NES-Drinking Water and Nitrate Contamination - Briefing to Ministers

Prepared by Greenpeace Aotearoa. May 2022

EXECUTIVE SUMMARY

Nitrate is the most widespread contaminant found in New Zealand's water[1] and risks human health at elevated levels. The stated aim of the National Standards for Drinking water (**NES-DW**) review is to make improvements in "how activities that pose risks to source water are regulated or managed".[2] However, the proposed standards do not control the activities that are causing increased nitrate contamination of source water and fail to uphold Te Mana o te Wai.

The Maximum Acceptable Value **(MAV)** for nitrate in the drinking water standard of 11.3 mg/L (NO3-N) is set to protect infants from Blue Baby Syndrome which can be fatal. In some areas, nitrate contamination already exceeds the drinking water standard and in many areas contamination is worsening.[3] The most at risk communities are rural people on household bore water, however contamination threatens all groundwater supplies including reticulated water such as the Christchurch town supply sourced from the Canterbury aquifer.[4]

Nitrate contamination is particularly worsening in dairy intense regions. 8% of ECan monitored wells now exceed the MAV and this has significantly worsened over time, up from only 1% of wells that exceeded the MAV in 1992.[5] New research shows that groundwater originating from intensive dairy farming areas in Canterbury will reach nearly double the current MAV, rendering much of it undrinkable, unless substantial reductions in nitrogen inputs are made.[4]

The Government must heed the Technical Guidelines for Water Source Protection produced by MfE which state:

> *"Exceedances of the MAV for nitrate-nitrogen at a number of sites around New Zealand indicate that non-point source nitrate contamination is not being attenuated sufficiently to reduce concentrations in groundwater to acceptable levels… Nitrate concentrations require a catchment-wide approach to management."*[6]

Livestock urine, particularly dairy cow urine, and synthetic nitrogen fertiliser are the main sources of nitrate contamination into New Zealand's water.[7] Over the last 30 years the dairy herd has nearly doubled and synthetic nitrogen fertiliser use has increased nearly seven fold causing a sharp increase in nitrate contamination.[8]

The sheer number and intensity of livestock, the volume of their excreta and the ongoing use of synthetic nitrogen fertiliser are the fundamental problem. A vast amount of nitrate from livestock urine and synthetic fertiliser is leaching through the soil into groundwater. However, the only controls proposed in the NES-DW are stock exclusion from surface waterways and a 5 metre setback for synthetic fertiliser application. These actions are inadequate and do not address the issue of diffuse nitrate leaching.

Given nitrate in groundwater in some areas is already above the MAV, and exceedances are increasing, the Government must act now to protect people's health within the current standard. Diffuse nitrate pollution can only be dealt with by reducing the volume of nitrogen entering catchments and this can only meaningfully be achieved by introducing a sinking cap on synthetic nitrogen fertiliser and stocking rate limits into the NES-DW.

Furthermore, while there is more than enough evidence to act now to uphold the existing MAV, an increasing body of evidence shows that nitrate levels at much lower concentrations than the MAV are associated with negative reproductive and foetal impacts, and various cancers, particularly colorectal cancer. Therefore action to protect source water from nitrate contamination is necessary both to uphold existing standards and as a precautionary approach to emerging health evidence.

The World Health Organisation has now classified ingested nitrate as **probably carcinogenic**, specifically when nitrate is ingested under conditions that promote endogenous nitrosation.[9] New Zealand scientists, including Prof Michael Baker, have recently warned that 100 cases of colorectal cancer and 40 deaths per year in New Zealand could be attributed to nitrate in drinking water.[10] US scientists found that there was nearly a 50% increase in risk of preterm birth with nitrate above 5 mg/L.[11]

The following briefing summarises the evidence regarding: the current levels of nitrate contamination in New Zealand's water; the sources of that contamination; and the human health risks of drinking water contaminated with nitrate.

Given the evidence in this briefing, Greenpeace makes the following recommendations. These are also included in the joint submission on the NES-DW made by Greenpeace, Forest & Bird, Environmental Defence Society, Fish & Game, and supported by the Cancer Society.

