BEFORE THE INDEPENDENT HEARING PANEL

ATSELWYN DISTRICT COUNCIL

Under	the Resource Management Act 1991
In the matter of	an application by KeaX Limited to construct and operate a 111ha solar array at 115 & 187 Buckleys Road, Leeston (RC235464).

BRIEF OF EVIDENCE OF RAYMOND JOHN HENDERSON

23 January 2024

QUALIFICATIONS AND EXPERIENCE

1 My name is Raymond John Henderson.

2 My relevant experience and qualifications are:

2.1 29 years working in ecology and ecotoxicology at Landcare Research;

2.2 15 years as director of Pest-Tech Ltd doing contract research and environmental risk assessment for the Animal Health Board and Department of Conservation; and

2.3 Decades of measuring the toxicity of hazardous substances, risk analysis for vertebrate poisons accidentally ingested by non-target species and the effects of the release of toxic substances into natural ecosystems.

EXPERT WITNESS PRACTICE NOTE

3 While this is a Council hearing, I confirm that I have prepared this evidence in accordance with the Code of Conduct for Expert Witnesses Code of Conduct for Expert Witnesses contained in Part 7 of the Environment Court Practice Note 2023. The issues addressed in this statement of evidence are within my area of expertise except where I state that I am relying on the evidence or advice of another person. The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence. I have not omitted to consider material facts known to me that might alter or detract from the opinions I have expressed.

SUMMARY STATEMENT

4 In preparing my evidence, I have read and reviewed the following information:

4.1 All documentation provided by the applicant;

4.2 The contents of the section 42a report and the supporting reports;

4.3 The expert reports and evidence submitted by the applicant for the previous applications , and for this application.

4.4 Various publications in science journals on risks and hazards associated with solar farms.

5 I address the issues of contaminants from solar panels, their impacts on the NPS-HPL and ‘highly productive land’. Heavy loams accumulate heavy metals and polyfluoroalkyl substances (PFAS) while contaminants readily permeate down through sandy soils out of the root zone of plants. Accumulated heavy metals impact colonies of soil microorganisms and soil invertebrates. The heavy metals changed pasture composition growing on contaminated soils. The literature indicates soils exposed to leached iron (Fe) and aluminium (Al) become more compacted with the development of clods and poor water dispersion.

6 Heavy metals and PFAS are widely reported to impact aquatic ecosystems covered by the NPS-FM. In this study the fine particles leached off solar panels will readily be washed into drains and creeks that surround the site. In a comparison with 1080 (sodium monofluoroacetate) at normal sowing rates, the leachates from solar panels are considerably more hazardous in water. Ironically those that do pest control are not able to apply 1080 within 100-m of a stream, yet solar panels with a potpourri of more hazardous materials can currently be placed on the banks of waterways. Materials in drains around the solar farm will flow down to Te Waihora and accumulate in the natural kai of Ngai Tahu.

7 Terrestrial vertebrates have the potential to be impacted through chronic and sub-chronic poisoning by heavy metals. The class of birds most affected will be passerines and aquatic

birds (especially waders). Heavy metals are taken up by grass, berry bushes, fruits, vegetables and especially root crops. These act as a medium for transfer to domestic and wild animals. Some plants that grow around the perimeter of the planned solar farm can accumulate very high heavy metal and PFAS concentrations (e.g., blackberry, briar).

8 Fire presents a serious risk for instant contamination at the proposed site, as all polymer adhesives and PFAS used to encapsulate heavy metals are instantly removed. A few inches of rain then move tonnes of hazardous materials into soil.

9 Increased electromagnetic fields (EMF) from an enlarged substation at Heights corner will not only reduce milk production of nearby cows but will impact animal health. Bees respond to EMFs as low as 0.26μT of electromagnetic flux; a force field that will extend well beyond the substation.

PURPOSE AND SCOPE OF EVIDENCE

10 The evidence presented is largely drawn from literature published in peer-reviewed science journals. The research undertaken on existing panels at Brookside is modelled on what has previously been undertaken during recent risk assessments at solar farms. Unsurprisingly, the results from the existing agrivoltaics on the property of Michael Dalley are consistent with previous international research on polycrystalline panels.

11 The results of local research to date are a little higher for iron and aluminium, but considerably lower for some of the toxic hazards (cadmium, arsenic, chromium, copper, zinc, Pb) during accelerated leaching. These differences are a result of leachates coming off panels in layers during 'normal' weathering: the outside glass layer comes off 1st, ARC layer 2nd, semi-conductor layer 3rd, absorber layer 4th, etc. At this stage weathering has taken off some silica glass containing boron. Some of the ARC layer, and some of the semi-conductor layer, plus a few materials from the 'absorber' layer (where Pb, cadmium, arsenic, etc reside). That will carry on until leachates from inside the 3rd and 4th layers of panels become higher in soils (Pb, Cd, Cr, As, Cu, Zn) and increase in the sample of leachates. We wanted to show that loams accumulate heavy metals as the literature indicated. Is our research unique? No, it was done to demonstrate that contaminants from panels exist, that the hazards associated with contaminants are serious, and that concentrations of contaminants will increase. Even at this moment in time the hazards to soils, soil organisms, and aquatic organisms present serious risks. Where will heavy metals and PFAS be in 20 years' time? They will never be less than they are now because 'forever chemicals' do not degrade, and rates of movement through Brookside loams are slow. If we accept previous published research, then lead (Pb) for example will increase.

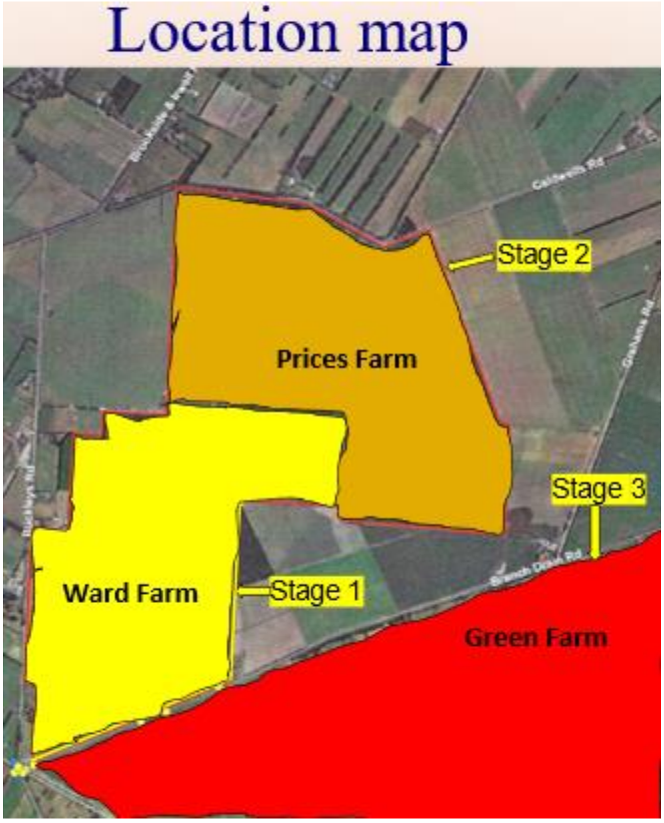
12 [redacted] These are real possibilities over the lifetime of the solar farm. There are no contingency measures to cope with these scenarios. Fine particles of lead and aluminium are already at levels on the soil surface that will impact aquatic organisms (including the endangered Mudfish). There are further risks to the NPS-HPL because of soil compaction (ADAS 2023), and risks to the NPS-FM are already too high. The only tangible solutions to insurmountable risks are to locate the solar farm elsewhere.

EVIDENCE

13 The Ward farm where solar panels are to be located (RC235464) is comprised of LUC2 and LUC3 soils (i.e., it is "highly productive land"). It is flat irrigated land that is periodically cultivated to establish greenfeed and undertake pasture renewal. Most other farms in the Brookside district have a similar classification.

14 [redacted]

[redacted] In my opinion the heavy loams at Brookside cannot accommodate 111ha of solar panels, let alone any further development.



15 The worst thing that could happen to this "highly productive land' would be for it become devalued by contaminants, the soils to be transformed by soil compaction, and for there to be changes to the communities of invertebrates and microorganisms living in soil. In this report we review:

15.1 the effect of soil type on movement of leachates out of the root zone of plants;

15.2 provide an overview of leachates from different types of solar panel;

15.3 summarize agrivoltaics on the property of Michael Dalley;

15.4 review the 'hazards' in materials contained in solar technologies;

15.5 then describe routes of 'exposure' to heavy metals and PFAS;

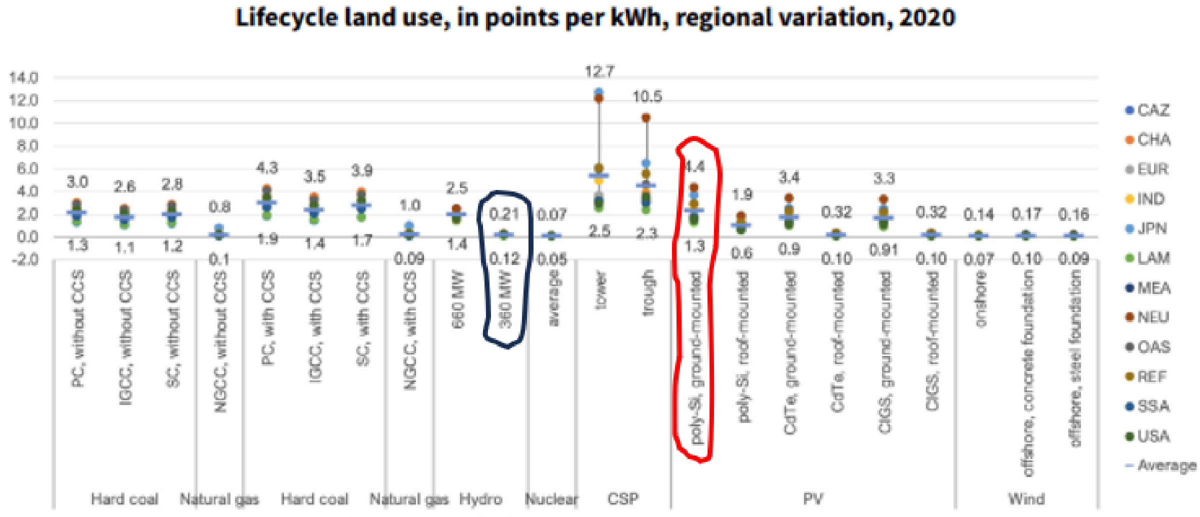
15.6 summarize the risks to aquatic organisms and birds;

15.7 look at risks of electromagnetic fields from a substation at Heights corner; and,

15.8 provide an overview of risk assessment.

16 The literature indicates that large areas of land are required to generate electricity. In his estimates Aman *et al.* (2015) estimated the area of land required for solar energy for 1Mw of power was over twice that required to generate 1Mw of hydroelectricity. The United Nations Energy Commission assigned a points system for utilization of land and estimated in the life

cycle of panels that photovoltaic power consumed 2-7x the land potential of hydroelectricity per kilowatt of power produced; with much of the variance in that range arising from the size of the hydro-electric plant.



17 We will see in the sections that follow much of this “good” land is progressively degraded by placement of a USSP (utility-scale solar photovoltaic) facility on it. In Wales a review of ‘Best and Most Valuable’ agricultural land shows soil compaction is a major issue under panels situated on heavy loams. In many cases this compaction was deemed irreversible when a USSP facility is established.

18 Published research has demonstrated the persistence of contaminants in topsoil is dependent on the type of soil (Schiedung *et al.* 2020), the presence of Fe and Al in soil (Ozcoban *et al.* 2022). Soils are degraded under panels by soil compaction (ADAS 2023, Choi *et al.* 2020), soil pH (Xu *et al*. 2022, Wen *et al.* 2022), levels of active potassium (AK) in soil (Xu *et al*. 2022), soil cultivation (Wen et al. 2022), and the extent to which heavy metals are blown or washed across soils onto a new site (Xu *et al.* 2022). Thus, the measured concentrations of heavy metal in soil are multi-factorial. In the next 4 paragraphs we will examine the <u>important attributes</u> of Brookside soils that make them vulnerable to accumulating contaminants.

19 The rate of movement of materials through topsoil and subsoil is dependent on whether it is a sandy soil or a loam (Schiedung *et al.* 2020). The graph below depicts movements of pyro-carbons (from a fire) through a porous sandy soil and a loam. It is self-evident that carbon in loams is inclined to stay in the root zone of plants.

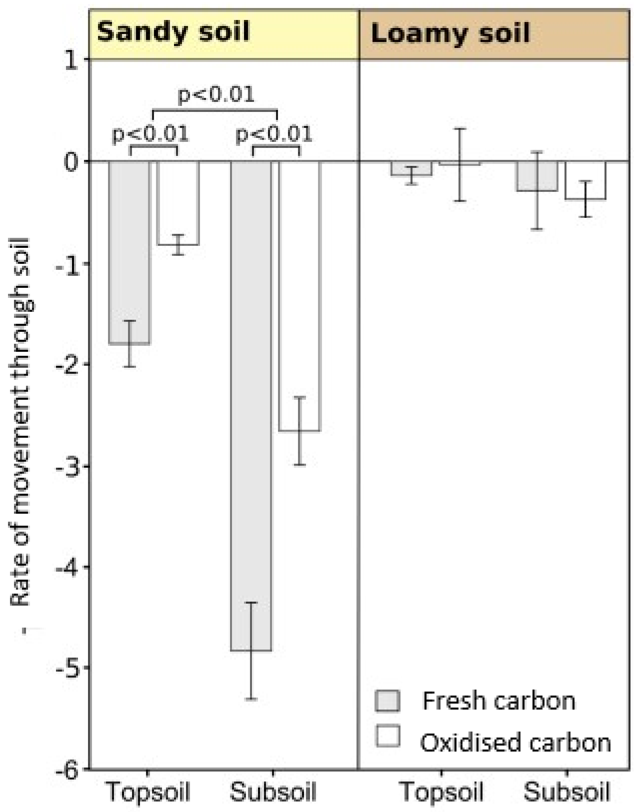


Figure 2. **Movement of pyro-carbon leachates through sands & loams (Schiedung *et al.* 2020)**

20 The rate of movement of leachates through a clay-loam is further slowed by adding Fe and Al to soil. These heavy metals not only facilitate soil compaction (Mazurena *et al.* 2017) and the development of clods but bind leachates to soil particles. In a white clay loam the soil progressively becomes less permeable as iron and aluminium oxide are added. Aluminium is an additive to all loams at solar farms irrespective of the type of solar panel.

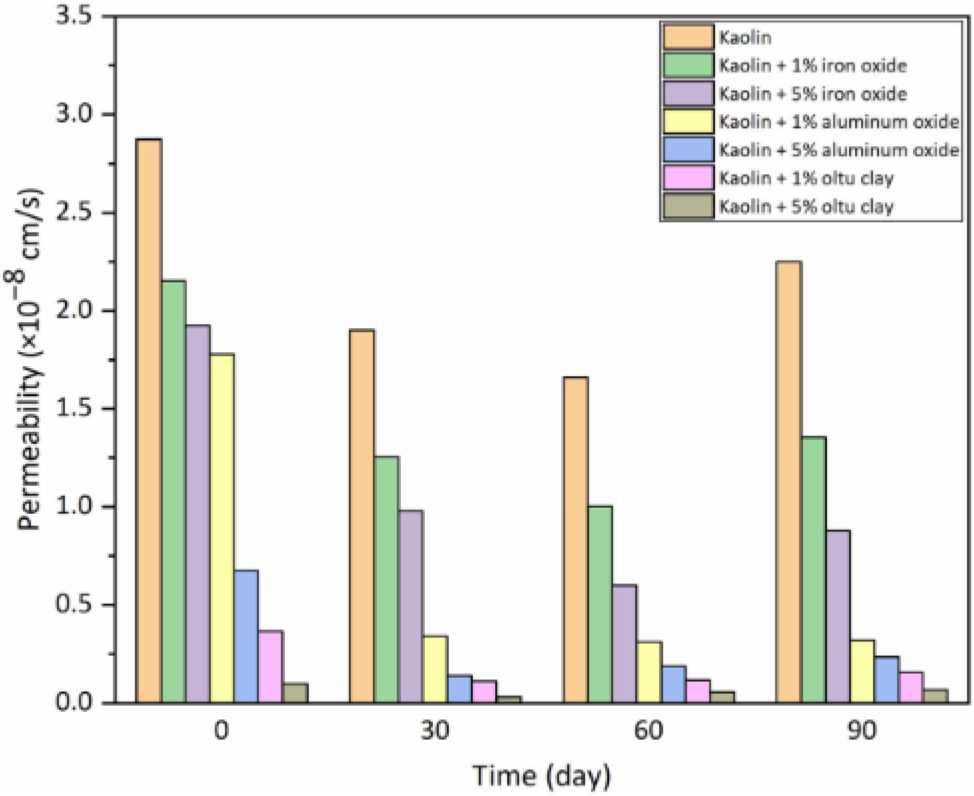


Figure 3. Movement of leachates through soils is further slowed by added Fe + Al (*from* Özçoban *et al*. 2022)

21 In this study between panels 826 mg of Fe was added per kg of soil over a 10-year period and 800mg of aluminium over the same timeframe. These concentrations will exacerbate soil compaction and the development of both a soil crust and iron pan on subsoil. They also slow the movement of contaminants down deep into the subsoil.

22 The leaching of aluminium and iron from solar panels causes soil compaction in loamy soils (Choi *et al.* 2020), and the development of clods. The Al and Fe in these clods bind phosphates and potassium through occlusion, adsorption and absorption thus reducing their bioavailability to plants (Fig 4 below). Over 2-3 decades added Fe and Al progressively creates an iron pan on a clay substrate (Cunningham *et al*. 2001). With a soil crust at the surface of land and an iron pan 8 inches deep in Brookside soils, inevitably the rate of run-off of floodwaters will increase. This process will inevitably shift many heavy metals and PFAS onto neighbouring properties, as is seen in the photos below, and into streams adjoining the property.

