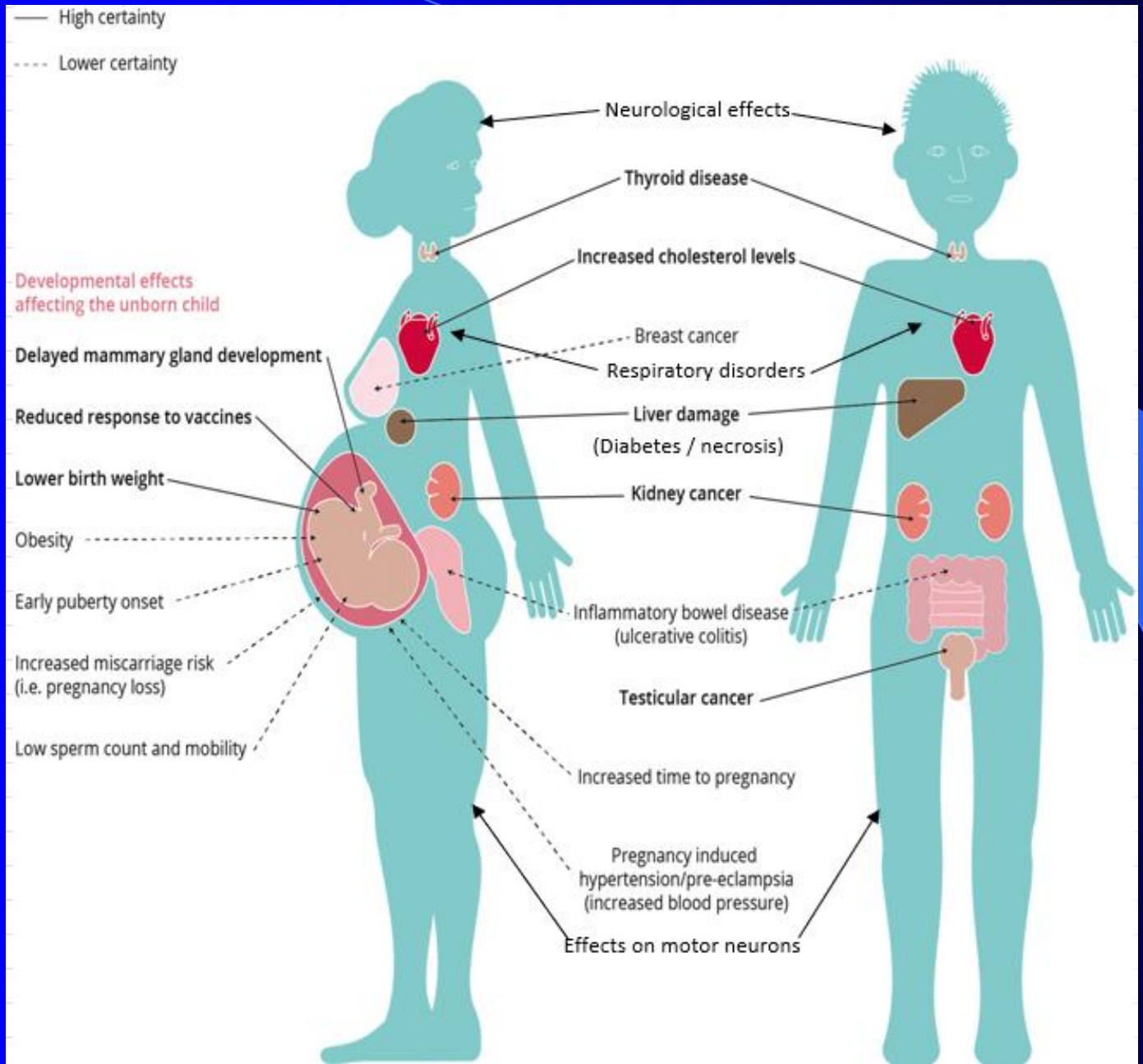
Impacts of solar power generation on the Brookside environment.