KEY RECOMMENDATIONS

Ensure that the NES-DW:

1. Gives effect to Te Tiriti o Waitangi and Te Mana o te Wai.
2. Recognises both synthetic nitrogen fertiliser and livestock urine (particularly from dairy cows) as direct, indirect, or source contaminants and addresses them as such.
3. Introduces a regulatory phase-out of synthetic nitrogen fertiliser using a sinking cap through the NES-DW to protect drinking water sources.
4. Introduces a stocking rate limit to reduce the number of dairy cows that is more strict in areas with highly porous soils, and prohibits new dairy conversions.
5. Protects everyone's drinking water, including rural communities on household supplies servicing fewer than 25 people.

NITRATE CONTAMINATION IN DRINKING WATER IS WORSENING

1. Nitrate is the most widespread water contaminant in New Zealand's water.[1]
2. Between 1998 and 2009, nitrogen pollution worsened more in New Zealand than in any other OECD country.[12]
3. Groundwater nitrate contamination already exceeds the MAV of 11.3mg/L in some areas. According to LAWA - 6% of groundwater sites exceed the MAV nationally and roughly a quarter have concentrations higher than half the MAV (5.65 mg/L) [3]
4. Nitrate contamination is worsening in dairy intense regions.
5. In Canterbury 8% of monitored wells exceed the MAV and this has worsened significantly over time, up from only 1% of wells exceeding the limit in 1992.
6. Nitrate trends in the region are very likely increasing at over two thirds of monitored sites (68%) (see Fig 1)[5]
7. Recent research finds that dairy farming will result in steady state nitrate concentrations on average of 21.3 mg/L (nearly double the current MAV) in groundwater originating from dairy farming areas in Canterbury, rendering much of it undrinkable, unless substantial reductions in nitrogen inputs are made. The Christchurch City drinking supply, will also become significantly polluted with nitrate from dairy farming[4]
8. Between 2021 and 2022 Greenpeace took over 900 nitrate water tests on household drinking water supplies which represents New Zealand's largest research-consented independent dataset of nitrate concentrations in rural household bore water.
9. Collating nationwide mail-in testing data from 264 bore samples, and results from town-hall testing in Ashburton, Dunsandel and Temuka, making a combined total of 581 bore water samples our preliminary analysis found: 7% were above the MAV of 11.3 mg/L; 27% were between 5 and 11.3 mg/L; 41% were between 0.87 and 5 mg/L. These findings are consistent with the ECan and LAWA findings cited above.

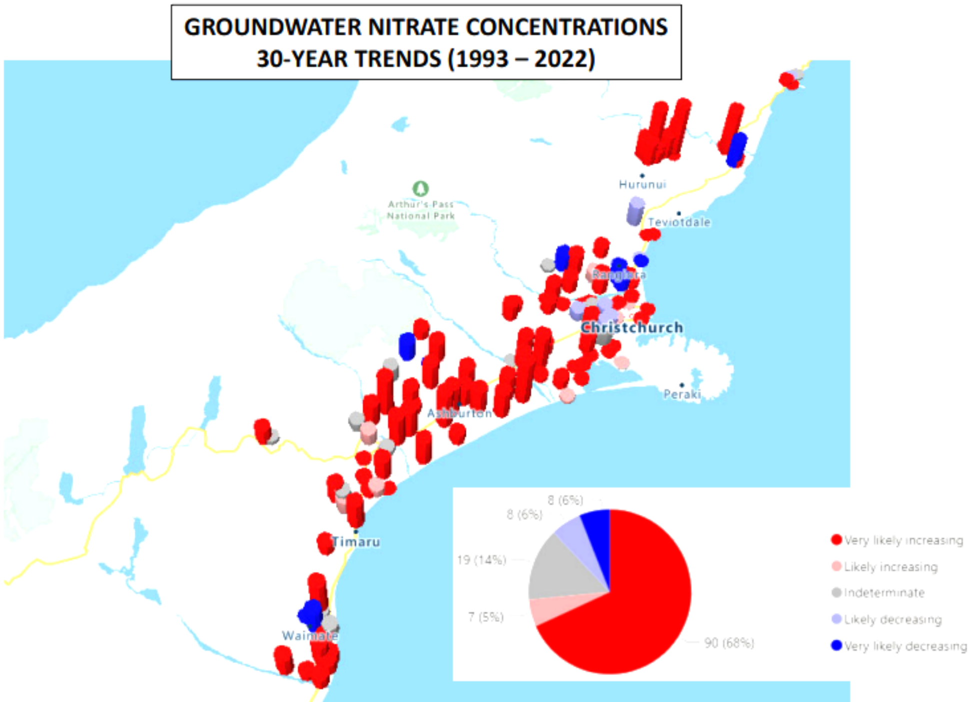

Fig 1: Nitrate trends over 30 years. Nitrate concentrations in 68% of monitored sites are very likely increasing.