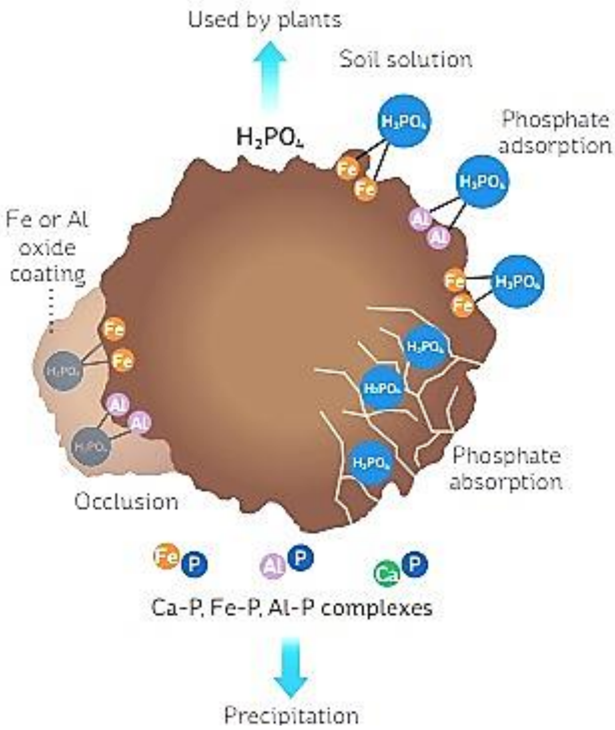


Figure 4. **Clod development with occlusion, absorption, and adsorption of nutrients potassium and phosphorous/phospahate.**

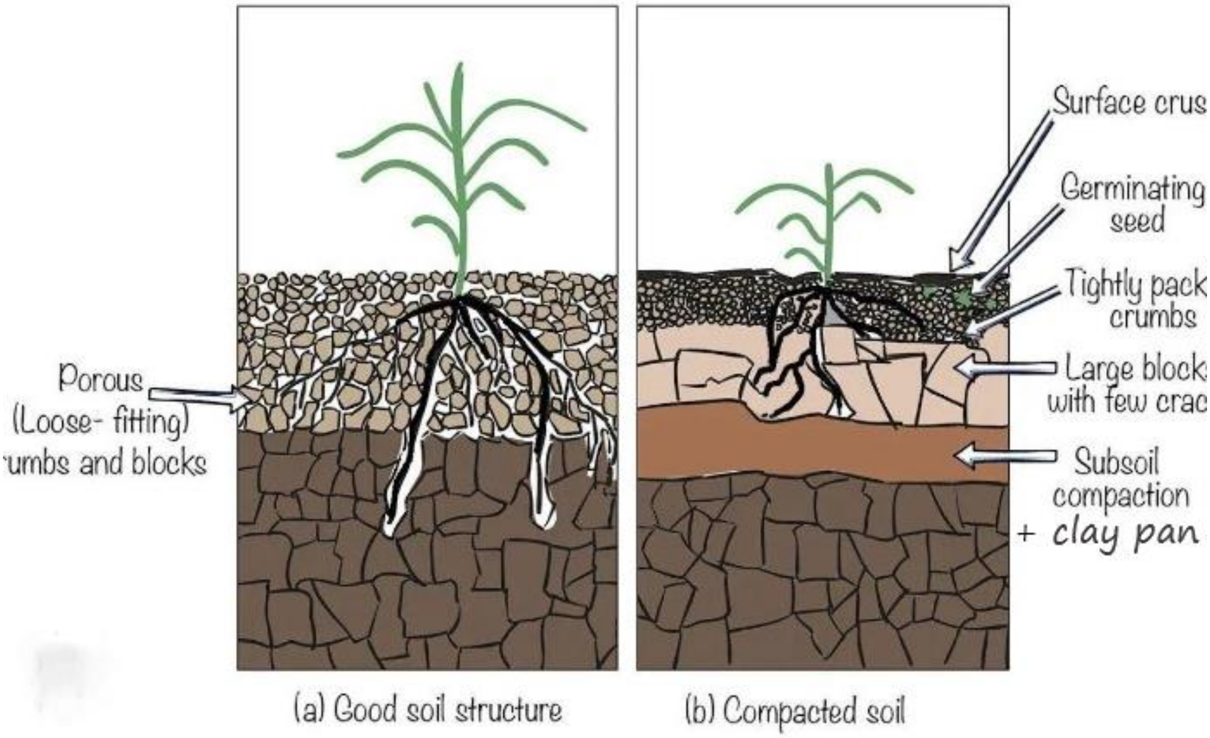


Figure 5. **Soil compaction and the development of a soil crust**

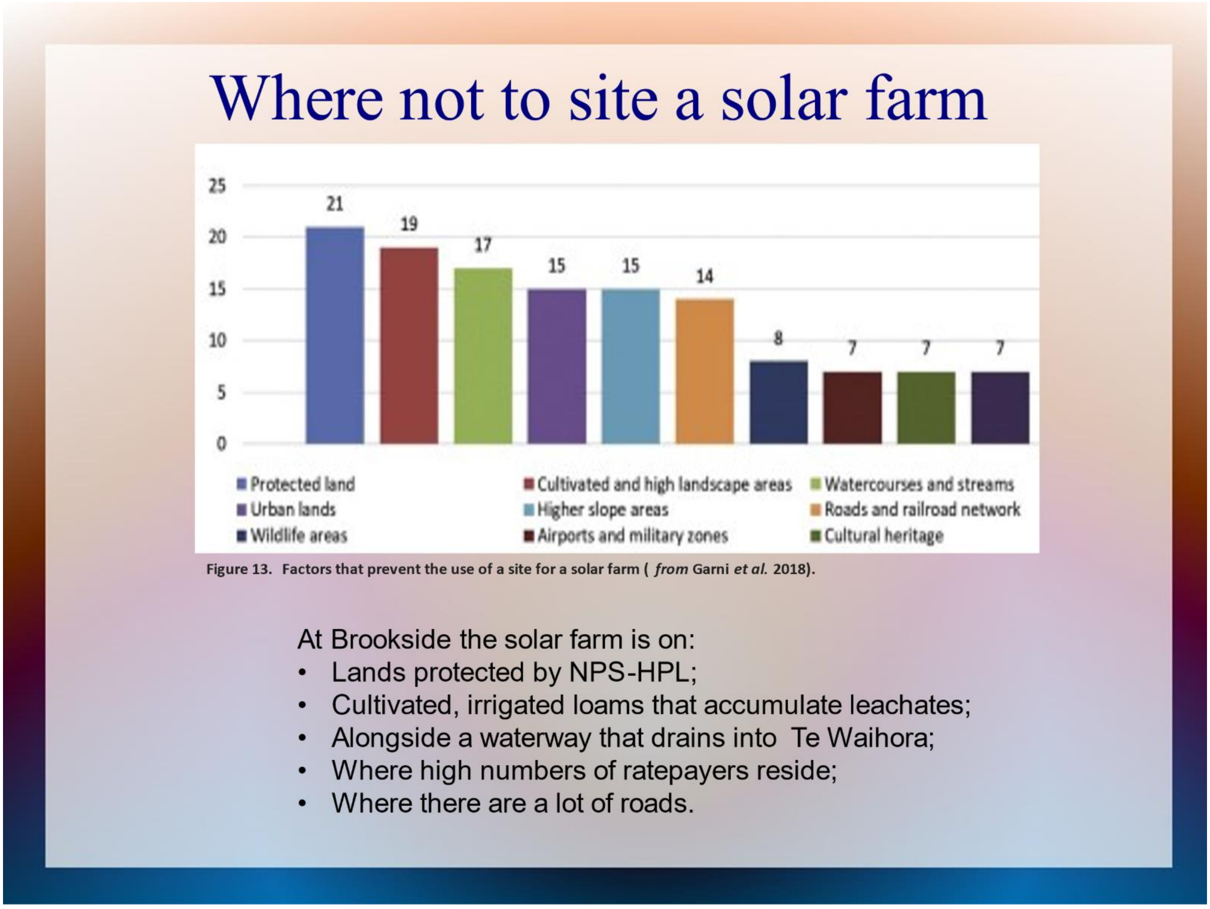
Figure 6. Run-off of surface waters at Brookside.

23 At Brookside the silt loams under the Dalley solar panels take heavy metals into soils in fine weather (photo 7). However, these soils do not drain very well in heavy rains. In a flood contaminants like fine particles of aluminium and lead will be translocated in those floodwaters to other properties and into stream water (photo 8).

24 Widespread use of solar panels will inevitably increase the run-off of contaminants in floodwaters. Currently floodwaters from the Ward property flow onto the Dalley farm during heavy rain (see photo below). At the minute those floodwaters contain only soil particles. However, the problems with risk grow exponentially once a solar farm is established. Those floodwaters will then contain large volumes of heavy metals and PFAS substances once the Brookside solar farm is established. The flood channels on the Dalley property will be coated in heavy metal and PFAS contaminants that research shows are found in the milk of cows. Even worse is the fact that leachates on the soil surface flow into creeks and down to Te Waihora. Those heavy metals are very toxic to aquatic organisms.

Figure 9. Run-off of waters from the proposed site of the solar farm onto the Dalley property.

25 The implications of soil contamination outlined above are encapsulated within a review of places to site Utility Scale Solar Power (USSP) facilities by Garni *et al*. in 2016. In that meta-analysis of over 40 publications on site selection for a solar farm, the things that most constrained the use of a site for USSP development were: a) the use of protected land, b) use of cultivated lands used for agriculture, c) the presence of watercourses and streams that could be contaminated with leachates, and d) lands populated with high numbers of residents.



26 Brookside is in effect the worst possible place to site a solar farm.

27 In summary, heavy loams are the soils most inclined to accumulate leachates in topsoil near the root zone of plants. Heavy loams become compacted by adding iron and aluminium and these contaminants slow the movement of contaminants through soil, and compacted heavy loams are prone to flooding and the run-off of contaminated water. Heavy loams will disperse contaminants suspended in floodwaters into streams, rivers, and lakes.

<u>Solar panels</u>

28 Within the marketplace there exists a plethora of solar panels with subtle differences according to manufacturer and model. Most are currently silicon-based photovoltaics that fall into 5 broad categories:

28.1 CIGS (copper, indium, gallium selenide).

28.2 CdTe or thin-film (cadmium telluride).

28.3 Mono-crystalline silicon panels.

28.4 Polycrystalline silicon panels.

28.5 Perovskite Solar Cells (PSC).

29 Each has its own unique hazards that are well documented in the literature [redacted] The reviewer for the section 42a report (Isobel Stout) also did not know the type of panel or types of leachates likely at the solar farm. Like the reviewer we presume it will be a polycrystalline panel because that is what the applicant refers to in discussions on

microclimates, and it is the type most used in the existing market. The new generation of perovskite panels are still slowly evolving but are still at the stage where they are renown for leaking large volumes of water-soluble lead.

30 Typically, leachates are measured in the laboratory using the Toxicity Characteristic Leaching Procedure (TCLP) with either acid or pH-neutral solutions. The acid solutions simulate the acid rains that are experienced in places like China. In the field leachates are measured by taking soil samples with a 15cm probe and analysing a homogenized soil sample within a myriad of “soil tests”. Internationally many papers have been written on the leaching of heavy metals from solar panels.

31 Leachates have been previously recorded from different makes of polycrystalline panels during international studies (a few examples are included in Table 1). Some researchers have focussed on specific materials in panels, others have taken a more holistic overview. The last author in an abbreviated list undertook a meta-analysis of all previous research.

Heavy metal leachates from polycrystalline solar panels.

Si	Cu	Cr	As	Ni	Hg	Ag	PFAS	References
Y	Y	Y				Y	Y	Sharma *et al.* 2021
Y	high	Y	Y	Y	Y		Y	Panthi *et al.* 2020
	high	Y	Y	Y				Sharma *et al.* 2020
						Y		Espinosa *et al.* 2016
Y	Y	Y	Y	Y	Y	Y	Y	Li *et al.* 2024[a]

[a] Meta-analysis of historical research

32 The composition of panels is layered (*see* schematic layout below) with everything held together and/or protected by polymer adhesives and polyfluoroalkyl substances (PFAS). Consequently, during “normal” weathering different leachates are released at different times depending on whether materials are released from the surface (e.g., the glass that contains boron), anti-reflective coatings underneath (Si_3N_4, Ti, NaN, Al, etc), a layer of semi-conductors (e.g., FeS_2) the “absorber’ layer, the substrate, and finally backing tape.

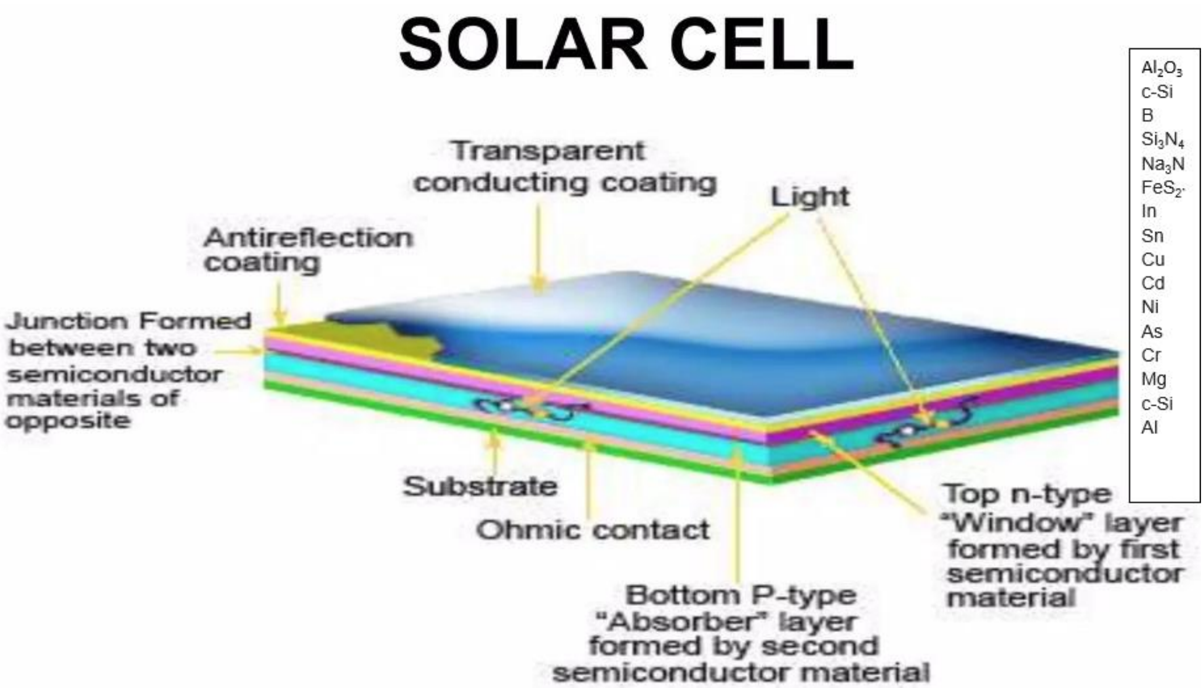


Figure 9. Structure of a solar panel

33 Each type of panel has its own unique hazards that are well-documented in the literature.

34 As a solar panel weathers, naturally the materials come off sequentially from different layers. It is a bit like peeling layers off an onion until near the end-of-life most of those materials that are going to be leached have found their way onto the ground. There is little point in putting up a solar panel and measuring leachates 1-4 years later, because at that stage negligible amounts will exist on soil. The cumulative leachates under panels grow year-on-year in heavy loams, while the materials available to be leached onto soils follow a typical decay curve (Fig. 10).

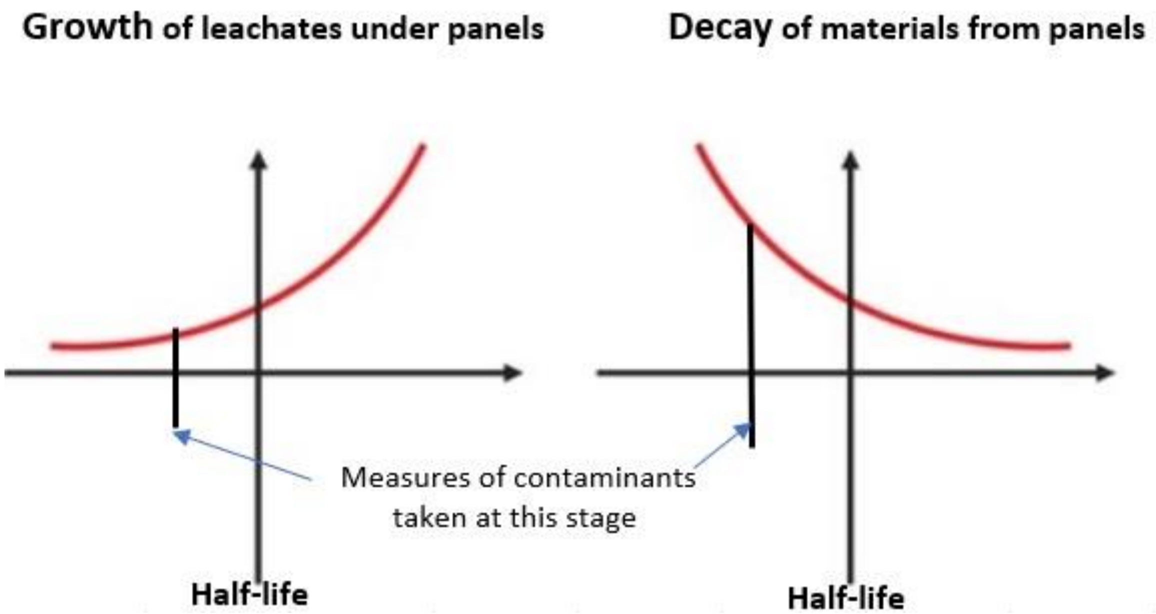


Figure 10. Typical growth curves for leachates in soils, and decay curves for loss of materials during the weathering of panels.

35 It has been demonstrated during international studies that contamination of land happens to different extents for all types of solar panels (Li *et al*. 2024) irrespective of type and protections afforded by glass, different layers of polyfluoroalkyl substances, and different polymer adhesives. This contamination doesn't matter where leachates are diffused deep into permeable soils, because recruitment of heavy metals happens at a similar rate to disappearance of them into subsoils. However, at Brookside the leachates appear to remain in the loams because of high iron and aluminium, an iron pan and a clay substrate. (see photo below). Floods and run-off of contaminants into creeks is common at Brookside.