Hazards

Table 1. The half-lives, health, and environmental risks of materials used in solar technologies.

Chemical	Metal half-life Liver (d)	Aquatic toxicity 9.1	Soil toxicity 9.2	Terrest. Vert. 9.3	Toxic 6.1	Muta 6.6	Carcin 6.7	Reprod 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, pH 9.1B, pH	9.2B 9.2C		6.1E				6.9B
Lead	36 blood 130 liver	9.1A	9.2B	9.3A	6.1C	6.6B	6.7B	6.8A	6.9A
Silica		9.1B							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		
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 & B	9.2C	9.3B	6.1C			6.8A	6.9B

Hazards of PFAS and Metal halides



‘Risk = Hazard x Exposure’

Hazards:

- Heavy metals in solar technologies.
- PFAS in solar technologies.
- A solar array has a high hazard rating.

Exposures:

- Encapsulation on panels fails;
- Leachates fall onto soils;
- Leachates “pulsed” by weather events and fires;
- Leachates blown or washed off-site into surface waters;
- Leachates accumulate in soils, toxic to soil organisms;
- Leachates bioaccumulate in plants;
- Leachates bioaccumulate in animals;
- Leachates persist in ecosystems of aquatic and terrestrial organisms.

Fire

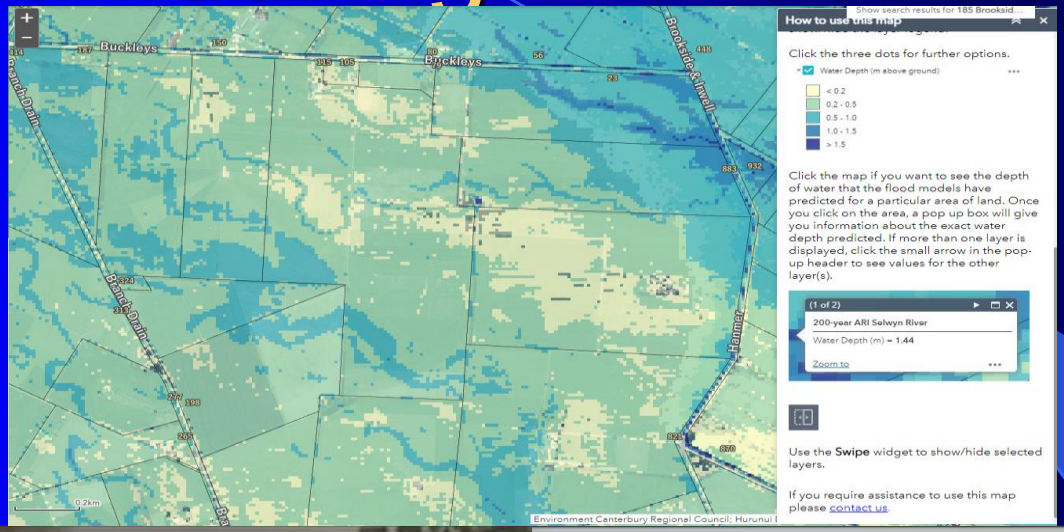
Risks of fire:

- Particulates in smoke from USSP fires include HCN, AsO_3, HF, H_3PO_4, AlF_3, PbO_2, PbI_2, CO, PFAS & metal halide particulates;
- FENZ has not seen a fire plan;
- Fires may elicit discharge of high wattage electricity;
- There were 1600 fires within USSP facilities in Italy up until 2014 (Cancelliere 2014).

Floods

- In a flood there may be electrical discharges into water & short circuits that start fires.