NITRATE CONTAMINATION RISKS HUMAN HEALTH

At elevated levels nitrate in drinking water has negative impacts on human health. Above the MAV of 11.3mg/L there are risks to infants that can be fatal. An increasing body of evidence is also showing that nitrate levels much lower concentrations than the MAV are associated with negative reproductive and foetal impacts, and various cancers, particularly colorectal cancer. These impacts are discussed in the following sections.

BLUE BABY SYNDROME

1. The use of nitrate-contaminated drinking water to prepare infant formula is a well-known risk factor for blue baby syndrome (Methaemoglobinaemia).
2. The current MAV (11.3mg/L) is set to avoid blue baby syndrome where nitrate ingestion inhibits the transport of oxygen in blood causing the baby to turn a blue colour.[13] The condition can progress rapidly and in severe cases it can be life-threatening causing coma and death.[14]
3. In Canterbury, midwives and family doctors are now required to encourage pregnant women to test their water if it comes from a shallow household bore. Those who find their water is contaminated, or at risk of nitrate contamination, are strongly advised to make up infant feeding formula using bottled water.[15]
4. The risk of blue baby syndrome alone and the current exceedances of the MAV should be evidence enough to take regulatory action immediately to reduce nitrate contamination. However, due to an increasing body of evidence of other health impacts

at much lower levels than the MAV, the 11.3mg/L nitrate limit has been described by public health physician Professor Michael Baker as “hopelessly out of date”[16].

FOETAL IMPACTS

1. At lower concentrations than the MAV, researchers have found an association between nitrate in drinking water and miscarriages in pregnant women, babies born underweight, or prematurely, neural tube defects, spina bifida and limb deficiency.[9] [17] [18] [19]
2. A 2021 study of 1.4 million births found pregnant people ingesting nitrate in drinking water above 5 mg/L increased the odds of a preterm birth by 47%. At 10 mg/L of nitrate it increased the odds of a preterm birth 2.5 times.[11]
3. The NZ College of Midwives says that pregnant women should consider avoiding drinking water with nitrate over 5 mg/L due to the associations with preterm birth.[15]
4. Researchers estimate as many as 138,000 New Zealanders could be on water supplies with nitrate above 5 mg/L.[18]

CANCER

1. The World Health Organisation has classified nitrate as probably carcinogenic to humans, specifically when ingested under conditions that promote endogenous nitrosation.[9]
2. Nitrate contaminated drinking water is associated with thyroid, colorectal, stomach, bladder, breast and ovarian cancers, and non-Hodgkin’s lymphoma. [20] [21] [22] [23] [24] [25] [26]
3. A Danish study of 2.7 million people found a statistically significant increased risk of colorectal cancer in drinking water levels above 0.87 mg/L, which is more than twelve times lower than the current MAV of 11.3 mg/L.[25]
4. Up to 17% of New Zealand’s population - 800,000 New Zealanders - could be exposed to levels of nitrate in their water that are above this cancer risk threshold of 0.87mg/L.[10]
5. Scientists warn that 100 cases and 41 deaths from colorectal cancer per year may be attributable to nitrate contamination of drinking water at a cost of $64.1million.[10]
6. Colorectal cancer is New Zealand’s third most prevalent cancer and the second most common cause of cancer deaths.[24] New Zealand’s colorectal cancer rate is significantly higher than the global average and among the highest in the world. [27]

LEACHED COW URINE AND SYNTHETIC FERTILISER ARE THE BIGGEST SOURCES OF NITRATE CONTAMINATION

It is widely accepted by scientists that the main sources of nitrate contamination into New Zealand's water are livestock urine, particularly dairy cow urine, and synthetic nitrogen fertiliser.[7]

Nitrate is highly soluble and is easily carried into streams, rivers, lakes and estuaries, or leached through soil into groundwater.[28] Once in the soil, excess nitrogen travels through soil and rock layers, ending up in groundwater, rivers, and lakes.[8] Once in the groundwater nitrate can persist for many years and travel long distances.[3]

Evidence shows that:

1. The growth in the dairy herd and in synthetic nitrogen fertiliser use has increased nitrate contamination through runoff to surface water and leaching to groundwater, also known as 'diffuse' pollution.[7] [29] [30] [31]
2. Diffuse nitrogen pollution occurs particularly through urine patches. Diffuse pollution cannot be addressed by setbacks or riparian planting alone.
3. Between 1990 and 2012, the estimated amount of nitrogen that leached into soil from agriculture increased 29% and according to MfE:

    ”*this increase was mainly due to increases in dairy cattle numbers (and therefore urine which contains nitrogen) and synthetic nitrogen fertiliser use*.”[8]
4. 80% of leached nitrate is from livestock and 65% of that is from dairy cows (see Fig 5).[32]
5. The primary direct sources of leached nitrate in order of magnitude are dairy urine 129,000 tonnes, beef urine (37,000 tonnes) synthetic nitrogen fertiliser (31,000 tonnes), and sheep urine (30,000 tonnes).[33]
6. There are no direct controls on livestock density and only one control on synthetic fertiliser in the NES-FW which is set at an extremely high level, allowing 190 kg/ha/yr.
7. Instead of input controls, most of New Zealand's regulatory regime for nitrate has relied on effects-based management. However, diffuse nutrient loss from farms is difficult to measure and there is a long lag between land use and effects. The main software used to measure nutrient loss on farms and used in monitoring and enforcement is Overseer. The 2021 independent review of Overseer found that it was not fit for purpose.[34]

INCREASED SYNTHETIC NITROGEN USE

1. Since 1990 there has been a nearly seven fold (693%) increase in the use of synthetic nitrogen fertiliser (see Fig 2) [35]
2. New Zealand had the highest percentage increase in use of synthetic nitrogen fertiliser of all OECD countries between 1990 - 2008.[12]
3. From 2002 - 2015 alone nitrogen applied to land via urea fertiliser more than doubled in Southland, Canterbury, Otago, and the West Coast.[36]
4. Up to 452,000 tonnes of synthetic nitrogen fertiliser is now used annually.[37]
5. 67% of synthetic nitrogen fertiliser used is by the dairy industry (see Fig 3).[37]
6. Synthetic nitrogen fertiliser is not only a direct contaminant into waterways, its use has enabled the intensification of dairy farming and led to higher stocking rates. This in turn has led to increased diffuse nitrogen leaching from urine patches.[30]

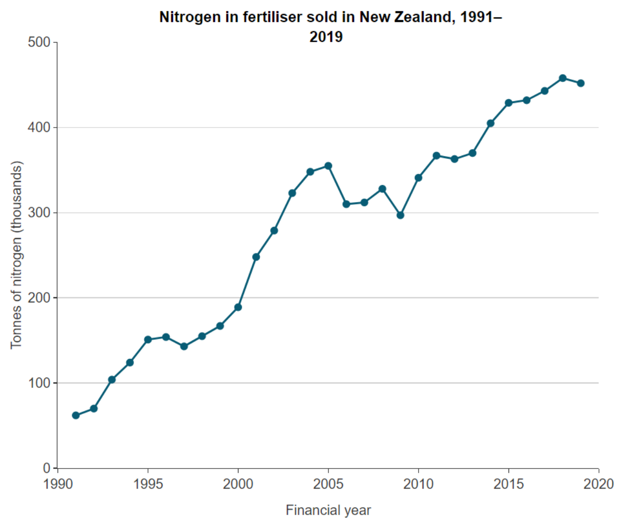

Fig 2: Nitrogen fertiliser sold in NZ 1991-2019.[37]

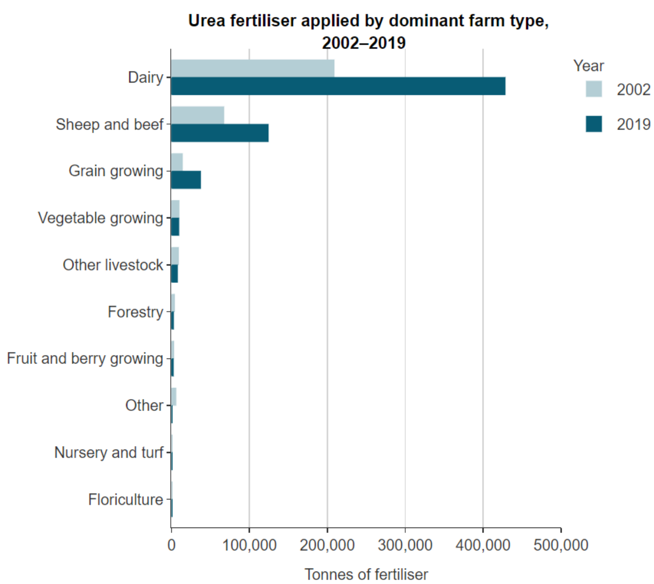

Fig 3: Urea fertiliser applied by farm type 2002-2019.[37]