36 The hazards of contaminants from solar technologies are reflected in the HSNO classifications assigned to them (Table 2).

Table 2.The half-lives, health, and environmental risks of materials used in solar technologies by HSNO classification.

Chemical	Metal half-life Liver (d)	Aquatic toxicity 9.1	Soil toxicity 9.2	Terrest. Vert. 9.3	Oral toxic 6.1	Mutagen 6.6	Carcinogen 6.7	Reproductive toxicity 6.8	Target Organs 6.9
Brodifacoum	114.6	9.1D	n/t		6.1E				6.9B
Aluminium	150 in liver; 7years brain	9.1A	9.2B		6.1E				6.9B
Lead	36 blood 130 liver 2 years brain	9.1A 9.1B	9.2B	9.3A	6.1C	6.6B	6.7B	6.8A	6.9A
Silica		9.1B		9.3C					6.9A
Cadmium	4 -19 yrs	9.1B			6.1C		6.7A	6.8B	6.9A
copper	21 d 435 d brain	9.1A	9.2D	9.3B	6.1B	6.6A			6.9B
Nickel	35 d	9.1B		9.3B	6.1C		6.7A		
Boron	1.5 d	9.1B	9.2D	9.3C	6.1E			6.8B	6.9A
Zinc	245 d	9.1A		9.3C	6.1D				6.9B
Silver	50d	9.1A	9.2B	9.3A	6.1C			6.8B	6.9A
Arsenic	10 hrs	9.1A	9.2B	9.3B	6.1C		6.7A		6.9A
Chromium	9 d	9.1A	9.2B	9.3B	6.1A	6.6A	6.7A	6.8A	6.9A
Selenium	150d	9.1C	9.2C		6.6B	6.6B			6.9B
Lithium	1-2d	9.1D	9.2D		6.1D				
Strontium	50.5 d	9.1C	9.2D		6.1D				
Titanium	12.7 d	9.1B			6.1E		6.7B	6.8B	
PFAS	5.5 – 8.5 yrs	9.1A 9.1B	9.2C	9.3B	6.1C			6.8A	6.9B

37 The important features of this table are:

37.1 All heavy metals are very hazardous in an aquatic ecosystem;

37.2 Most heavy metals are toxic to soil microorganisms;

37.3 Many materials are either a carcinogen, mutagen, or reproductive toxicant;

37.4 All heavy metals have an oral toxicity that is chronic or sub-chronic which results in hazards to target organs where substances bioaccumulate in the body;

37.5 Most metals have a long half-life in the liver which is an indication they persist in tissues where blood is filtered.

38 In the event of a fire at the facility we can add to the list of materials shown above HCN, $AsO_{3,}$ HF, H_3PO_4, AlF_3, PbO_2, PbI_2, SO_2, HCl, POF_3, PF_5, a range of volatile organic compounds

released during combustion of solar panels, as well as assorted PFAS, and carbon monoxide. Anything with a hazard rated below CO in a fire I have excluded. These are all very toxic respiratory poisons and soil contaminants.

The solvents used in the electrolyte in Lithium Ion (LI) cells are normally hydrocarbon based; ethylene carbonate (C3H4O3) and diethyl carbonate (C5H10O3) are commonly used solvents. In a fire, depending on the available oxygen, they will typically evolve into carbon monoxide (CO), carbon dioxide (CO2) and water (H2O). However, there are far more potent constituent parts in an LI cell. The lithium salt commonly used in the electrolyte is lithium hexafluorophosphate (LiPF6), the binder commonly used for the electrodes is polyvinylidene fluoride or PVdF (C2H2F2). Both of these compounds contain fluorine. As the electrolyte breaks down during combustion, phosphorous pentafluoride (PF5) is released, this combines with water released during combustion of the solvents, to evolve phosphoryl fluoride (POF3) and hydrogen fluoride (HF), both of which hydrolyse rapidly with water to form phosphoric acid and hydrofluoric acid respectively (Larsson, Andersson, Blomqvist & Mellander, 2017). Phosphoric acid and hydrofluoric acid in smoke represent extremely hazardous substances when inhaled. Trials indicate 30ppm of these substances in smoke for 3 min is fatal. In some countries USSP storage batteries are not permitted close to a town.

39 A lithium-ion battery fire burns very hot (>1000^{0}C) and so is very hard to extinguish *(see* below where the area of the car containing a battery is unrecognizable). At the solar farm batteries will eventually be used that present a significant risk to the community because of toxic smoke.

40 Highly toxic materials from a storage battery fire include phosphorous pentafluoride (PF5) phosphoryl fluoride (POF3), hydrogen fluoride (HF), phosphoric acid, and hydrofluoric acid

41 It is a requirement for a fire plan to be included in a resource consent application for commercial premises, but despite numerous requests this it has been overlooked by both the applicant and Selwyn District Council. It is surprising the council could approve a resource application for a commercial site containing very hazardous substances without fulfilling this basic requirement. Solar farms have a 4.1.2A classification (viz. they can self-ignite) so a fire plan is mandatory.

42 The ATSDR (Agency for Toxic Substances and Disease Registry) reviews the list of hazardous materials annually and ranks the risks they present in relation to public exposure. Arsenic, lead, mercury, and cadmium make the top 10 on that ATSDR list. All hazardous substances on sit other than silica listed above were in the top 200 during the last assessment. Therefore, it is a given that the release of these materials into the environment

either by leaching or release into the air as smoke during a fire represents a significant risk to soils, water, air, flora, and fauna.

Agrivoltaics

43 The term agrivoltaics has entered the vernacular of the farming fraternity.

Agrivoltaics on the Brookside property of Michael Dalley

44 It was decided by Brookside ratepayers that in the interests of transparency they would undertake the work that should have been done before agrivoltaics become a widespread activity on good loams throughout New Zealand. [redacted]

45 Any completed science requires replication which will be done during the autumn. Furthermore, a treatise on solar farms requires an assessment of not only cause, but effects. Because it is planned to graze sheep under the panels we will evaluate the effects of leachates on the health of livestock through blood analysis, histopathology of tissues, and measures of toxic residues in liver, kidney, brain, and muscle. I will use the skills of Donald Arthur at Rakaia Vet Services who has vast experience in histology to assist with this work; and the services of Hill laboratories (Hamilton) that specialize in measuring tissue contaminants for assessment of toxicology. If necessary, I will contact a former colleague that has worked in toxicology for around 40 years for outside opinion and co-authorship (viz. Dr. Eason).

46 During this pilot study of risks at Brookside, a soil technician from Ravensdown independently took soil samples from under solar panels located on the property of Michael Dalley and sent them away to Analytical Research Laboratories for analysis. These panels had been in place for 9.5 years and because of the heavy soils we expected that leachates may have accumulated. That proved to be the case.

47 The measured increase of contaminants in 'test' compared to 'control' soils after almost 10-years weathering were 826 mg/kg of iron (Fe), 800mg/kg of aluminium (Al), high amounts of manganese (Mn), and a significant increase in boron. This data suggests Fe and Al have been leached at an average rate of around 80mg per kg of soil over a 10-year period. The boron has come out of borosilicate glass on the upper surface of panels, and sodium from Na_3N and Si_3N_4 in the anti-reflective coatings. A smaller amount of Pb, Cu, Zn, As, Cd, and Cr from a lower layer in panels has begun leaching, so, it is expected concentrations of these will grow over the next few years.

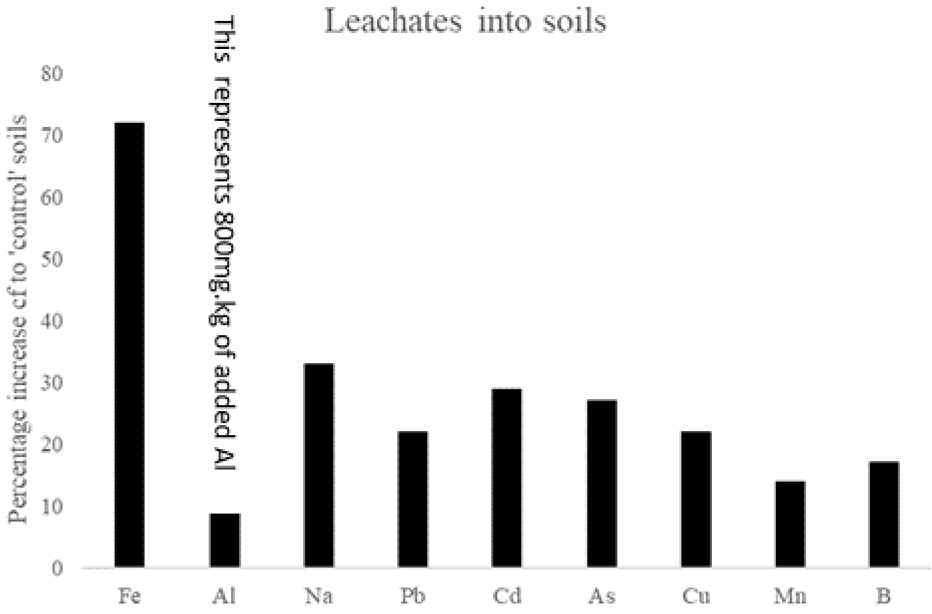


Figure 13. The percentage increase in heavy metals in ‘test’ soils under panels compared to ‘control’ soils not exposed to leachates.

48 The results above were as expected because as outlined above they are the materials leached during previous research. The loam appears to accumulate leachates year after year.

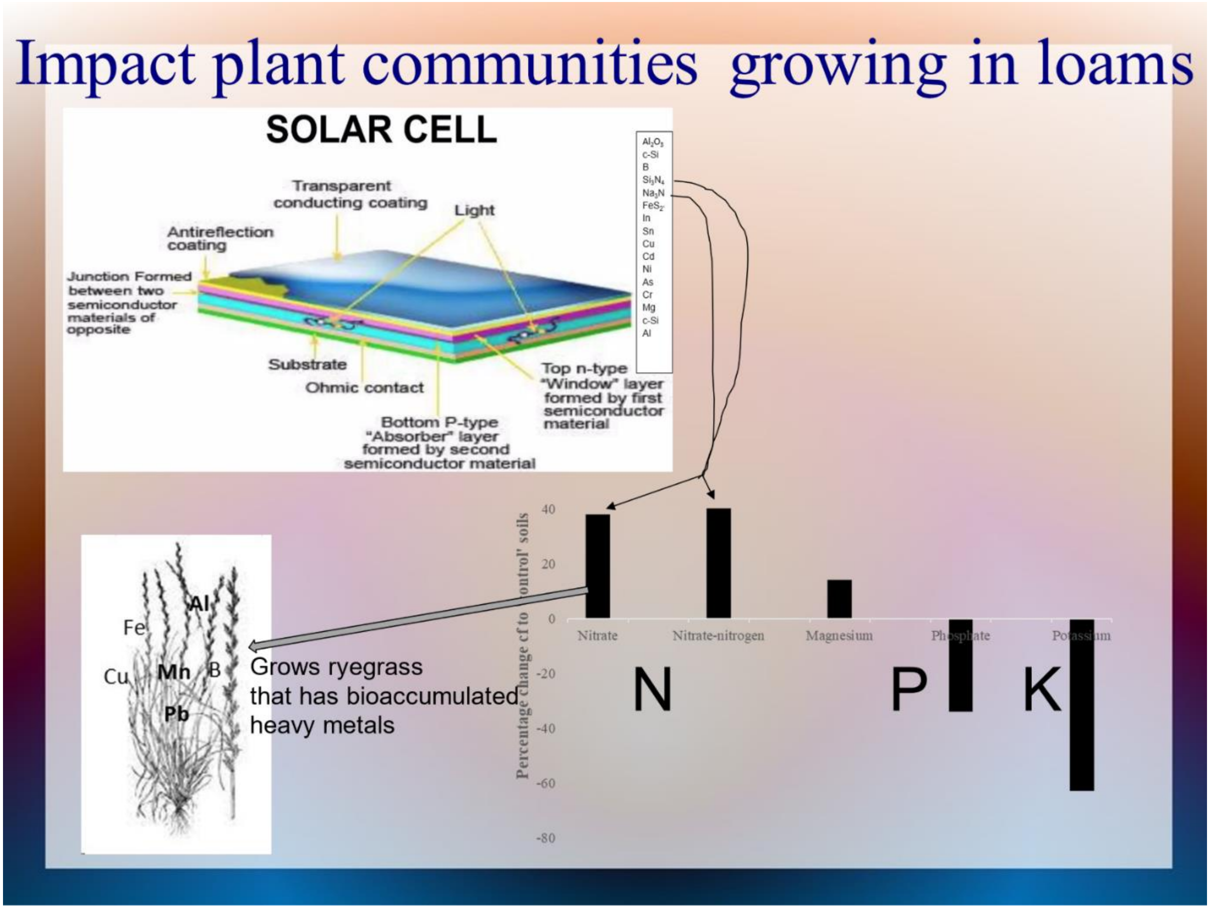
49 This site is completely different to that reported by Dr. Zac Beechey-Gradwel. The research at Waiau was undertaken on what I presume are “moderately deep Manapouri soils” (as described in soil maps) that have large stones and the site is free draining. Although I haven’t been to the Waiau site it is likely to be the type of place a solar farm should be situated because permeable soils will allow leachates to go deep underground out of the root zone of plants. No valid comparisons can be made between the results reported from the Waiau site and Brookside site: it is like comparing apples with pears because they are completely different soils.

50 The effect of iron and aluminium build-up in soils can be seen as bronzed and stunted vegetation in the photographs supplied by the applicant. These areas will increase in size with the passage of time because Fe and Al will inevitably spread over an ever-increasing area of soil.

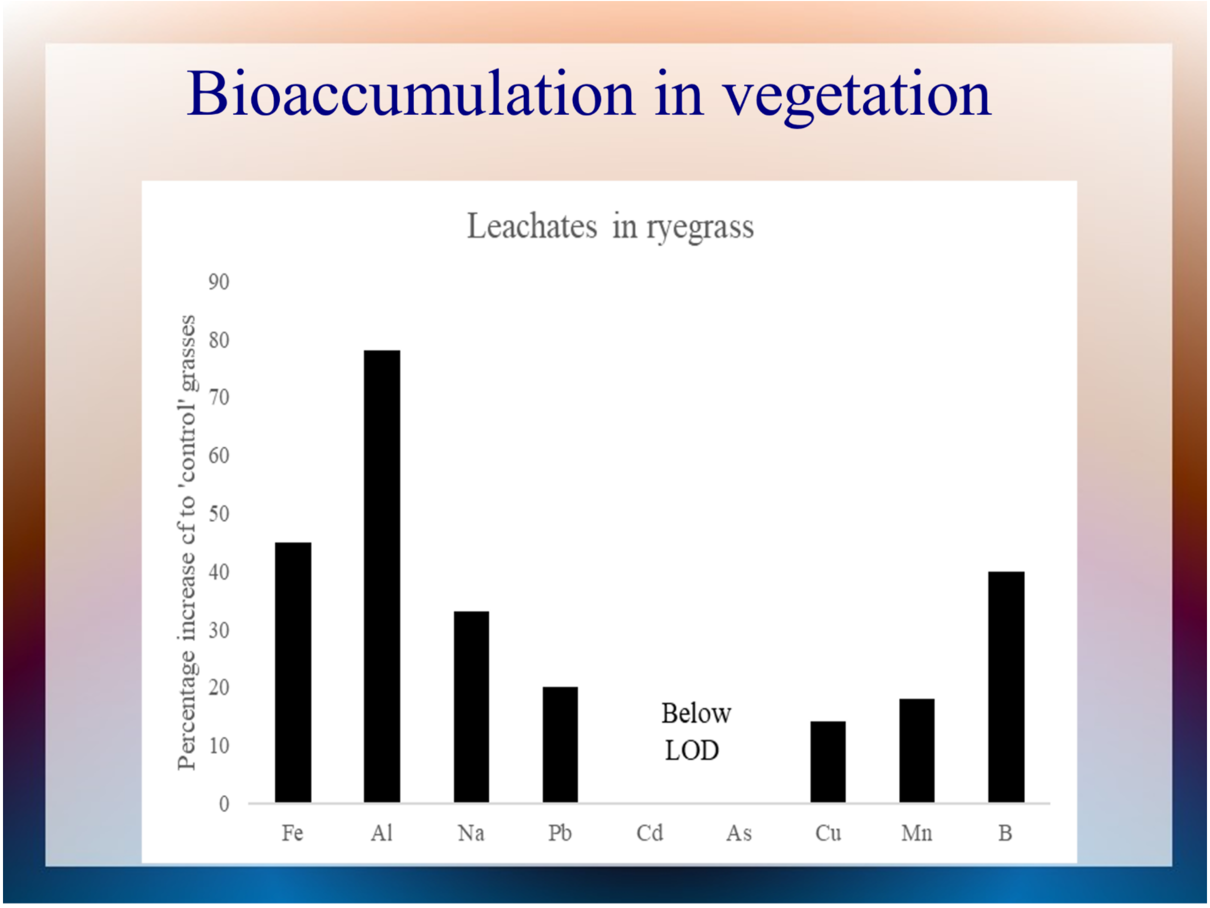
51 The heavy metals Fe and Al have been leached off panels into soils. Those materials either absorb phosphates and potassium (absorption), bind phosphates to the surface of soil particles (adsorption), or they form a coating over phosphates and potassium (occlusion). The reduced bioavailability of potassium and phosphates changes the NPK of soils.