Flooding in and around Brookside & Doyleston during the last 35 years



1986

1988

Flooding in and around Brookside & Doyleston in the last 35 years

1992

2013

2017

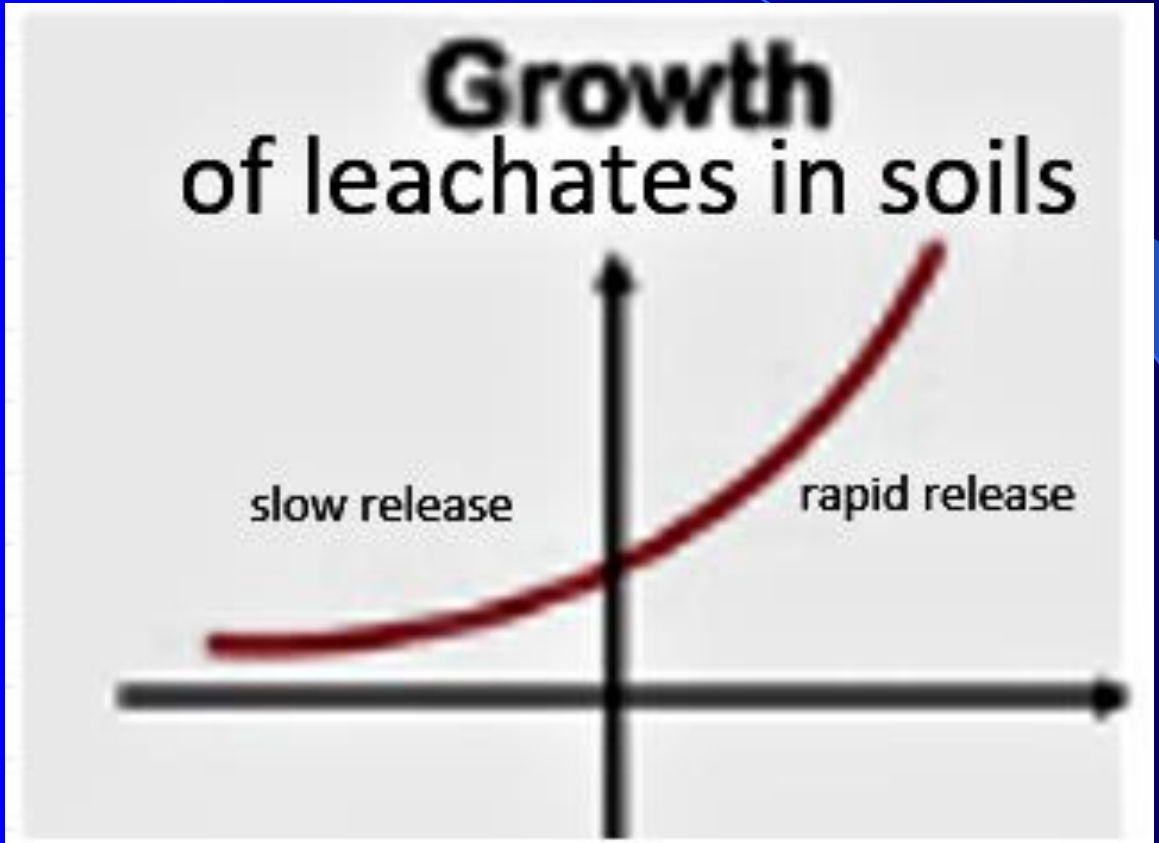
2021

Leachates

All solar panels leach heavy metals & PFAS that:

1. Are toxic to soil micro-organisms;
2. Are increased by fire or weather events;
3. Reduce soil organic carbon and soil nitrogen;
4. Are toxic within terrestrial vertebrate ecosystems
5. Are very toxic in aquatic ecosystems;
6. 'Old panels' cannot be placed into landfills and must be recycled with heavy metal and PFAS recovery (viz. Sustainability Act).