SIGNIFICANT DAIRY COW INCREASE

1. New Zealand has recently experienced one of the world's highest rates of agricultural intensification.[38]
2. Dairy cattle numbers nearly doubled nationally (82% increase) between 1990 and 2019, increasing from 3.4 million cows to 6.3 million (see Fig 4).
3. In the same period, the Canterbury dairy herd increased tenfold (973%) from 113,000 cows to 1.2 million cows and the Southland dairy herd increased sixteen-fold (1584%) from 38,000 cows to 636,000 cows.[39]

4. There are currently no direct controls on livestock density. Despite decades of effects-based management and changes to the freshwater regulations, stocking rates on dairy farms remain high and there has been no significant decrease in the herd.[40]
5. New Zealand also lacks a prohibition on converting further land to dairying, despite the PCE stating that:

> *"Even with best practice mitigation, the large-scale conversion of more land to dairy farming will generally result in more degraded freshwater"* [30]

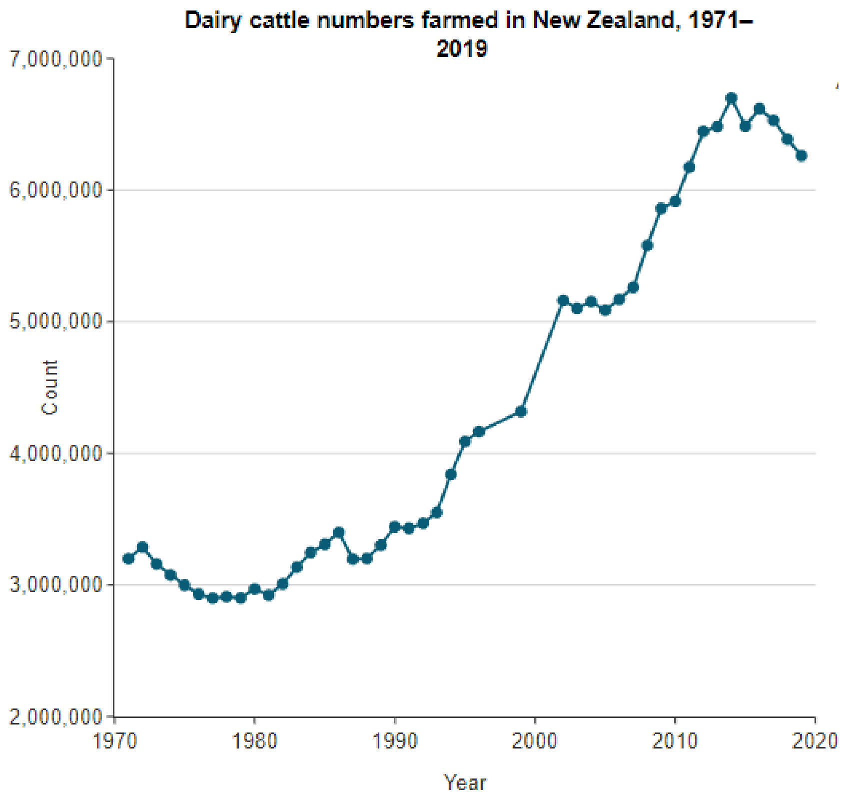

Fig 4: Dairy cattle in New Zealand between 1971-2019 [39]