52 From the antireflective coatings (ARC) on the panels there is leaching of silicon nitride (Si_3N_4) and Na_3N. As the results show below this has caused an increase in nitrogen and nitrates in soils. These have elevated nitrates in 'test' soils by 40% above those in 'control" soils; these are nitrate levels typically monitored on a dairy farm. The constant referral by Mr. McMath to reducing nitrates in Brookside soils by putting in solar panels is simply not true. The added nitrogen actively grows ryegrass. I do not believe this ryegrass growth has much to do with micro-climates as suggested by the applicant; but is simply a result of added nitrogen to soil. The other facet of leachates could be that heavy metals destroy aerobic microorganisms and increase the presence of anaerobic microorganisms able to metabolize ammonia in soils into nitrogen. Either because of nitrogen leaching or nitrogen synthesis, the nitrogen measured in ryegrass was up 7% and phosphates down 12% (because phosphates were occluded by Fe and Al). Interestingly sulphur and sulphates were up 18% in ryegrass because of the leaching of metal sulphates from panels and the chemicals reacting to turn pyrites (FeS_2) into Fe^{2+} and SO^{4-} in soils. The substances in the ryegrass plant in effect reflect the substances found in soils. As panels further degrade, inevitably the traces of Pb, Cd, As, Cr, Zn, Cu found in this study will increase in concentration in leachates.

53 Ryegrass actively grows because of added nitrates from panels and this growing grass takes up soil contaminants.



54 The accumulation of heavy metals has resulted in a significant increase in heavy metals in ryegrass growing under the Dalley solar panels. The concentrations of leachates in actively growing ryegrass reflect increases in heavy metals in soils.



55 The dearth of cadmium and arsenic in grass is because it is occluded by added Fe and Al to soils.

56 Replicated international studies have shown that heavy metals are toxic to soil microorganisms. In this study, heavy metals in soils increased on average by around 32% compared to control soils. These metals had predictably lowered soil fungi below solar panels by 55-60%, soil protozoa were lowered by 90-95%, and soil bacteria by 17% (Fig 17).

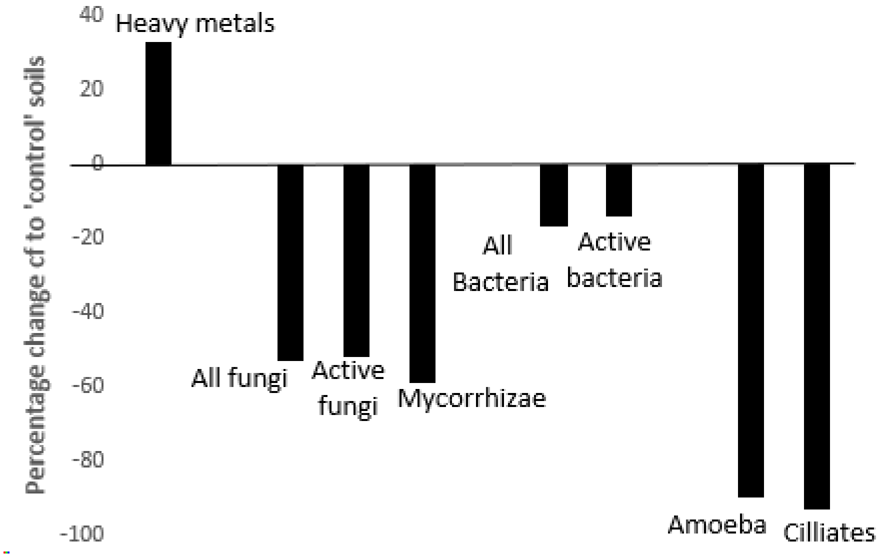
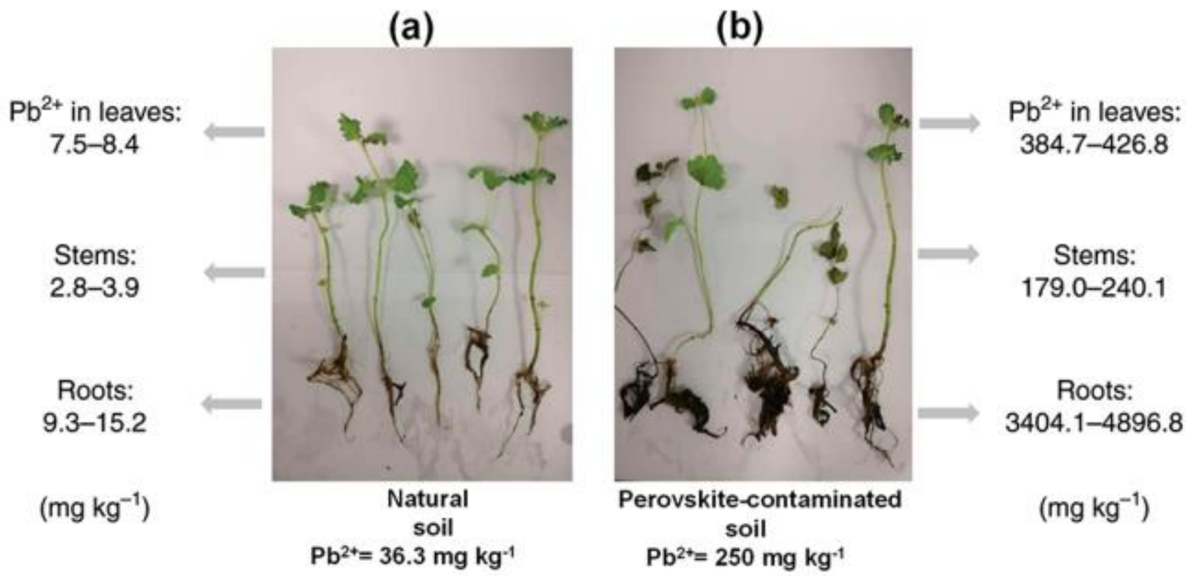


Figure 17. **Increase in heavy metals in soils has significantly lowered soil fungi and protozoa.**

57 The explanation for bioaccumulation in plants is included in the diagram below. Mint was grown in Chinese soils containing 36 mg/kg of lead and throughout the mint plant lead levels were a quarter of those in soil. When the leachates of lead from perovskite panels are added to soils so they contain high Pb, there were substantial changes in where Pb is stored in relation to soil concentrations. The rise in soil Pb from perovskite panel contaminants, caused the plant to bioaccumulates high concentrations of lead in roots (14x soil levels), and in leaves (1.6x soil concentrations). The concentration recorded in mint leaves is 40x the permitted levels for mint (10 mg/kg). This is a ramification of bioaccumulation.



58 Just as ryegrass bioaccumulates heavy metal, so too do brassicas. In the study below (Su et al. 2019) added solar panel leachates to soils have increased heavy metal levels in vegetables way above the maximum allowable levels (MAL) for human consumption.

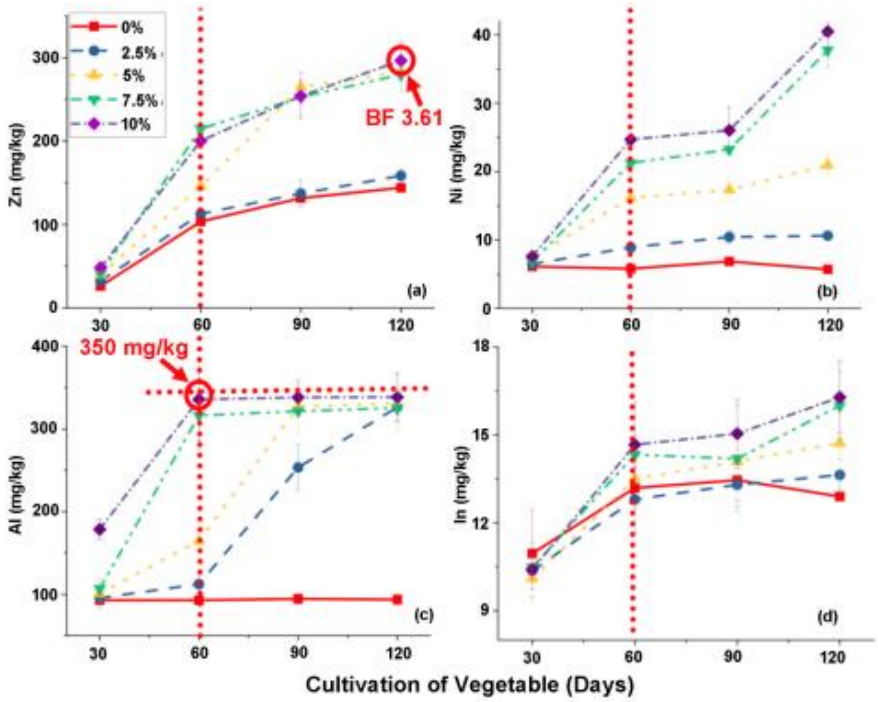


Figure 21. The bioaccumulation of heavy metals in brassicas grown in soils containing leachates (0, 2.5, 5, 7.5 and 10%) from monocrystalline solar panels (Su *et al*. 2019).

59 The photo below shows a man growing brassicas commercially in amongst solar panels. He is pointing out a row of plants growing in the “dripline” below the panels that are dying from overload of aluminium. All his brassicas will contain heavy metals well above the permitted MAL levels. This activity is promoted by lobbyists for solar farms, and although it may occasionally be alright in sandy soils where leachates leave the root zone of plants and disappear quickly into subsoils, in Brookside soils that accumulate contaminants this type of activity is very dangerous.

60 Plants that accumulate heavy metals represent a hazard to livestock.

61 In Poland cereal grown in contaminated soil bioaccumulated heavy metals in grain, when that grain was fed to pigs, they similarly bioaccumulated heavy metals in vital organs and muscle. When that meat above MALs is eaten by consumers it contains sufficient contaminants to impact human health.

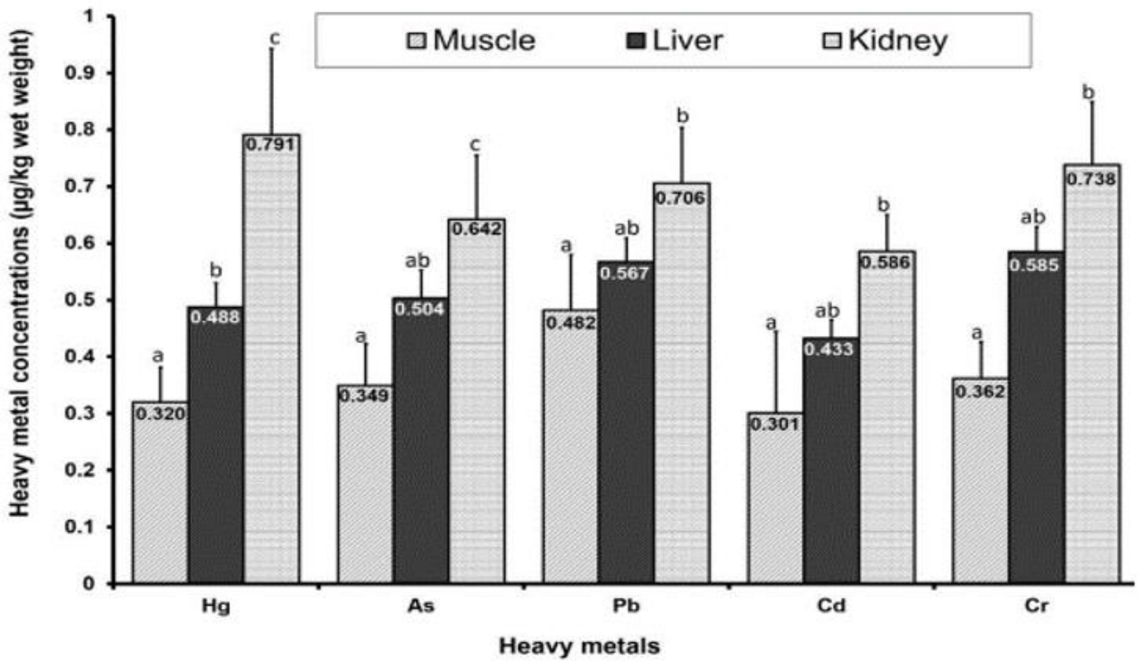
62 In the 2nd example shown below sheep that were imported from Australia into Kuwait were maintained on pelleted food and contaminated vegetation before they were slaughtered. All sheep contained contaminants at levels well in excess of internationally recognized MALs for human consumption.

Cereal from contaminated soils grows contaminated grain that then contaminates pig meat

Type of heavy metal in soil / food	MAL in meat (EU)	Contaminants in soils[1]	Contaminants in cereal used to feed pigs	Heavy metals in pig meat	Heavy metals in pig liver	Heavy metals in pig kidney	Wild boar livers contain high contaminants[2]
Cadmium	0.05	0.03 – 1.0	0.125	0.005	0.043	0.05	0.483
Lead	0.1	0.1 -40	0.147	0.09	0.756	0.60	0.195
Copper	0.5	0.01 – 50	27.3	13.7	30.5	35.8	
Zinc	0.3	5 – 150	179	128	230	116	63
Iron	0.5	50 – 3,000	207	81	486	185	
Manganese	n/a	0.02 - 0.5	94	1.2	11.3	6.2	
PFAS	0.7	n/a		1.4			117

[1] Tomczyk *et al*. 2023. [2] Kasprzyk *et al*. 2020

Sheep ingesting contaminants in feed bioaccumulate high concentrations of heavy metals



63 I should state here, at this stage in the weathering of panels we do not expect contaminants to be above the MAL in sheep during histopathology and toxicology on the Dalley sheep. What I expect to find is traces of aluminium and manganese in pulmonary and brain tissue, traces of Pb and manganese in liver, and some necrosis of cells in kidney, liver and lung tissue. Essentially it is being done to demonstrate that there are effects on animal health from grazing sheep under panels, and is a matter that will require more detailed research by CRIs in the future.

64 The abundance of clovers in pasture at the solar farm was measured with a 1-m^2 hoop. The distance from the centre of that hoop to solar panels was measured with a fibre tape. The location of plots was located semi-randomly by marking a 120-metre length of baling twine with dazzle paint every 4-m and stringing that tape between posts at opposite ends of the enclosure. At each plot (*n*=140) the number of clover plants was counted and recorded in relation to the distance from panels.

65 Results showed clover abundance was directly correlated with the distance from panels (Fig. 23).

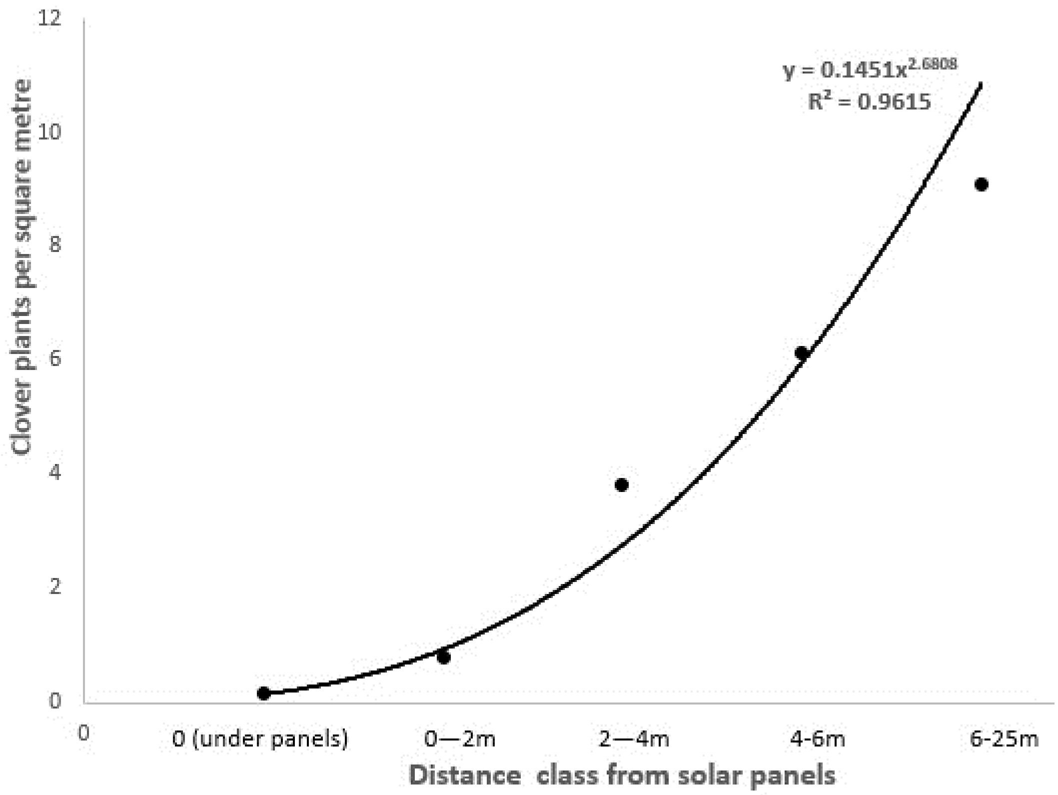


Figure 23. Trends in the abundance of clovers in pasture in relation to the proximity of plants to contaminants leached from solar panels.

Clovers close to panels showed obvious signs of potassium (K) deficiency (Fig. 24)

Figure 24. The increasing impacts of potassium deficiency on clover leaves (>15m from panels far left) to under solar panels (far right).

66 Different plants have differing requirements for phosphorous. Legumes, such as clover, require higher amounts of phosphate than grasses. Clover plants with phosphorus/phosphate deficiency have poor seedling and root development. Furthermore, with the destruction of root mycorrhizae by heavy metals, then the volume of soil from which plants can absorb phosphates is vastly reduced (Fig. 25).

