believes there may be an explanation. "Nitrosamines can travel to the colon attached to meat compounds. There's also some suggestion that nitrate-reducing bacteria in the large intestine contribute to nitrosamine formation," he says.

Baker points out that fitting together all the pieces of a cancer puzzle is often a protracted process. "It took years to confirm even the dramatic association between asbestos exposure and mesothelioma."

Meanwhile, several meta-analyses of studies have shown a statistically significant link between nitrate in water and colorectal cancer. One study, published last year, originally showed no association, but Chambers and his colleagues found errors and wrote to the journal that published it. "The lead author agreed, made the changes we suggested, and says it completely changed the results."

The Otago scientists plan to delve further. "We hope to accumulate a data set that will nail it for New Zealand," says Cox. He has data on colorectal cancer; Chambers is trawling councils for longer-term drinking water data. "We're in the early phase of figuring out if a study is viable."

Responsible dairy: instead of draining wetlands, farmers are creating new ones.

Down on the farm

The use of nitrates in farming has long been controversial. But for the past two decades, farmers have been doing their best to reduce their nitrogen footprint, says Dr David Burger, strategy and investment leader for responsible dairy at DairyNZ.

As well as fencing off waterways, farmers have been managing effluent and using fertiliser better and putting environmental plans in place, he says. The sector has also poured money into finding scientific ways to improve water quality and reduce greenhouse-gas emissions.

Using alternative pasture plants such as plantain has helped reduce nitrogen losses by up to 30%. And instead of draining wetlands, farmers are creating new ones, which can help reduce nitrate loss by 25-50%.

According to the Ministry for Primary Industries, the Government is investigating a range of options to manage nitrogen loss from farms, including potentially greater control on practices and inputs. A new cap on synthetic fertiliser application for pastoral farming was recently put in place.

It has been estimated that if all known and developing mitigation actions were implemented by all dairy, sheep and beef farmers by 2035, within an average of five years potential nitrogen loads entering rivers might drop by a third compared with 2015.

Improved farming practices since 1995 have already prevented far more nitrogen loss than would otherwise have occurred, according to calculations from the Our Land and Water National Science Challenge. But dairy has expanded and intensified, and beef has increased per-hectare production, so total nitrogen loss has increased.

DAWN DUTTON PHOTOGRAPHY

THE PRICE OF MILK

Contrasting local documentaries put our dairy industry under the microscope. by RUSSELL BAILLIE

New Zealand dairy has come down with a double dose of docos.

Milk & Money and *Milked* both feature variations on Fonterra's boast about its milk having the smallest carbon footprint in the world. But they also offer alarming reminders about the industry's not-insignificant impact on the environment.

Both were instigated and fronted by twenty-somethings, suggesting the industry's communications strategy may not be washing with a generation anxious about climate change and the provenance of everything.

Milk & Money arrived with little fanfare on TVNZ OnDemand three months ago. It's fronted by journalist Baz Macdonald, who grew up in rural Southland. He begins by revisiting his home paddock and observing how much the dairy boom has changed the place.

His New Zealand On Air-funded series of six 20-minute episodes takes an explanatory and balanced approach to a wide range of issues, including the personal toll on farmers themselves. The easy-going but forthright Macdonald mixes down-on-the-farm case studies with a small herd of talking heads, ranging from environmental advocates and scientists to the chief executives of Fonterra and fertiliser giant Ballance Agri-Nutrients.

It's a well-made, illuminating series that ponders possible solutions as well as problems, and deserves more attention than its slot suggests.

Young and restless: Baz Macdonald in *Milk & Money*. Below, Chris Huriwai in *Milked*.

Milked, which is debuting at this month's New Zealand International Film Festival, is a somewhat different beast. It's a spirited piece of lactose-intolerant polemic taking on a wider number of issues through a narrower lens.

If it's preaching to the vegan-green choir, it has got an impressive chorus of its own, such as prominent environmentalist Jane Goodall. It's also endorsed by well-known Wairarapa farmers and film-makers James Cameron and Suzy Amis Cameron – she is the doco's executive producer and an interviewee.

It's fronted by Chris Huriwai, who grew up on a farm near Kaikohe, where he has been a youth worker and a world-champion street unicyclist. His film, directed by Amy Taylor, would seem an extension of his social-media activism – its beginnings sprang from seeing the 2014 US anti-animal-agriculture film *Cowspiracy: The sustainability secret*.

When Fonterra started its milk-in-schools programme, he posted a video against it. Fonterra reached out to Huriwai asking if he'd like to discuss his views over a coffee. He has upped the ante, sort of. Quite a bit of the early part of *Milked* has him on the phone asking various people why they don't want to talk to him on camera.

Around two dozen supporting interviewees are happy to explain why dairy is bad on several levels. Outspoken academics Peter Fraser and Dr Mike Joy are as generous with their time and insightful in *Milked* as they are in *Milk & Money*. Agriculture Minister Damien O'Connor tells Huriwai he doesn't think the rivers are as bad as all that, while succinct former politician Gareth Hughes proves he's a loss to the parliamentary wing of the Green Party.

There's a dash of offline activism with Huriwai out on a Farmwatch stake-out, and it ends with him wandering the vast organic vegetable patch at chez Cameron. There's not a cow within cooee – a vision of an effluent-free future in an affluent present. ▮

Milk & Money *is on TVNZ OnDemand;* Milked *is at the NZ International Film Festival;* Cowspiracy *is on Netflix.*