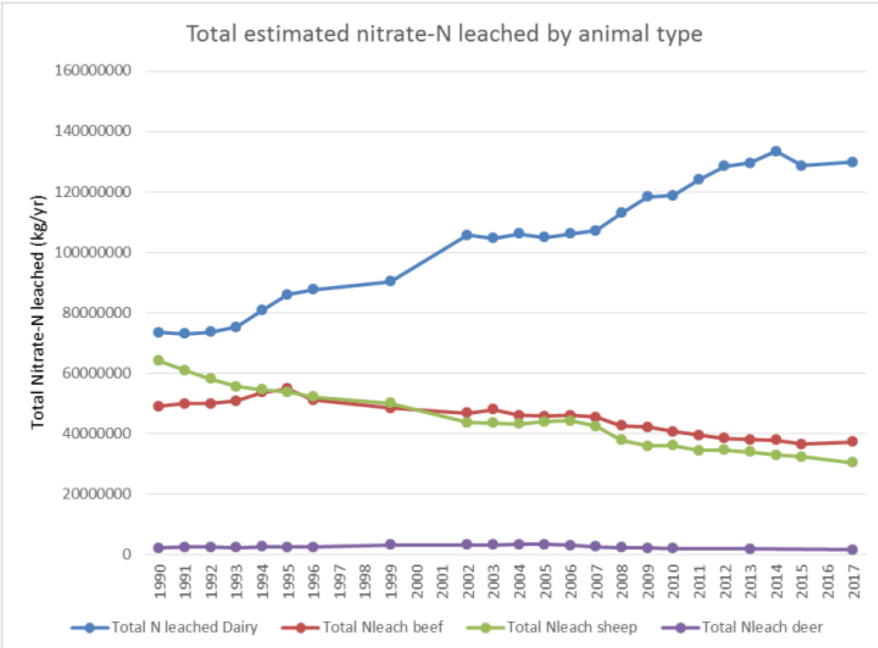

Fig 5: Nitrate leached by animal type from 1990 to 2017[41]

HEALTHY WATER IS A TIRITI TAONGA

The Government must give effect to Te Tiriti o Waitangi, and recognise Te Mana o te Wai. This means:

1. Recognising the centrality of water to Māori culture and wellbeing, and meaningfully addressing the primary causes of its contamination.
2. Placing the health of the water before all else and acknowledging the fundamental importance of water to the health and wellbeing of people and the environment".[42]
3. Giving effect to the requirements in ss8 and 45 of the Resource Management Act 1991 that decision-makers take into account the principles of Te Tiriti o Waitangi.
    a. The principle of active protection obliges the Crown to proactively identify and take steps to protect Māori interests, including spiritual and cultural interests.
    b. Protection of these interests requires a holistic approach to considering what contamination is, as well as what the response to contamination should be.
4. Recognising the importance of water not only for humans (as a means of sustenance of both body and spirit) but as something with its own mauri.
5. Recognising that rivers are a "taonga essential to the identity, culture and spiritual well-being of the people".[43]
6. Recognising that Māori interests in water bodies were guaranteed under Article 2 of Te Tiriti o Waitangi.[44]
7. Recognising that as at 1840, water bodies were a taonga over which hapū or iwi exercised tino rangatiratanga and customary rights, and with which they had a relationship under tikanga Māori, including kaitiaki obligations to care for and protect the water resource. [44]

FARM PROFITABILITY WITH FEWER COWS AND CUT FERTILISER

Studies show that eliminating synthetic fertiliser is good for farmers and the environment:

1. A ten year in-field study by DairyNZ compared a farm with no synthetic nitrogen application and a farm using 181/kg/ha/yr of urea. It found that in a system using no synthetic nitrogen at all:
   a. "Profitable milk production systems can be achieved without N fertiliser applications"
   b. At a lower milk price ($4.60 kg/MS) the farm using no synthetic nitrogen fertiliser was more profitable than the one using 181 kgs.[45]
2. A recent economic model done by the NZ Landcare Trust compared farms with varying stocking rates, fertiliser use and imported feed. It found that:
   a. The farm with the lowest synthetic fertiliser use and the second smallest herd had the largest increase in profitability (29%) and a 13% reduction in nitrate leaching and an 18% reduction in GHG emissions.[46]
3. A decade-long study in the USA found that a farm can reduce 100 kg/ha of nitrogen fertiliser by simply increasing the varieties of pasture crops used in the field from 1 to 16 species, and still produce the same yield as the farm using the 100 kgs/N/ha.[47]