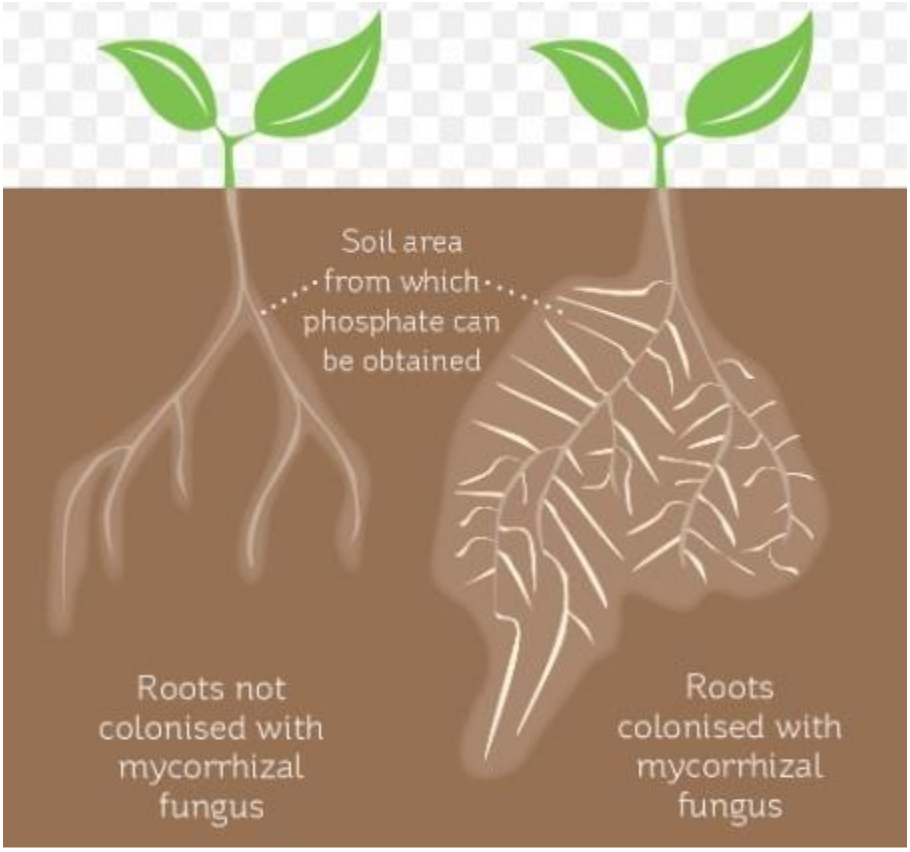


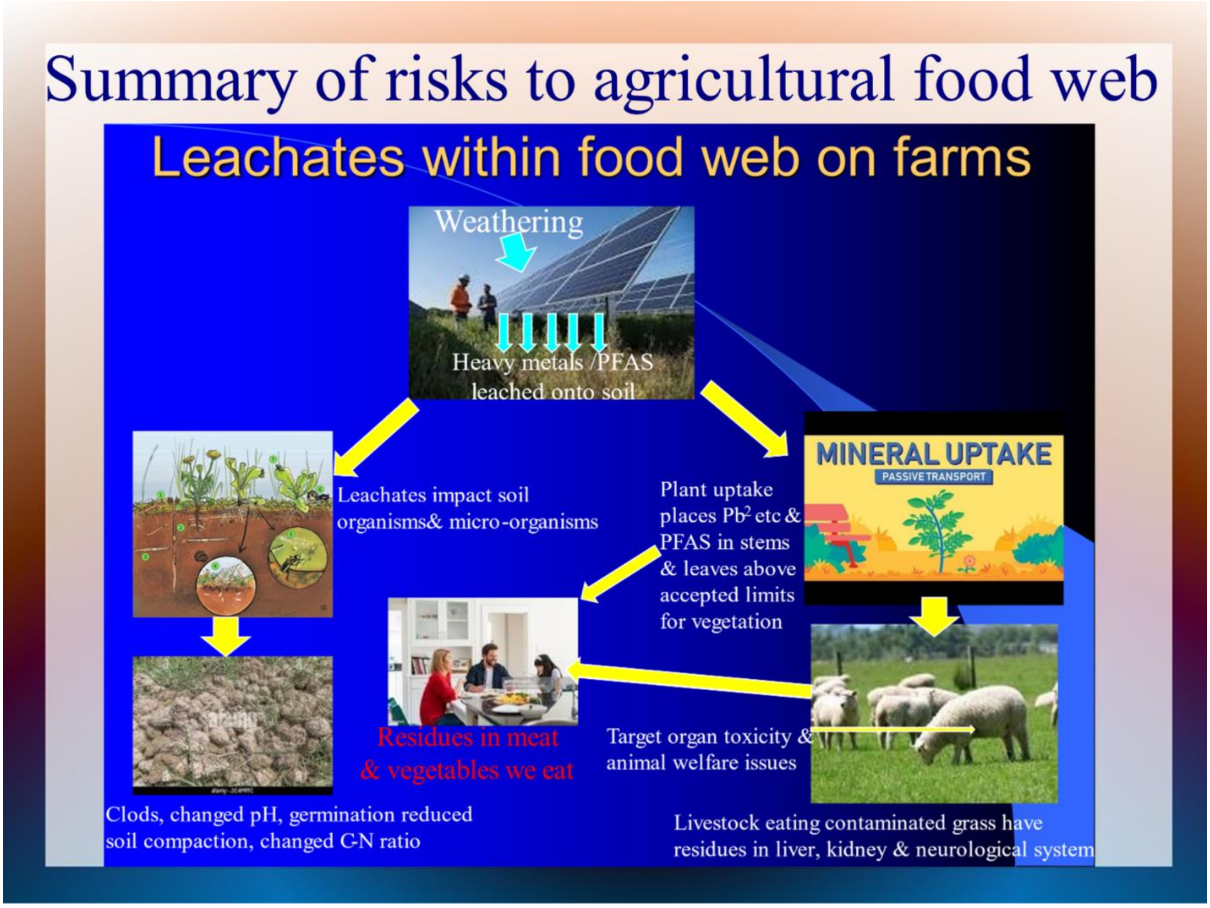
Figure 25. Loss of mycorrhizae because of heavy metals limits the uptake of phosphates and potassium. The reduced bioavailability of phosphate also impedes plant growth.

67 As stated previously, changes to NPK, changes to soil microorganisms, and changes to abundance of soil contaminants all affect plants growing in those soils, and the composition of plants. Changes to plant communities around solar panels are frequently recorded in the literature (e.g., Bai *et al*. 2022, Li *et al*. 2023, Lambert *et al*. 2021) because of contaminants, shading, and changes in communities of soil microbes.

68 In summary, in soils that accumulate leachates, clearly the agricultural food web is placed at risk. Heavy metals leached onto loams with poor soil permeability result in soils progressively accumulating leachates. These leachates result in reduced populations of microorganisms and soil invertebrates. This impacts soil health. The soils then become compacted with the development of a soil crust and an iron pan above the subsoil. Clods form that occludes the bioavailability of essential macronutrients (e.g., phosphate and potassium) and ultimately this process reduces pasture production. These changes are all in deference to the national policy statement on highly productive land.

69 If there are high leachates, then it is a given that some types of plant will bioaccumulate heavy metals and PFAS into plant tissue. Those leachates are then found in cereal as well as green leafy vegetables. When stock eat that vegetative matter, they too bioaccumulate heavy metals and PFAS in meat and vital organs. That produce when eaten by humans causes a plethora of health issues.

70 At the minute the siting of solar farms is not regulated. Brookside is the worst place in Canterbury that I can think of for a solar farm because of the heavy loams and clay subsoil. We have a local council and a businessman taking undue risks to facilitate the development of renewable energy.



71 The ramifications on the health of consumers eating leachates from solar panels is shown pictorially in the diagram below. The main issues are neurological, with both the central nervous system and motor neurons affected. The implications for an unborn child are severe; with mothers contaminated by PFAS and heavy metals having unbelievably high levels of heavy metals and PFAS in the placenta. A percentage enter the unborn child, so many babies are now born in China with contaminants in their system well above international standards. Babies in areas where e-waste and solar panel leachates proliferate are now plagued with persistent health problems from the time a baby inhales their first breath. Those wanting to know in detail about these health issues should read Parvez *et al*. 2022.

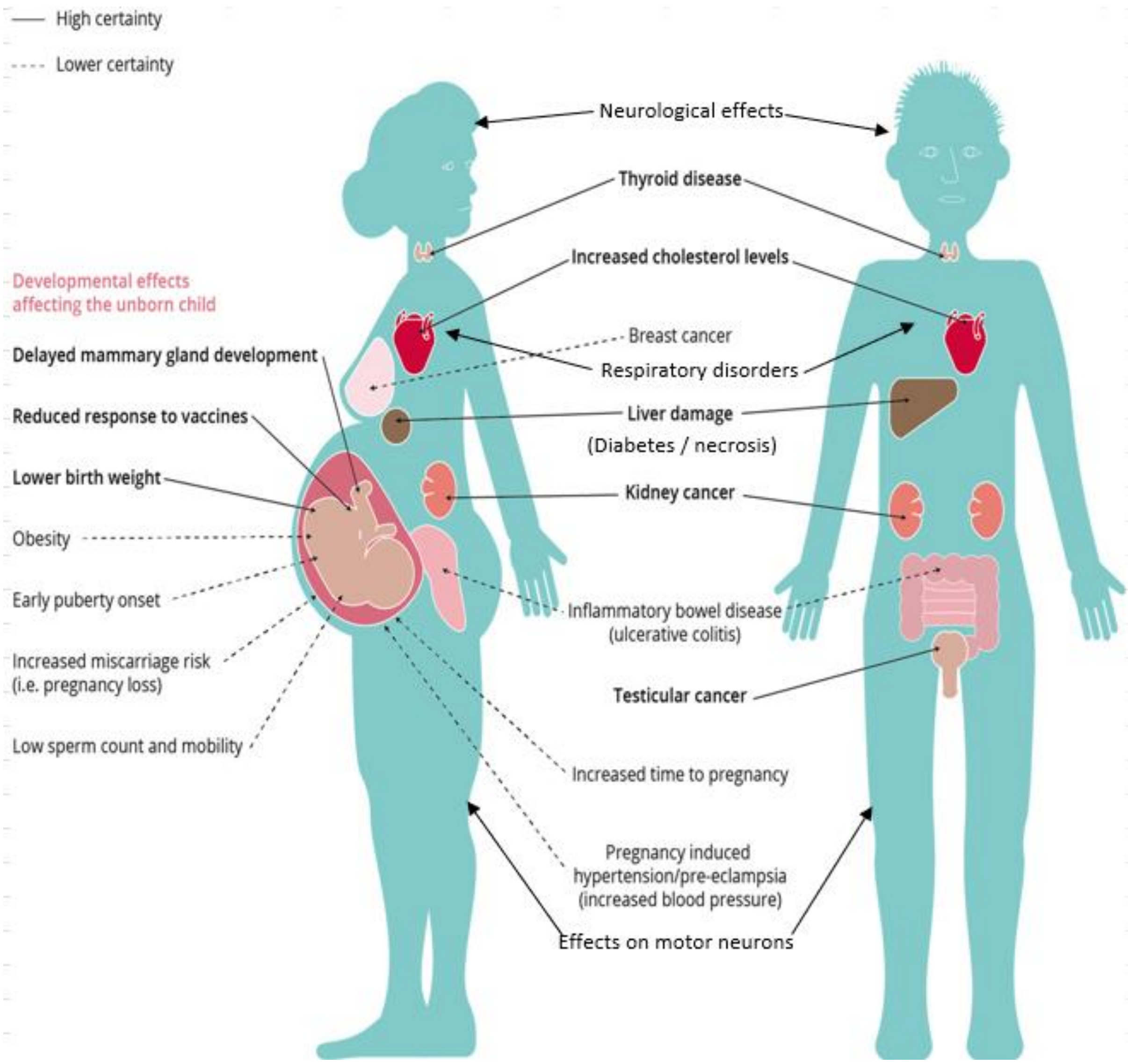
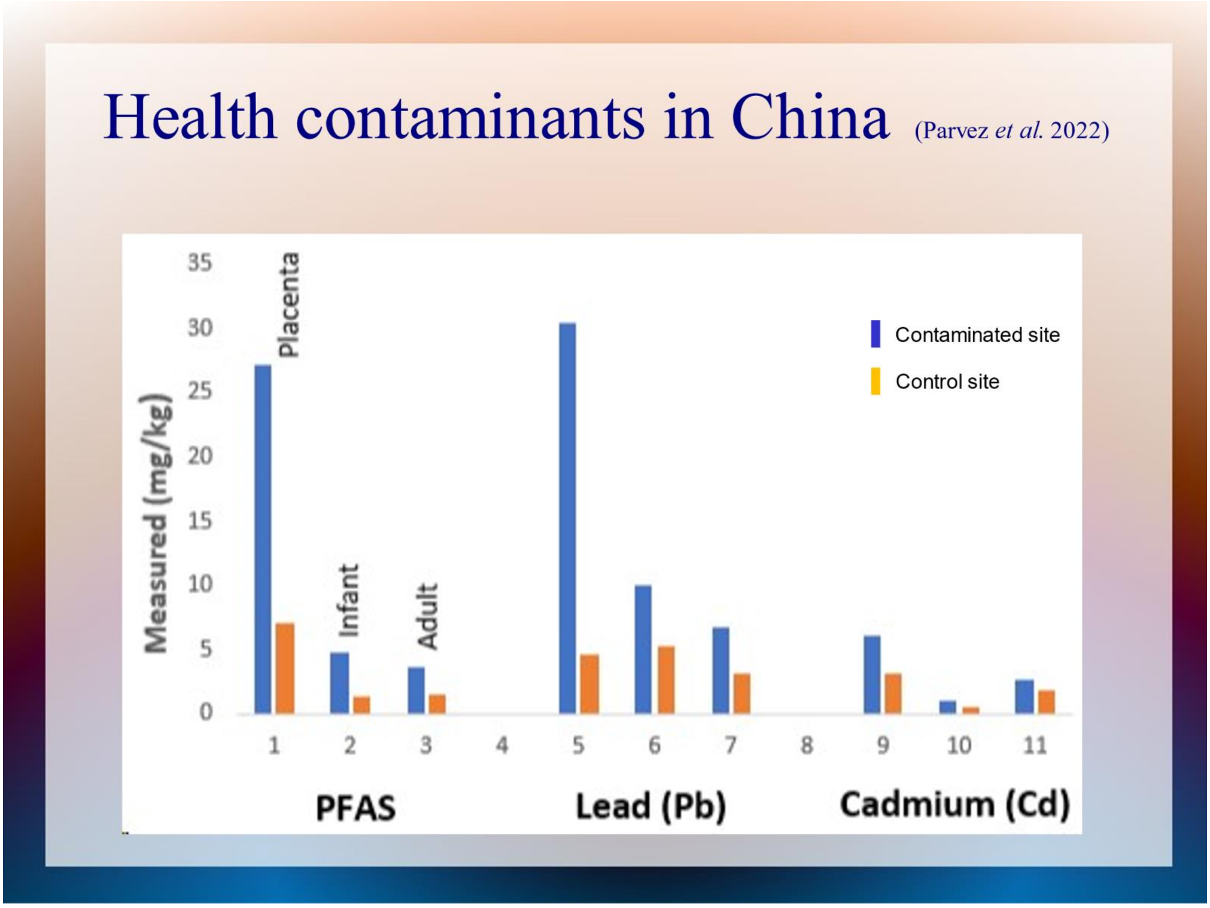


Figure 24. Health impacts from repeated exposure to heavy metals and PFAS.

72 In China, the levels of contaminants in the placentas of mothers exposed to heavy metals and PFAS at the time their baby is born are huge (c. 30 mg/kg). The baby in the womb that is being fed nutrients through these contaminated placentas is subsequently born with high levels of PFAS, lead, cadmium, and other toxic substances in blood that impact their health throughout life.



73 Contaminants from solar farms in New Zealand must not enter the food web of the population.

AQUATIC ORGANISMS

74 Replicated studies have shown **leachates** from solar panels **are highly toxic to aquatic organisms**.

75 From historical data published in international journals it was of no surprise that soils under polycrystalline panels situated on the property of Michael Dalley showed high levels of leachates; most of which are highly toxic to aquatic organisms.

76 The fact that contaminant levels are high in Brookside loams is an attribute of leachates moving slowly through a clay loam compared to sandy soils. Oxidation and hydrolysis of leachates slows the rate they move through soil. However, the catalysts that most impedes the movement of leachates from the surface of ground are the addition of large quantities of Fe (826mg *per* kg of soil) and Al (800mg *per* kg of soil).

77 If these contaminants are washed into aquatic ecosystems what will be their impact on fish? Below I make a comparison of the toxic effects of 1080 with lead and aluminium.

78 If I was undertaking an aerial poison operation with 1080 at Brookside there would be an exclusion zone of 100-m around waterways where bait could not be sown. Why? Because 1080 has a HSNO classifications of 9.1A and is very toxic to aquatic organisms. This is not a 1080-operation, but the leachates from solar panels will eventually accumulate to a stage where they become significantly more toxic to aquatic organisms than sodium monofluoroacetate.

79 Aluminium has a HSNO classification 9.1A (i.e., it is highly toxic to aquatic organisms just like 1080). If we do a comparison, in a 1080 operation the poison bait would be spread at 1.5kg/ha; so along a 1km strip of land next to the creek with a 100-m wide exclusion zone this 10ha equates to 15kg of toxic bait containing 1.5g/kg or a total of 22.5g of poison.

80 If that strip contained aluminium leachate on the surface of ground at a rate of 1mg of "active" aluminium per 10 square metres of ground (a **very** conservative figure), then the calculation is (1x10x1,000)/1000) =10gm of active aluminium present in the same strip of land. It must be remembered in a kg of soil fine aluminium (at a molecular level) had increased 800mg *per* kg of soil. As stated the 1 mg per 10 sq metres is ridiculously low.

81 If we go to the next level and compare the toxicities, then the LC_{50} of 1080 to trout is 54mg/litre of water or 54ppm in solution. In comparison the toxicity of aluminium in pH neutral solutions is 1.5ppm and at pH 5.2 it is 0.2 ppm (i.e., 200 µg/l). For a simple risk analysis, the comparison is 22.5/0.054=416 dead trout if an exact concentration of 54 ppm could be maintained in water. In comparison for aluminium the calculation is 10/0.0015=6666 dead trout if an exact concentration of 1.5ppm could be maintained in water. So, the aluminium leached onto soil represents **a risk** that is 6666/416=**16 times greater** than that of 1080.

82 The other contaminant that is ubiquitous to all types of solar panels is lead (Pb). Lead is similarly just as toxic to trout as aluminium. The LC_{50} of Pb to trout is 1.3 mg/L of water (1.3ppm). If lead was leached onto soil at 1mg/100 square metres (once again a very conservative figure), then that is 1 gm of lead over 10ha. So, in the comparison with 1080 if all the fine particulates of Pb were washed into the creek and maintained at the toxic concentration it could potentially kill 1/0.0013=769 trout. That **risk for 1-gram of finely ground lead is 1.8 times greater** than potential for 22.5gm of 1080 to kill fish.