Rates of leaching



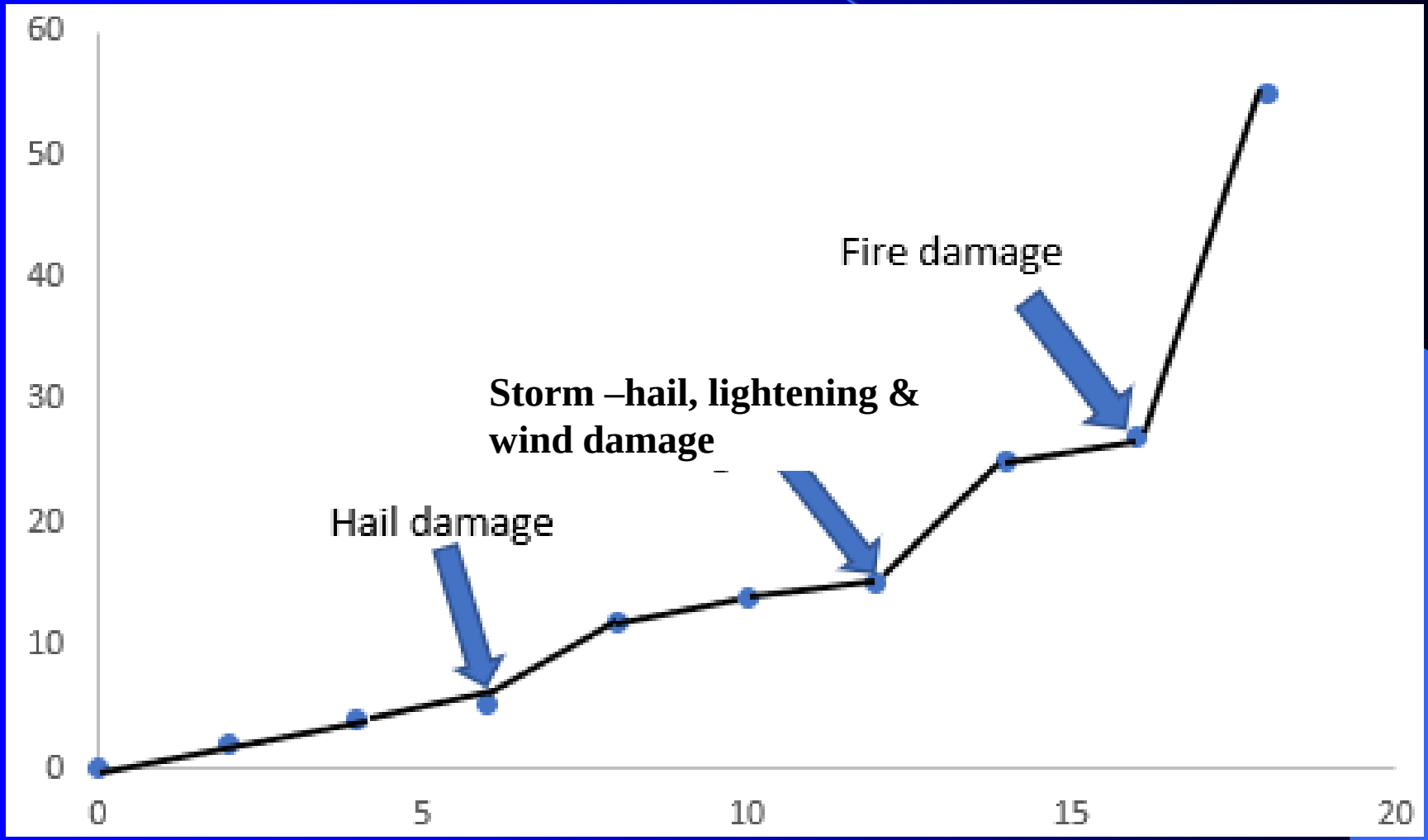
Loss of leachates will be exponential–slow rate of release in first half of panels life, which grows at a rapid rate in 2nd half as panel delaminates / weathers