ENDNOTES

1. National Institute of Water and Atmospheric Research (2018) 'Time for a closer look at nitrates?' Accessed via link
2. Ministry for the Environment (2022) 'NES-DW Consultation Document' pp10. (link)
3. Land Air Water Aotearoa (2022)'Scientists r elease updated summary of NZ groundwater quality' Accessed via link
4. Joy, M. K., Rankin, D. A., Wöhler, L., Boyce, P., Canning, A., Foote, K. J., & McNie, P. M. (2022). The grey water footprint of milk due to nitrate leaching from dairy farms in Canterbury, New Zealand. Australasian Journal of Environmental Management, 1-23. link
5. Hanson, C, Groundwater Science Manager, ECan (2022) 'Long Term Trends - groundwater and surface water Natural Environment Committee report' Presented at ECan Natural Environment Committee 6 April 2022 . pp109 (link)
6. Ministry for the Environment (2018) - 'Technical Guidelines for Drinking Water Source Protection Zones,' Appendix C - Contamination Types and Attenuation, pg.C-2, PDF pg.86, link
7. Ministry for the Environment & Stats NZ (2017) 'New Zealand's Environmental reporting series: Freshwater and nitrogen leaching.' (link)
8. Ministry for the Environment & Statistics New Zealand (2015). New Zealand's Environmental Reporting Series: Environment Aotearoa 2015. Page 54. (Link)
9. International Agency for Research on Cancer (IARC) monographs on the evaluation of carcinogenic risks to humans. Volume 94. Ingested nitrate and nitrite, and cyanobacterial peptide toxins. Lyon: International Agency for Research on Cancer, link
10. Richards, J, Chambers T, Hales S, Joy M, Radu T, Woodward A, Humphrey A, Randal E, Baker, M., (2022) 'Nitrate contamination in drinking water and colorectal cancer: Exposure assessment and estimated health burden in New Zealand,' link
11. Sherris, A. R., Baiocchi, M., Fendorf, S., Luby, S. P., Yang, W., & Shaw, G. M. (2021). Nitrate in drinking water during pregnancy and spontaneous preterm birth: A retrospective within-mother analysis in California. Environmental health perspectives, 129(5), 057001. (link)
12. Organisation for Economic Co-operation and Development (2017). OECD Environmental Performance Reviews: New Zealand 2017. OECD Publishing, Paris.
13. Ministry of Health (2022)' Potential effects of high nitrate levels in drinking-water' Accessed via link
14. Knobeloch, L., Salna, B., Hogan, A., Postle, J., & Anderson, H. (2000). Blue babies and nitrate-contaminated well water. Environmental health perspectives, 108(7), 675-678.. link
15. NZ College of Midwives (2021) Member Advisory, 'Nitrate levels in drinking water: risks for pregnant women and formula-fed babies'(link)
16. Radio New Zealand (2019) "Health expert renews call for study on nitrates in drinking water" Accessed via link
17. Corvalan, C., Hales, S., McMichael, A. J., Butler, C., & McMichael, A. (2005). Ecosystems and human well-being: health synthesis. World Health Organization. p.652- 660