Toxic material on soil	EC_{50}	Toxicity compared to 1080	Amount in 10Ha	Relative risks of contaminants to aquatic systems
Sodium monofluoroacetate (1080)	54ppm	1	22.5 g	1
Aluminium (Al)	1.5	36 x	10 g	16 x
Lead (Pb)	1.3	41.5 x	1 g	1.8 x

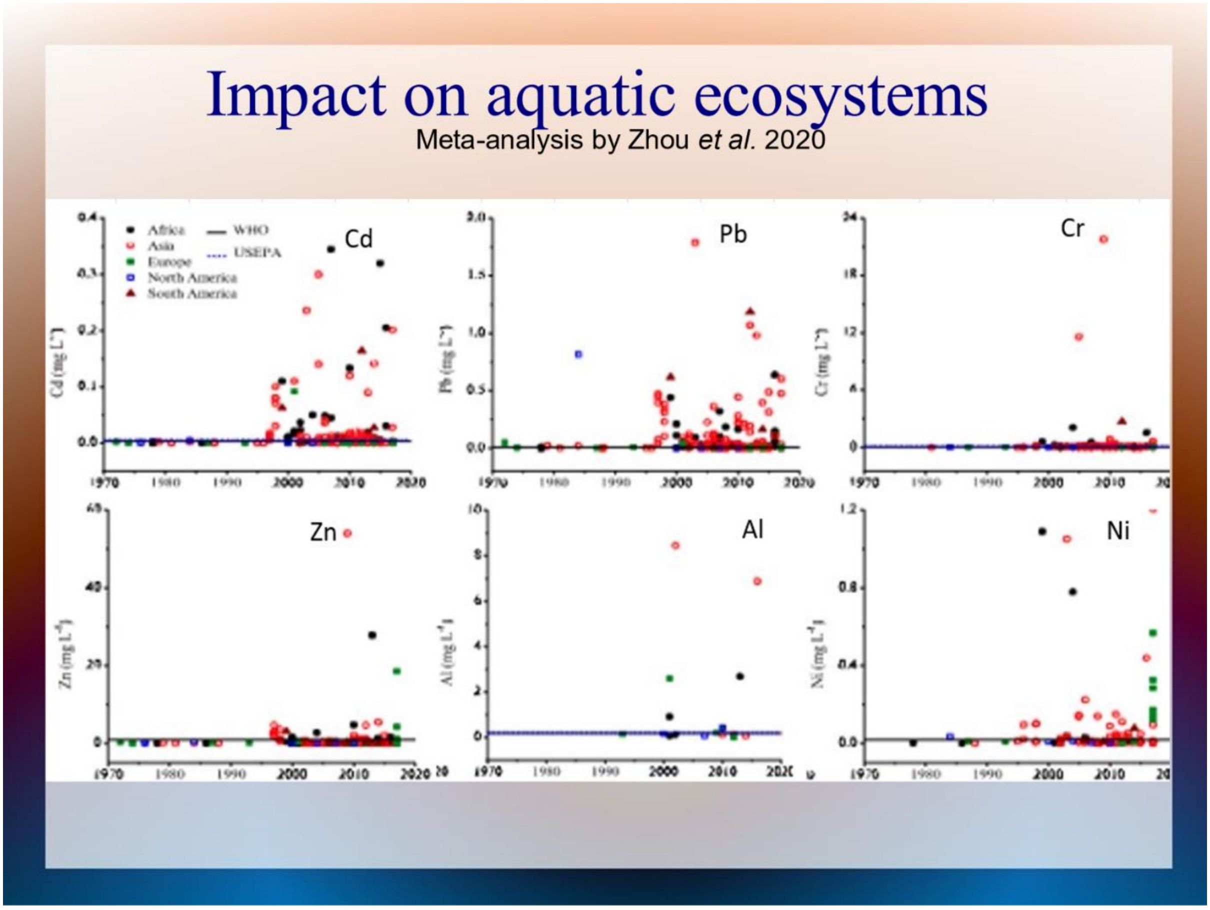
83 We could carry on with all the other leachates (arsenic, cadmium, manganese, copper, zinc etc that are all toxic to fish) and establish a cumulative risk (additive effects) which for a 48-hr period will be more than 20x that of 1080. However, it is much worse than that, because unlike 1080 the heavy metals are 'forever chemicals' that do not degrade. Once the fish falls apart the aluminium and lead are there to kill another fish. What is more likely is that the dead trout would be eaten by an eel which bioaccumulates the heavy metals, and the eel is then caught in an eel net and consumed by people.

84 [redacted] I could do this calculation for all the other materials leached from solar panels and will do so once I have replicated measures of leachates dropped into soil and pasture. In the meantime, we can state unequivocally that heavy metals represent a high risk to aquatic ecosystems that are at least an order of magnitude greater than the risks presented by 1080. Furthermore, the risks from PFAS have not been factored into these equations. PFAS are also toxic to fish.

85 If I said to Maori, I'm going to broadcast 1080 bait over Te Waihora there would justifiably be a public outrage. However, replicated research shows the 1080 in unpolluted water degrades relatively quickly (2-3 days) into non-toxic residues; and where water turbidity is high as it is in Te Waihora, very little 1080 would exist in the lake after 1-day. In comparison, the 'forever

chemicals' associated with the solar farm will remain in the lake and continue to bioaccumulate in aquatic organisms year after year. After 30-years of heavy metal leachates from a solar farm at Brookside, the risks to aquatic organisms in the lake will be several orders of magnitude greater than the short-term risks from a fast-acting poison like 1080. As stated above heavy metals do not degrade, so trout dying from aluminium (Al) and lead (Pb) are then eaten by eels that are then caught and eaten by Maori. Some of these contaminated fish are eaten by waterbirds that also place them at risk. At each trophic level we get bioaccumulation and impacts on health. The planners at Selwyn District Council must sit down and do some calculations because at the minute their risk analysis for this solar farm is not even in the same orbit as "the real risks" that it presents to the environment.

86 A review of heavy metals in surface waters was undertaken by Zhou *et al.* (2020). Since the advent of solar farms in Asia from the start of the new millennium, heavy metals in water have increased significantly. It cannot be claimed that these substances are all coming off solar panels, but at least a large portion of this problem arises from solar farm leachates.

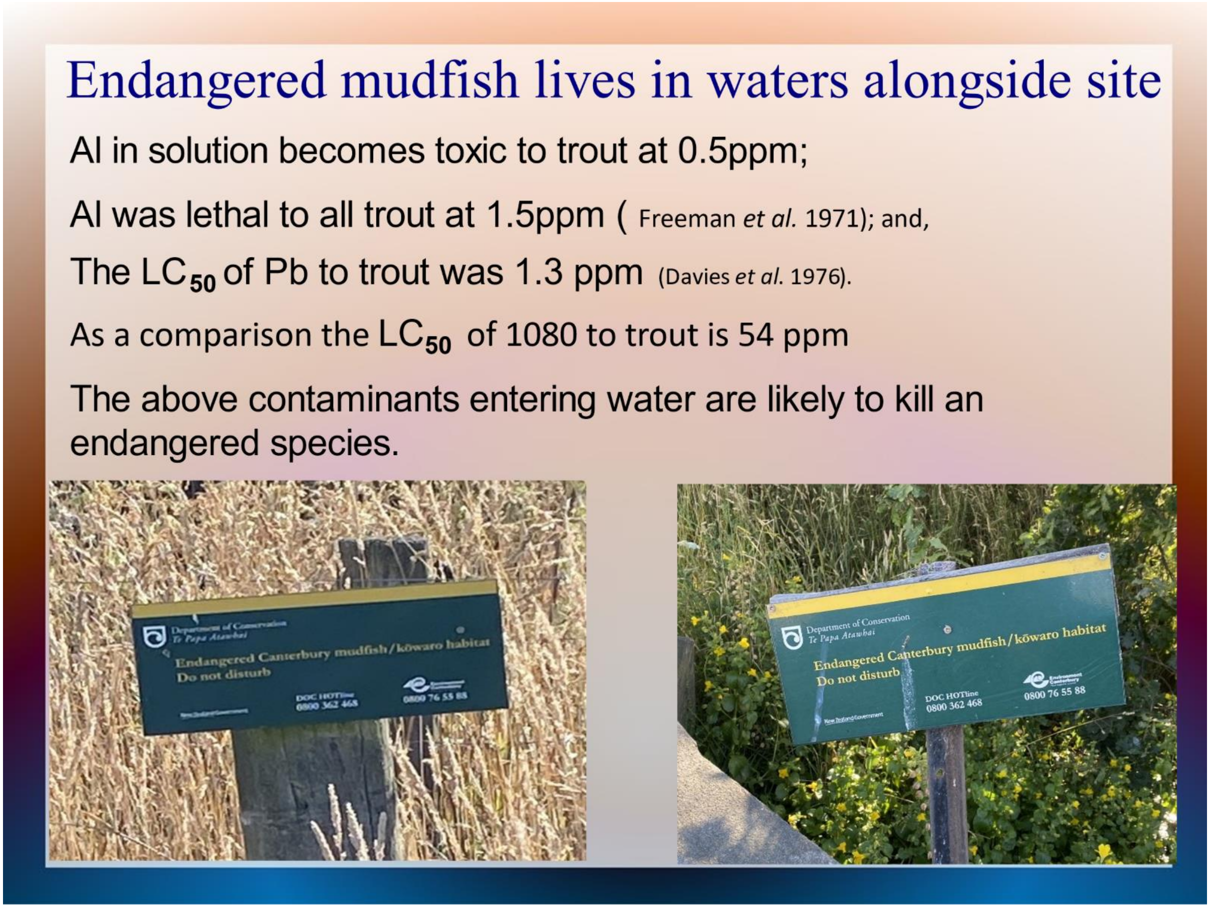


87 In the long term the hazardous "forever chemicals" leached from solar technologies will inevitably see creeks, rivers, and lakes of the Selwyn district festooned with notices like that seen below. Through poor consenting the planners at councils have already made every lowland river that drains from the foothills in Canterbury eutrophic. Every lowland lake in Canterbury is eutrophic. It would be unforgiveable to carry on with poor consent processes and make these surface waters toxic and eutrophic, but that is what will happen if projects like this are approved.

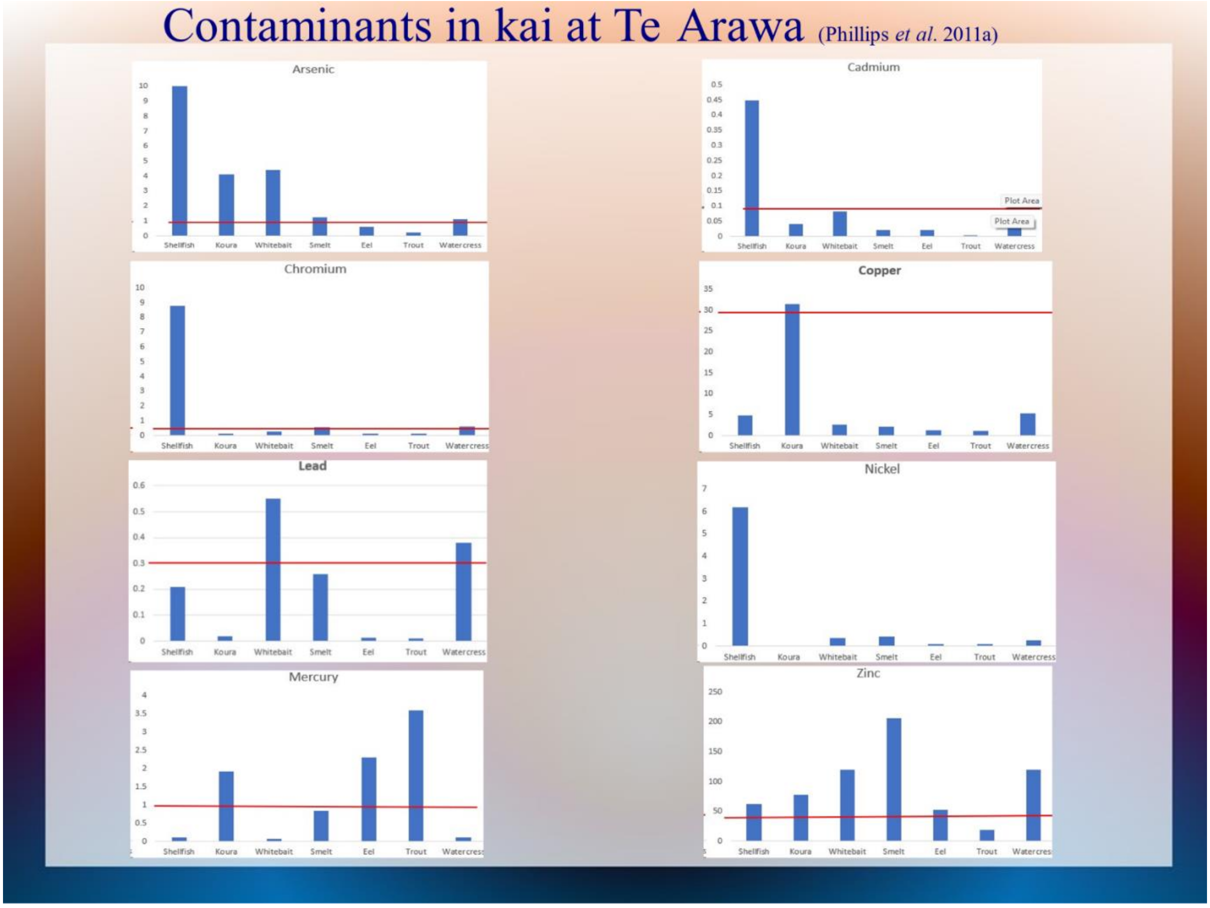
88 These notices exist because fish bioaccumulate both polyfluoroalkyl substances (PFAS) and heavy metals. In a science paper published in *Environmental Research* it is stated that “a single fish harvested from freshwater in the USA now presents more of a risk to that person’s health than that person drinking PFAS contaminated water for a month” (Barbo *et al.* 2023).

89 In a further publication in the *journal of aquatic science* it is stated that “fish are a rich source of nutrients, however, its nutritional value may be affected by the environment in which it exists. The threat of toxic and trace metals in the environment is more serious than those of other pollutants due to their non-biodegradable nature. This is coupled with their bio-accumulative and bio-magnification potentials. Within the aquatic habitat fish cannot escape from the detrimental effects of these pollutants. Heavy metal toxicity as a result of people consuming fish can result in damaged or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, bones, liver and other vital organs. Long term exposure may result in slowly progressing physical, and muscular conditions, as well as Alzheimer’s disease, Parkinson’s disease, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals, or their compounds may cause cancer. Heavy metal toxicity is a chemically significant condition” (Isangedighi *et al*. 2019).

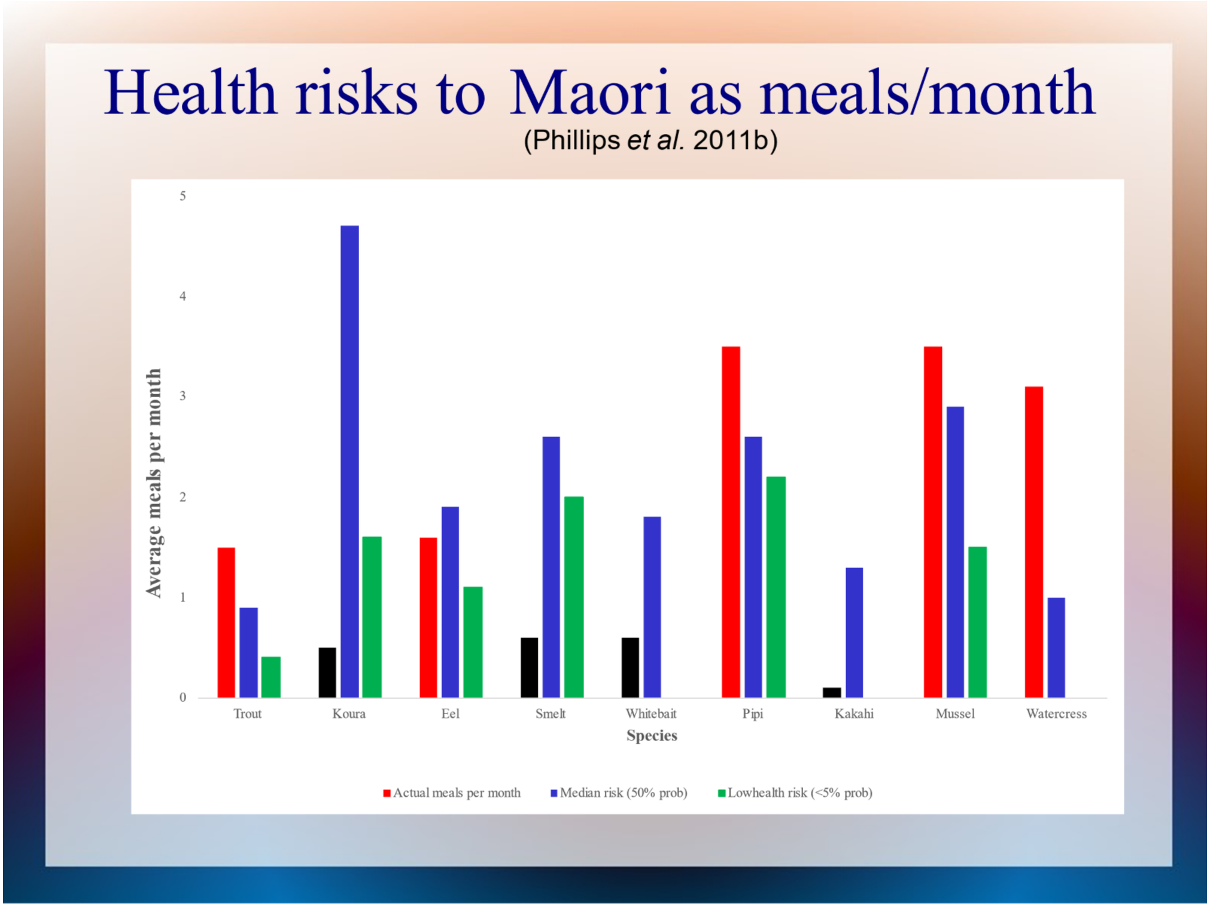
90 The other area of concern is of course is the endangered mudfish that lives in the creek adjoining the site of the solar farm. The Department of Conservation has notices up in plain view of every ecologist, every council worker, and every expert that his visited the site over the past 3 years. I made it quite clear in my evidence statement of February 2023 the project would kill an endangered species. Somehow the notices, the written statements of fact, and the presence of these rare creatures has not registered with council planners. It is an offence to knowingly kill them, but that is exactly what the solar farm will do.