18. Chambers, T., Wilson, N, Hales, S., Baker, M., (2021) ‘ Nitrate contamination in drinking water and adverse birth outcomes: emerging evidence is concerning for NZ’ Posted on May 24, 2021. Accessed via link
19. Brender, J. D., Weyer, P. J., Romitti, P. A., Mohanty, B. P., Shinde, M. U., Vuong, A. M (2013). Prenatal nitrate intake from drinking water and selected birth defects in offspring of participants in the national birth defects prevention study. Environmental health perspectives, 121(9) link
20. Canterbury District Health Board (2014). Public Health Implications of Land Use Change and Agricultural Intensification with respect to the Canterbury Plains: A Literature Review.
21. Ward, M. H., DeKok, T. M., Levallois, P., Brender, J., Gulis, G., Nolan, B. T., & VanDerslice, J. (2005). Workgroup report: drinking-water nitrate and health—recent findings and research needs. Environmental health perspectives, 113(11), 1607-1614.
22. Burkholder J, Libra B, Weyer P, Heathcote S, Kolpin D, Thome P and Wichman M (2007). Impacts of waste from concentrated animal feeding operations on water quality Environmental health perspectives, p.308-312.
23. Ward, M. H., Jones, R. R., Brender, J. D., De Kok, T. M., Weyer, P. J., Nolan, B. T., ... & Van Breda, S. G. (2018). Drinking water nitrate and human health: an updated review. International journal of environmental research and public health, 15(7)
24. New Zealand College of Public Health Medicine and the Public Health Association (2019) “Submission to the Ministry for the Environment: Action for Healthy Waterways”
25. Schullehner, J., Hansen, B., Thygesen, M., Pedersen, C. B., & Sigsgaard, T. (2018). Nitrate in drinking water and colorectal cancer risk: A nationwide population‐based cohort study. International journal of cancer, 143(1), 73-79.
26. Espejo‐Herrera, N., Gràcia‐Lavedan, E., Boldo, E., Aragonés, N., Pérez‐Gómez, B., Pollán, M., ... & Villanueva, C. M. (2016). Colorectal cancer risk and nitrate exposure through drinking water and diet. International journal of cancer, 139(2), 334-346.
27. Ferlay, J., Colombet, M., Soerjomataram, I., Mathers, C., Parkin, D M., Piñeros, M., Znaor, A., Bray F., (2018), Estimating the global cancer incidence and mortality in 2018: GLOBOCAN sources and methods, Int J Cancer, 2019 Apr 15;144(8):1941-1953.
28. Ministry for the Environment and Statisstics New Zealand (2019) “New Zealand’s Environmental Reporting Series: Environment Aotearoa 2019.” Wellington: Ministry for the Environment pp47
29. Vogeler, I., Shepherd & Lucci (2014) ‘Effects of fertiliser nitrogen management on nitrate leaching risk from grazed dairy pasture’, Proceedings of the New Zealand Grassland Association 76: 211-216
30. Parliamentary Commissioner for the Environment (PCE) 2013: Water quality in New Zealand: Land use and nutrient pollution. Page 16 (Link)
31. Carran, R. A., & Clough, T. (1995). Environmental impacts of nitrogen in pastoral agriculture. NZGA: Research and Practice Series, 6, 99-102.
32. Clarke, S, MfE (2021) ‘The Ministry for the Environment response to the Environment Select Committee’s request for evidence regarding the petition from Greenpeace NZ and 30,000 others, for a phase out of synthetic nitrogen fertiliser by 2024’ - sent in letter to Eugenie Sage, 20 September 2021 Accessed Feb 2022: Link
33. Calculated based on 2017 livestock population and fertiliser figures from StatsNZ data (link) and MfE (link) which “assumes 7 percent of the nitrogen applied nationally is lost as leachate. This is based on the New Zealand-specific value adopted for greenhouse gas reporting (Ministry for the Environment, 2014; Thomas et al, 2005),” quoted by figure.nz (link).
34. Parliamentary Commissioner for the Environment, 2018 Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways. Page 15 (Link)
35. Ministry for the Environment (2022) New Zealand’s Greenhouse Gas Inventory 1990–2020, pp. xxxiii, (link)
36. Statistics NZ, (2019) ‘Nitrogen and Phosphorous in Fertilisers’ accessed via link
37. Statistics NZ (2021) ‘Nitrogen and Phosphorous in Fertilisers’ accessed via link
38. Ministry for the Environment & Stats NZ (2017). ‘New Zealand’s Environmental Reporting Series: Our fresh water 2017.’ Retrieved from www.mfe.govt.nz and www.stats.govt.nz.
39. Statistics NZ (2021) ‘Livestock numbers’ accessed via link
40. DairyNZ (2021) NZ Dairy Statistics accessed via link
41. Landcare Research (2018) ‘Spatial nitrate leaching extent: an update for environmental reporting’ pp 5 Link
42. Ministry for the Environment (2021) ‘Te Mana o te Wai implementation guidance’ Accessed via link
43. Waitangi Tribunal (1999) ‘Whanganui River Report WAI 167’ at pp. 25
44. Waitangi Tribunal (2012) “The Stage 1 Report on the National Freshwater and Geothermal Resources Claim WAI 2358’ pp. 77.
45. Glassey, C.B., Roach, C.G., Lee, J.M. and Clark, D.A., (2013). The impact of farming without nitrogen fertiliser for ten years on pasture yield and composition, milksolids production and profitability; a research farmlet comparison. In Proceedings of the New Zealand Grasslands Association. Vol. 75. Page 71 (Link)
46. A.J. Litherland (NZ Landcare Trust), B. Riddler (E2M modelling), M. Langford (Fonterra), M Shadwick (DairyNZ) (2019). ‘CASE STUDY Finding a win-win for the farmer and the environment.’ Page 2 (Link)
47. Tilman, D., Reich, P.B. and Isbell, F., (2012). Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory. Proceedings of the National Academy of Sciences, 109(26), pp.10394-10397. Page 1 (Link)