91 The risk to kai harvested from the lake by Maori has not been adequately assessed. Background information regarding existing contamination of the lake is very piecemeal or out of date. A review of heavy metal contaminants in kai harvested from the Te Arawa lakes around Rotorua was undertaken in 2011 (Phillips *et al.* 2011). That review showed the combination of geothermal activity in the region and effluent from human activities had raised heavy metals in shellfish, koura (freshwater crayfish), whitebait, smelt, eel, trout, and watercress in that order as shown in the figure below. The organisms that accumulated most heavy metals were shellfish as filter feeders followed by whitebait, koura, trout, watercress, and eels. The red line in each graph is the average MAL for each food (it does vary slightly by species).



92 In risk analysis the amounts of these foods with heavy metals eaten by Maori are a measurable health risk. The red bars below are foods eaten by Maori in amounts that represent a significant health risk.



93 With heavy metals going into Te Waihora it will similarly represent a serious health risk to Maori. It is inevitable the risks will increase year-on-year until the health of Te Taumutu taking food from the lake is regularly affected.

94 The contamination of kai falls outside the co-governance agreement between Maori and Selwyn District Council, Christchurch City Council, and DoC, and is in conflict with sections 4 of that agreement.

RISK TO BIRDS

95 *Hazards of lead*. Eisler (1988) summarized the risk to birds from lead (Pb) as an LD_{50} of 28 mg/kg with signs of poisoning as low as 2.8 mg/kg. It is a reproductive toxicant with fertility severely impaired at 50 mg/kg. Tissue Pb levels were elevated in mice given doses of 0.03 mg Pb/kg BW, and in sheep given 0.05 mg Pb/kg BW. So, although birds are affected, they are not as affected on a dose basis as rodents and sheep. The key parameter is body size. If we take a sparrow weighing 25-30g that ingests 1-mg of lead that represents a dose of 40 mg/kg; whereas a sheep ingesting 1-mg of lead has received a dose of 0.02 mg/kg. The effects on each species are entirely different.

96 *Exposure to lead*. There are 6 routes for bird exposure to toxic doses of lead: in earthworms and invertebrates; in seeds and cereals; in fruits and berries; through feeding on contaminated fish (highly likely), in nectar of plants (unlikely), in flying insects (unlikely), and through the predation of rodents/other birds (highly likely). If we look at earthworms Beyer *et al*. (2013) established that residues in worms were directly correlated with soil concentrations and some worms contained up to 3000 mg/kg through bioaccumulation. If we add the effects of bioaccumulation of metals in fruit (Zeiner *et al* 2018 established concentrations of 15.3 mg/kg in briar berries)), berries (Vlad *et al*. 2019 demonstrated lead concentrations as high as 85.3 mg/kg) in blackberry), seed and grain, then exposure of passerines to lead in

contaminated Brookside soils may eventually be high. Passerines are at a low risk after 10-years of solar panels, but that risk will inevitably rise to moderate after 20-30 years of solar panels and increased lead exposure. I have reviewed elevated contaminant levels in nectar for all heavy metals, and even at very contaminated sites the heavy metals in honey will not place nectar-feeders at risk. Insectivorous birds will be exposed but, in the life-cycle of egg-larvae-pupae-adult it is the pupae stage where contaminant levels are highest (once again mainly passerines); so, exposure by insect-feeding birds is generally low. As alluded to previously waterfowl and waders will have high exposure because they feed on aquatic organisms. The classes of birds most at risk are waders, apex predators (raptors such as falcons, kestrels, owls, hawks), and passerines. Overseas evidence shows that the decline in Pb in raptors following the removal of Pb from petrol has continued in Sweden where there are few solar farms but has since turned upwards at locations like Spain where 43% of electricity is now photovoltaic.

97 Below we present two graphs: a) the first is from Sweden where less than 1% of energy is solar and since the removal of lead from petrol there has been a slow but steady decline in lead (Pb) in raptors over the past 40 years (Fig. 30); and, b) the second is from Spain where solar energy evolved from the late 1990s until by 2018 around 43% of their energy was solar. Figure 16 shows a steady decline in lead (Pb) in kestrels until 2000, and then the Pb in kestrels dramatically increased with more environmental contamination. The graphs for other heavy metals in kestrels (Cu, Cr, Li, Zn) are almost identical to that of lead (Pb). The risks of heavy metals in the environment must be taken seriously when establishing a solar farm.

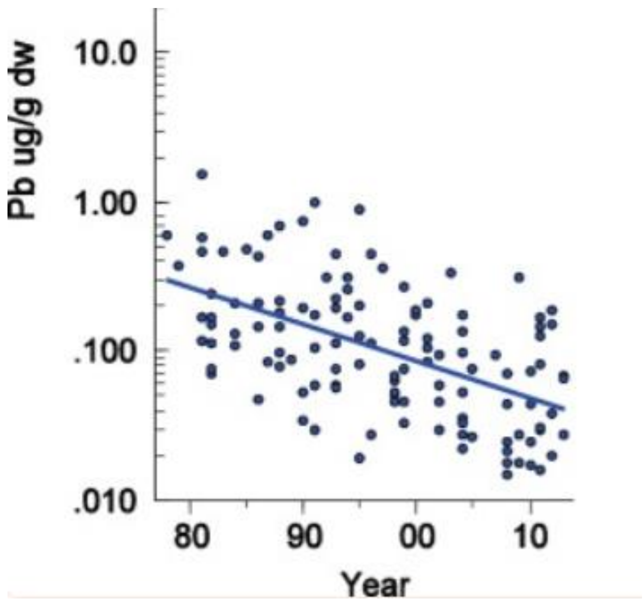


Figure 30. Measured lead (Pb) in raptors in Sweden (Helander *et al*. 2019).

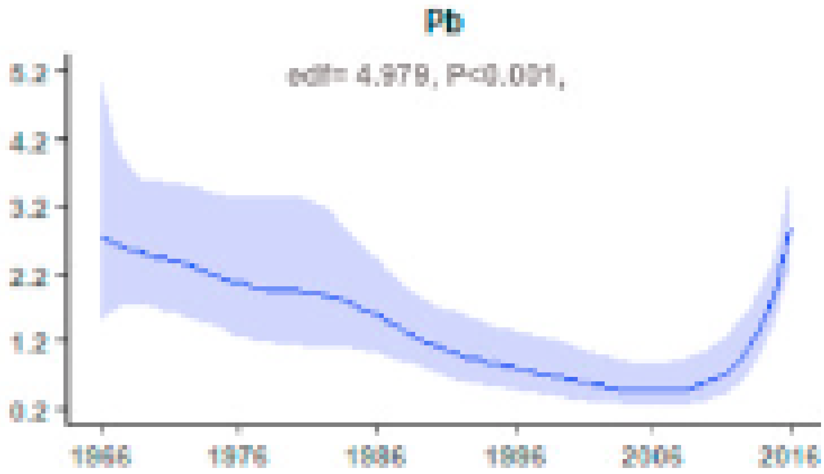


Figure 31. Measured lead (Pb) in raptors in Spain (Manzano *et al.* 2021)

98 **Hazards of aluminium -** It is generally accepted that the hazards of aluminium to birds is low (i.e., LD_{50} >4,000 mg/kg). The risks are also low.

99 **Hazards of copper to birds -** Birds are sensitive irrespective of whether copper is administered as an acute dose (LD_{50} = 98 m/k for bobwhite quail) or as a sub-chronic poison (hazards= 5-28 m/k). The re-registration data for copper indicates small passerines feeding on fruits and berries are most vulnerable. Copper contaminants in passerines, raptors, and waders feeding on fish at Te Waihora will also be an issue.

100 **Hazards of zinc to birds -** Although birds experience target organ toxicity when repeatedly exposed to zinc the LD_{50} is high (viz. >5,000 m/k) irrespective of whether it is acute or chronic dosing.

101 **Hazards of nickel to birds -** Nickel on a clay-loam is reported to bioaccumulate in earthworms where sub-chronic poisoning of passerines is moderate. The secondary poisoning risk of raptors is low-moderate.

102 Away from the site aquatic birds like herons, stilts, oystercatchers, spoonbills, and bitterns with a diet of small aquatic organisms will experience moderate-high health effects as a result of feeding on aquatic fauna. Below I give an example of contamination of aquatic fauna at a site in India (Pandiyan *et al*. 2022). We note in the first table that the aquatic organisms most contaminated had eaten food containing arsenic, chromium, lead, and zinc. Birds in the bottom table similarly contained arsenic, chromium, lead, zinc. So, if aquatic organism are contaminated ten the birds that feed on them are similarly contaminated.

Metals	Crabs (N = 6)	Prawn Species (N = 6)	*Claris batrachus* (N = 6)	*Mystus vittatus* (N = 6)	*Cyprinus carpio* (N = 6)	*Labeo rohita* (N = 6)	*Tilapia mossambica* (N = 6)	*p* Value
As	5.58 ± 0.029	2.06 ± 0.06	13.04 ± 0.038	1.79 ± 0.036	2.45 ± 0.378	2.29 ± 0.298	0.43 ± 0.002	$p < 0.001$
Cr	1.81 ± 0.039	0.34 ± 0.010	9.70 ± 0.100	5.75 ± 0.142	3.02 ± 0.112	0.85 ± 0.079	0.35 ± 0.004	$p < 0.001$
Cu	3.60 ± 0.190	2.49 ± 0.186	1.83 ± 0.052	0.51 ± 0.015	0.11 ± 0.029	0.12 ± 0.008	0.008 ± 0.003	$p < 0.001$
Pb	8.48 ± 0.234	5.56 ± 0.171	4.86 ± 0.103	2.61 ± 0.107	6.88 ± 0.108	5.74 ± 0.073	5.76 ± 0.056	$p < 0.001$
Hg	0.05 ± 0.0006	0.13 ± 0.064	0.28 ± 0.072	0.10 ± 0.004	0.10 ± 0.047	0.05 ± 0.031	0.01 ± 0.004	$p < 0.001$
Ni	2.43 ± 0.039	0.50 ± 0.017	5.03 ± 0.027	0.79 ± 0.088	1.18 ± 0.383	0.23 ± 0.028	0.91 ± 0.024	$p < 0.001$
Zn	2.99 ± 0.006	1.34 ± 0.032	3.68 ± 0.092	2.82 ± 0.091	2.73 ± 0.120	1.70 ± 0.095	1.86 ± 0.059	$p < 0.001$

Figure 32. Heavy metals in the foods eaten by waders

Metals	Tissue	Kidney	Liver	Feather
As	1.92 ± 1.46	3.04 ± 0.31	2.63 ± 0.04	0.43 ± 0.007
Cr	0.72 ± 0.004	1.62 ± 0.13	6.98 ± 0.10	2.25 ± 0.09
Cu	0.54 ± 0.03	0.15 ± 0.08	0.51 ± 0.01	0.84 ± 0.63
Pb	5.39 ± 0.03	4.07 ± 0.69	5.63 ± 0.08	5.53 ± 0.05
Hg	0.01 ± 0.003	0.15 ± 0.13	0.04 ± 0.01	0.02 ± 0.007
Ni	0.54 ± 0.03	0.16 ± 0.08	0.57 ± 0.02	0.63 ± 0.08
Zn	1.26 ± 0.02	0.23 ± 0.08	1.41 ± 0.01	0.92 ± 0.01

Figure 33. Heavy metals in waders eating contaminated food

103 Bird mortality at solar farms often relates to bird impacts with solar panels. Extensive studies have demonstrated that around 10.5 birds hit solar panels and die per megawatt of electricity produced per year (Walston *et al.* 2016). This suggests a 100MW site will kill 1,050 birds per year or around 36,800 birds in the 35-year period. The reasons for this high avian mortality remain unclear, just as avian mortality by birds striking household windows remains unclear. None-the-less, in the course of this project around 37,000 birds will die by hitting solar panels.

104 The risk to passerines and raptors after 15-20 years of a solar farm at Brookside is moderate mainly as a result of lead, copper, nickel, and PFAS poisoning and bird strikes. The heavy metals arsenic, cadmium and chromium are not yet at levels that will affect the welfare of birds. There are plenty of passerines in the district, and the little German owl is a common raptor that will be affected. The consequences of poisoning are dire in terms of humaneness with reports of diminished immunity to pathogens, population die-off, emaciation, and poor fertility.

105 It is anticipated around 1500 birds may die each year as a result of the solar farm; with these deaths increasing year-on-year as soils become increasingly contaminated. The most iconic on-site species affected will be the little German owl, while at Te Waihora the Royal Spoonbill, visiting white herons, and godwits will be affected.

106 I believe overall effects to avifauna will be similar to the effects of brodifacoum on the food web of birds. Brodifacoum has been banned on the conservation estate by DoC. However, people are able to freely use brodifacoum on farms. The comparison would suggest, the risks to birds is not triggered.

107 If we do some risk analysis for sheep. We find 12 sheep exposed to finely powdered metallic lead in their diet (doses, 0.5 to 16 mg/kg bw) during entire pregnancy had blood levels of Pb that were about 0.4 mg/L, without resulting in death. Nine animals served as controls. Rate of lambing was 18% in exposed ewes (27% abortions) and 100% in unexposed sheep (no

abortions). If ewes are grazed under solar panels at Brookside, it will likely result in reduced lambing percentages.

108 A review of the impact of heavy metals on ruminants (Gupta *et al.* 2021) shows sheep are less affected than cattle. If cows are grazed on pasture with heavy metal contaminants, then the levels of lead and cadmium in blood is directly correlated with the lead and cadmium measured in the milk from cows. A plethora of literature shows cows are very susceptible to lead poisoning. This has serious implications for Mr. Dalley who grazes his dairy cows on pasture where contaminants will be washed off the Ward solar farm by floodwaters onto Mr. Dalley's property..

109 Copper poisoning in livestock (viz. especially ruminants) is common when pasture contains more than 15ppm in dry-matter. At this stage of leaching from panels, pasture Cu is below that (it is only 8ppm). The copper we are currently measuring is coming from inner layers of the solar, so, in the long-term (30 years) as panels further degrade there may be problems. Copper levels in pasture will also rise as pH further declines and soils become more acid. Liming of pasture is a means to control copper poisoning. However, the addition of lime will release arsenic, cadmium, and chromium into grass. The farm manager has a conundrum; he lowers copper with lime but increase 3 other heavy metals that are substantially more toxic.

110 Levels of arsenic in pasture are constrained in the same way as phosphates and potassium. Arsenic is occluded, adsorbed, or absorbed into clods by high levels of iron (Fe) and aluminium (Al) in soil. For this reason, negligible arsenic was measured in ryegrass during this study. The risks from arsenic in compacted soils are mainly a result of it being washed into waterways.

111 The aluminium in grass near panels is already high. However, aluminium is an amphoteric substance that becomes more bioavailable as pH is lowered. Mr McMath talked about hay and baleage off the solar farm. If we look at published research, we find that hay off pasture where aluminium is naturally high, and pH is low, contains high levels of aluminium. This can be remediated by liming, but an elevation of pH above 6.5 frees up substances like cadmium, arsenic and chromium that are currently occluded in clods. The management of pasture containing a mix of heavy metals becomes very complicated.

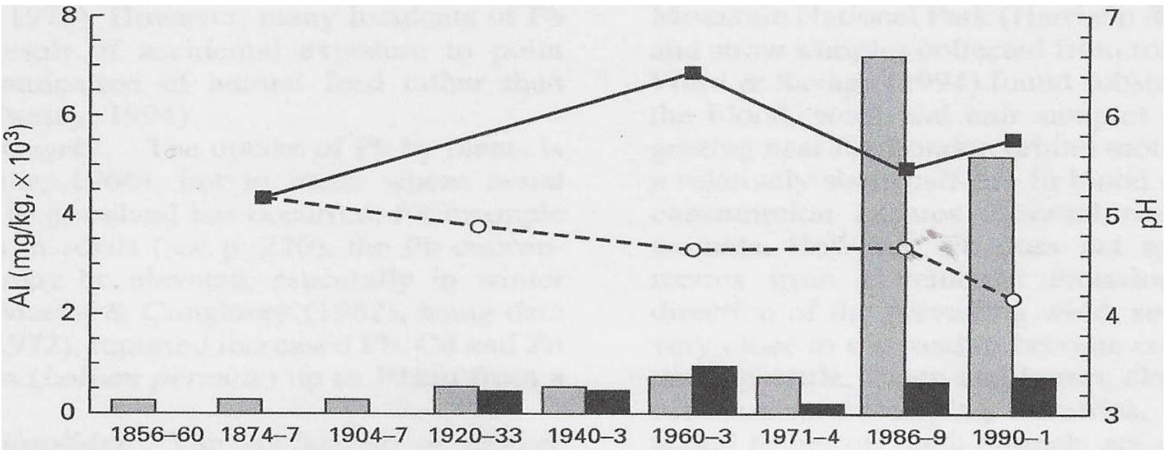


Figure 32. The levels of aluminium in hay from acid soils (solid line) and soils that have been limed (dashed line).

112 If I read Mr. McMath's consent application his farm management practice it is simply a matter of putting sheep in, turning on irrigation (which blasts the panels with water and thus increases rates of leaching), baling hay (that is full of aluminium and other heavy metals), grazing sheep at random, and hoping for the best.

ELECTROMAGNETIC FIELDS

113 At the previous hearing the applicant indicated that the farm needed to be located near the Brookside substation to transform low wattage electricity into high voltage power for conveyance along Orion's grid. This was misleading because:

113.1 The existing substation (10Kva) is at capacity (10Mw), and is nowhere big enough to handle 160Mw of electricity that he initially intended to generate from his solar panels in RC225180;

113.2 The power-lines out of the substation are completely inadequate to convey 100Mw (RC235464), let alone 160 Mw of added electricity (RC225180) when the Price farm is included during Stage 2. In evidence the applicant stated there were three 66kv lines leaving the substation, whereas in fact at that time there were only two.

113.3 Given that the site at the corner of Branch Drain and Buckleys Roads is nowhere big enough to accommodate a larger substation, the locals will inevitably object to any subdivision of the Ward property to accommodate an electrical edifice that is not only an eyesore, but a source of both high electromagnetic fields and irascible noise. The issues surrounding development of a larger substation should have been included in RC235464.

113.4 If Orion is to build a large substation to accommodate the applicant's electricity, would it not be a far better option to locate it elsewhere on unproductive land?

113.5 The differences between the existing substation and a new version are massive;

114 10Mw versus possibly 200Mw; and a 0.18ha site versus a 2.00 ha site, a source of noise and electrical arcing that was once 40db that will now be 70db, a source of EMF that was once 30-40 μT will become 70-80 μT.

115 Risks from electromagnetic fields to invertebrates and migratory birds are significant. The mechanisms for magnetoreception in different species vary. Generally, bees, monarch butterflies, and ants use iron-based receptors in antennae for navigation, while many birds use a cryptochrome protein for navigation. Populations of most species of migratory birds have declined as electromagnetic fields have disrupted navigation to northern hemisphere habitats over winter. More EMFs contribute to lower numbers each decade of shining cuckoo, long-tail cuckoo, godwits, terns, and petrels. In America monarch butterflies have been decimated by a combination of pesticides and EMFs because historical migration paths between Canada and Mexico have been blurred by high magnetic fields.

116 Bees reliant on magnetic fields for navigation lose their way back to a hive when foraging crops, bees stressed by magnetic fields are less inclined to leave the hive and actively feed, and bees stressed by electromagnetic fields have lowered fertility. Many apiarists who once thought colony collapse disorder was a by-product of agrichemicals, now accept that it is more likely a result of electromagnetic radiation. Cropping farmers reliant on bees to optimise crop yields are affected by fewer bees visiting clover florets during pollination, which reduces yields. Some bees are affected by EMFs as low as 0.025μT, and all are impacted by 0.26μT. It would be surprising if a 200Mw substation and the high voltage cables for conveyance of electricity did not affect bee activity over large areas of Brookside.

117 Burchard evaluated the effects of EMFs on milk production and found a 16% reduction in the amounts produced over 3 oestrous cycles of a cow when they were housed near high-voltage cables. The EMFs have been shown to increase cow anxiety, lower rumination, lower fertility (more dry cows); lower prolactin, lower thyroxine, lower oestrogen, (3 hormones essential to calcium metabolism during lactation) and reduce the effectiveness of the cow's immune system (so more mastitis, increased cataracts, etc). These facets of dairy herd management will impact the profitability of farms in proximity of the substation and high voltage power transmission lines.

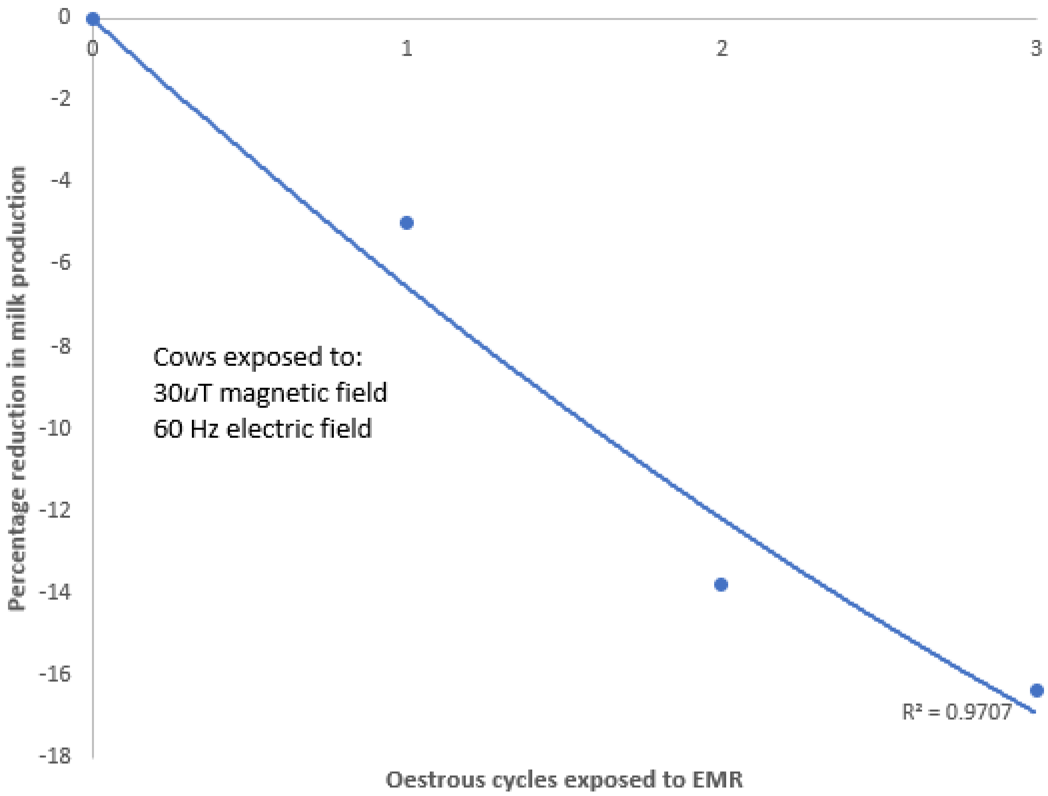


Figure 33. The drop in milk production by cows exposed to a 30µT electromagnetic field (Burchard *et al*. 2003)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

122 [redacted]

productive land (this application, RC235464) or 258 ha of land (RC225180) that is even more productive because they have vested interests in the project.

123 During the hearing in February 2023 I submitted a written summary on ecotoxicology entitled "ecological and health impacts of heavy metals and PFAS leached by solar technologies into soils, water, air, and the food web at Brookside". This came with relevant references to science journals that should have been sourced by Selwyn Council planners in their assessment of Risk Management for RC235464. It outlined risks to soils, vegetation, aquatic ecosystems, and air in the case of fire. It seems to have been overlooked, so I present that document again at this hearing.

124 I also attach the following relevant documents:

124.1 Summary of acoustics (+ references);

124.2 Summary of cost-benefit analysis (+ references);

124.3 Summary of electromagnetic fields (+ references);

124.4 Summary of hazards (+ references);

124.5 Report on risks to food web (+ references)

SUMMARY

ASSESSMENT AND METHODOLOGY

125 I have undertaken the best literature review and synopsis of risk that I can within the time available.

126 I have reviewed literature on: legislation around RMA consents; the direct impacts of solar farms on the 'rural amenity' (acoustics and visual impacts); the effects of added electromagnetic fields from 100 MW of power generation; the on-site and off-site hazards associated with a USSP facility; the long-term effects of exposure to hazards, the effects of leachates on plant growth, the health of livestock eating plants, ecosystem health, and the health risks to Brookside residents; and, the cost-benefits of a USSP-facility at Brookside. This information was conveyed to the Brookside community in a series of e-mails and public meetings, and they then provided feedback on issues they felt were important. The dossiers submitted to Selwyn District Council therefore represent the views of the entire Brookside community that participated in the democratic process.

127 The research at the Dalley solar array is a "work in progress" We hope to have it completed and published with a comprehensive risk assessment profile in place before an Environment Court hearing. At this early stage, contaminants of Fe and Al have accumulated at a rate of around 80mg per kilogram of soil under panels over the 10-year period that panels have been in place. Other contaminants from lower layers of panels are now just appearing in soils (e.g., Pb, Cd, As) and they will inevitably accumulate with the passage of time. We will develop a robust picture of where the prototype solar farm and livestock are at the 10-year stage of weathering. It would be nice to measure PFAS leachates (they are no less harmful than heavy metals), but our budget does not allow that.

APPLICANT'S EVIDENCE

[redacted]

[redacted]

[redacted]

132 The applicant insists the electromagnetic fields associated with the activity will be minor. We all understand that we do not get electromagnetic fields until inverters turn DC into AC, and we understand that buried cables have very small EMFs. However, a substation with 200Mw of AC power has massive EMFs (c. 80µT), as do 66 or 132kv cables from that substation on rights-of-way (58µT).

133 The leachates measured at Waiau on permeable soils have no relevance to the Brookside scenario with impermeable soils.

134 The ecology report fails to encapsulate the serious implications associated with ecotoxicology. The release of contaminants into air, water, soil, flora, and fauna has serious impacts on natural ecosystems.

[redacted]

SECTION 42A REPORT

139 [redacted]

[redacted] What the report must substantiate is that the RMA 1991 is being complied with. The issue of accumulation of contaminants is not addressed. Risk assessment for managing contaminants is barely touched on. There is nothing substantive about how the NPS-HPL will be complied with other than platitudes that "we will look after the land", and the NPS-FM barely gets a mention. The **risks** to both soils and freshwater are **HIGH**. This project is in my opinion **very unsafe** because of the type of land where it is located. Leachate accumulation cannot be mitigated. Discharges of toxic materials in stormwater place the Mudfish in creeks around the site at risk. Discharges into Te Waihora increase the hazards in kai eaten by Maori. In the event of a fire, discharge of toxic respiratory contaminants into the air places not only Brookside ratepayers at risk, but in the event of a nor-west wind the residents at Leeston are similarly caught in toxic smoke. The health and welfare of local residents barely rates a mention, and there is nothing about reverse sensitivity effects on adjoining cropping and dairy farms.

[redacted]

[redacted]

142 It is inevitable that the resource consent will finish in the Environment Court because of unacceptable risks to 'highly productive land', unacceptable risks to aquatic ecosystems, unacceptable risks to the health and wellbeing of locals, and unacceptable risks to the economics of adjoining farms and produce that is harvested from that land.

[redacted]

144 No one has addressed ecotoxicology in the section 42a report.

[redacted]

146 I cannot find one reference to HSNO classifications, and signage.

147 No one has mentioned a schedule of compliance inspections.

148 Last, but not least, no one knows what is going to be on site.

149 This is not a solid consent application. It is more a statement of intent.

CRC CONSENTS.

150 I note that the Canterbury Regional Council has granted resource consents authorising the discharge of stormwater (CRC223909) and the undertaking of earthworks over an unconfined aquifer. Having reviewed those consents and the reports on the basis of which they were granted, it is my view that the consent for discharge of stormwater has not been correctly assessed. I have spoken to Cherie-Lyn Lewis at Ecan who is aware of the serious issues with ecotoxicology and has a note on file that the consent cannot be renewed without supporting evidence that it is "safe" to do so. The stormwater is a vector for conveying contaminants into creeks and ultimately Te Waihora. They have also not provided mitigation measures in the conditions imposed for a number of additional sources of contamination. I address those below. I also address the existence of a real risk of significant and irreversible adverse effects on soils and aquatic ecosystems.

Unaddressed Contaminants

151 Per- and polyfluoroalkyl substances (PFAS) will be leached onto soils, and washed into drains and creeks that flow into Te Waihora (Lake Ellesmere). Offshore they are increasingly found in drinking water. The scale of this development is large enough to create concentrations of contaminants that will place aquatic flora and fauna at risk. No attempt was made to measure existing water contaminants in the Dalley et al. assessment of risk, so, we are reliant on published science to bridge that information gap.

152 Assorted metal halides of lead (Pb^{2+}), aluminium (Al), zinc (Zn), copper (Cu), arsenic (As), cadmium (Cd), Chromium (Cr), and other less hazardous metal halides will continue to be leached onto soils and then washed into creeks and Te Waihora. We can only speculate on the end result at 30-40 years, but it seems inevitable that contaminants will continuously accumulate in both soils and aquatic ecosystems until both environments have hazards that compromise their effectiveness. Cleaning hazardous materials out of those systems will be problematical and expensive. In 2021 China spent US$28 billion attempting to clean contaminants out of its soils.

153 The materials during a fire at the facility will be converted to oxides, iodides, and toxic derivatives from combustion that include HF, H_3PO_4, HCN, As_2O_3, CO, NO, SO_2, etc; all of which present a significant risk to human health and the health of aquatic systems around the site. Fire-damaged panels will leach massive amounts of metal halides, PFAS, and derivatives into soils and aquatic ecosystems. A fire presents a massive rise in unaddressed contaminants.

Real Risk

Table. Summary of risks

Risk factor	Hazard	Exposure	Risk
Heavy metal leachates	High	Soils, soil organisms (high)	**High for NPS-HPL**
Heavy metal leachates	High	Aquatic organisms, Mudfish	**>1080 for NPS-FM, High**
Heavy metal leachates	High	Terrestrial vertebrates. High raptors, mod passerines Low insect feeders	**Similar to brodifacoum** (banned on Doc estate)
Heavy metal leachates (Humans)	High	Low-Mod, pregnant women & babies most vulnerable. Leachates must not enter agricultural foodweb.	Moderate for babies MAL for produce tested **Read Parvaz** 2022.
PFAS	High	Not measured, but all fresh-water fish in USA affected. Pigs bioaccumulate	Moderate. Transfer via placenta to baby. Sig. effects on birds/fish
Electromagnetic fields (Size of substation unknown; visual effect	Moderate	Bees and Monarch B. effects Affects migratory birds. **Crop pollination, milk production**	Existing farming activity affected. All bees sensitive to 0.25µT
Noise	Low	Human factor important Destruction rural amenity	Children more sensitive **Impacts on sleep**
Fire	High	1600 fires in Italy to 2014 66 fires in UK 1st 6 months 23 **No fire plan** (is a 4.1.2A site)	Airborne hazards in smoke a serious health risk
Kai (Te Waihora)	High	**Contaminants affect eel, trout, watercress.** Waterbirds impacted.	Biomagnification, Bioaccumulation **Outside co-governance**
HSNO classifications Signage is essential	High	Where risk classifications triggered, signs mandatory	**These are mandatory**, but not in consent
End-of-project	High	Must be recycled to stop cycling of contaminants. This must be in resource consent.	Falls outside **Waste Management Acts**

154 The main problem identified within the model 'Risk=Hazard x Exposure' is that hazards are all high. Therefore, for risk to be acceptable exposure must be consistently low. However, Brookside soils cause leachates to accumulate, and as a result exposure is moderate to high. It is a simple way of assessing risk, without caveats and convoluted pathways for mitigation of risk.

155 The risks for highly productive land are **high**.

156 Although existing contaminant levels are below MALs, these are likely to rise.

Table 9. The existing and revised standards for critical heavy metals in soils as proposed by Landcare Research (Cavanagh *et al*. 2023).

	As	Cd	Cr	Pb	B	Cu	Zn
Existing rural lifestyle	17	0.8	290	160	15	190	285
Suggested changes	17	0.8	200	160	7	95	180

157 The risks to aquatic ecosystems are high. The ‘hazards’ of heavy metals to aquatic organisms are high, so standards for ‘exposure’ of metal contaminants in freshwater are all very low (see Table ss below).

Table ss. The MALs for heavy metals in water expressed as ppm (mg/L)

	Al	Pb	Mn	Ni	Se	Hg	Cu	Cd	B	As
freshwater	0.0005	0.00005				0.00002	0.00014	0.00005		0.00024
drinking water[b]	1	0.01	0.4	0.08	0.04	0.007	2	0.004	2.4	0.01

a

[b] Drinking water regulations 2022

158 The risks to terrestrial vertebrates are moderate (depending on species). If as expected, leachates of lead, cadmium, arsenic, chromium, and copper (viz. all in the lower layers of panels) rise then risk factors also rise then the risk factors also rise because of higher concentrations of contaminant .

159 The risks inherent in the project have become overt at this late stage because of:

159.1 Poor compliance with the ‘information required’ during preparation of the resource consent;

159.2 HSNO classifications not being identified that should later be shown on signage;

159.3 Failure to write a fire plan, provisions for containment of contaminants, or protocol for end-of-life management of e-waste; and,

159.4 Poor public consultation. As described by Boffa Miskell in their publication “Managing rural amenity conflicts” consultation is important. Furthermore, despite Commissioner Hughes-Johnson advising ‘public notification’ in his review of RC225180, the applicant and Selwyn District Council continue to try and sneak the consent through a process with ‘limited notification’ to selected neighbours. Without engaging those qualified to critique risks, the project has reached this impasse where risks are insurmountable.

These risks above were identified in RC225180. They were explained in reports on ecotoxicology and hazards submitted at the last hearing and are still evident in RC235484.

Consequences if Risk Materialises

160 Soils at Brookside will be impacted through progressive accumulation of contaminants, and by ongoing soil compaction. The soil compaction issues have been identified offshore (ADDAS Remediation of soils at the end of the project will be both expensive and may take some time. The cost to clean up soils at Mapua where the ICI chemical plant was located exceeded $8 million in the early 2000s.

161 The health consequences arising from poor site selection for this solar farm are serious. Food contamination (wild and domestic) is likely. It may take 1-2 decades for those contaminants to exceed MALs

162 The risks to aquatic ecosystems are high. Because contaminants are ‘forever chemicals’ it is likely to take many decades for the effect of pollutants in Te Waihora to be diminished.

MITIGATION

163 There is only one form of mitigation available; the solar farm must be located at a more appropriate location.

164

165 The arguments for the current location are moot. There is no infrastructure to accommodate the solar farm (viz. a new substation must be built, new cables established for conveyance of electricity, and new amenity plantings established to screen glint, glare, and visual impacts); the long-term impacts to the local community are significant; and, reverse-sensitivity issues will continue to plague established farms, and farming productivity will be affected.

CONCLUSION

[redacted]

167 I believe solar farms should not be located on agricultural loams.

168 I believe solar farms should instead be located on unproductive lands (LUC ≥4) where permeable soils take leachates deep into the subsoil out of the root zone of herbaceous plants.

169 Solar farms should be sited some distance from aquatic ecosystems.

170 Developers should avoid areas where more than 2-3 houses exist within a 1-kilometer radius of the site.

171 These attributes listed above are not new. They are already entrenched within published literature. That literature must be formally reviewed by MPI or MfE to develop guidelines and 'best practice' for establishment of renewable energy resources.

Dated 23 February 2024

23 February 2024

Raymond John Henderson