Fire damage

Wind damage

Hail & Lightening damage

Cataclysmic events will ‘pulse’ leachates into soils and into water

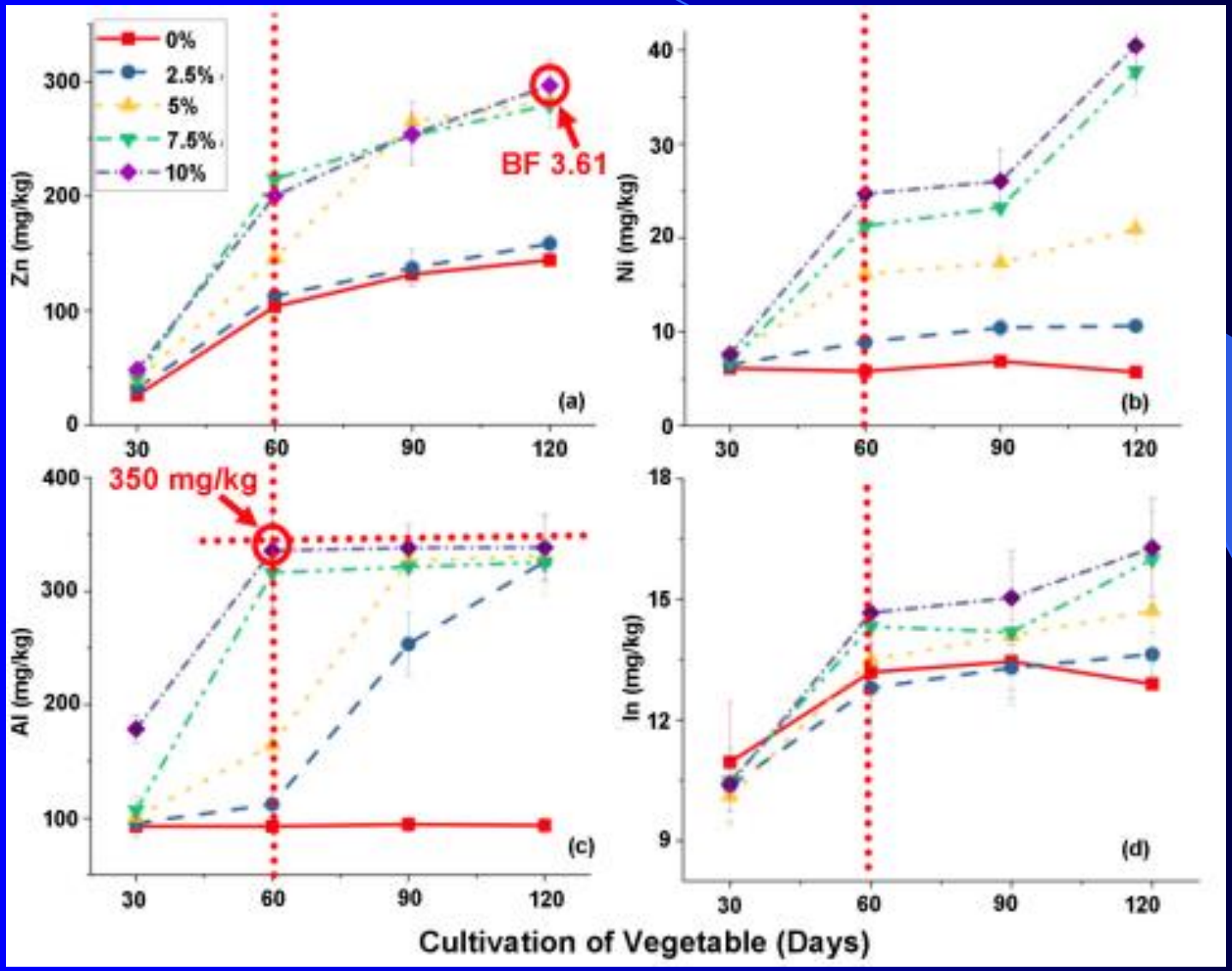


Leaching of heavy metals, PFAS

Is My Solar Panels Burning my Grass?

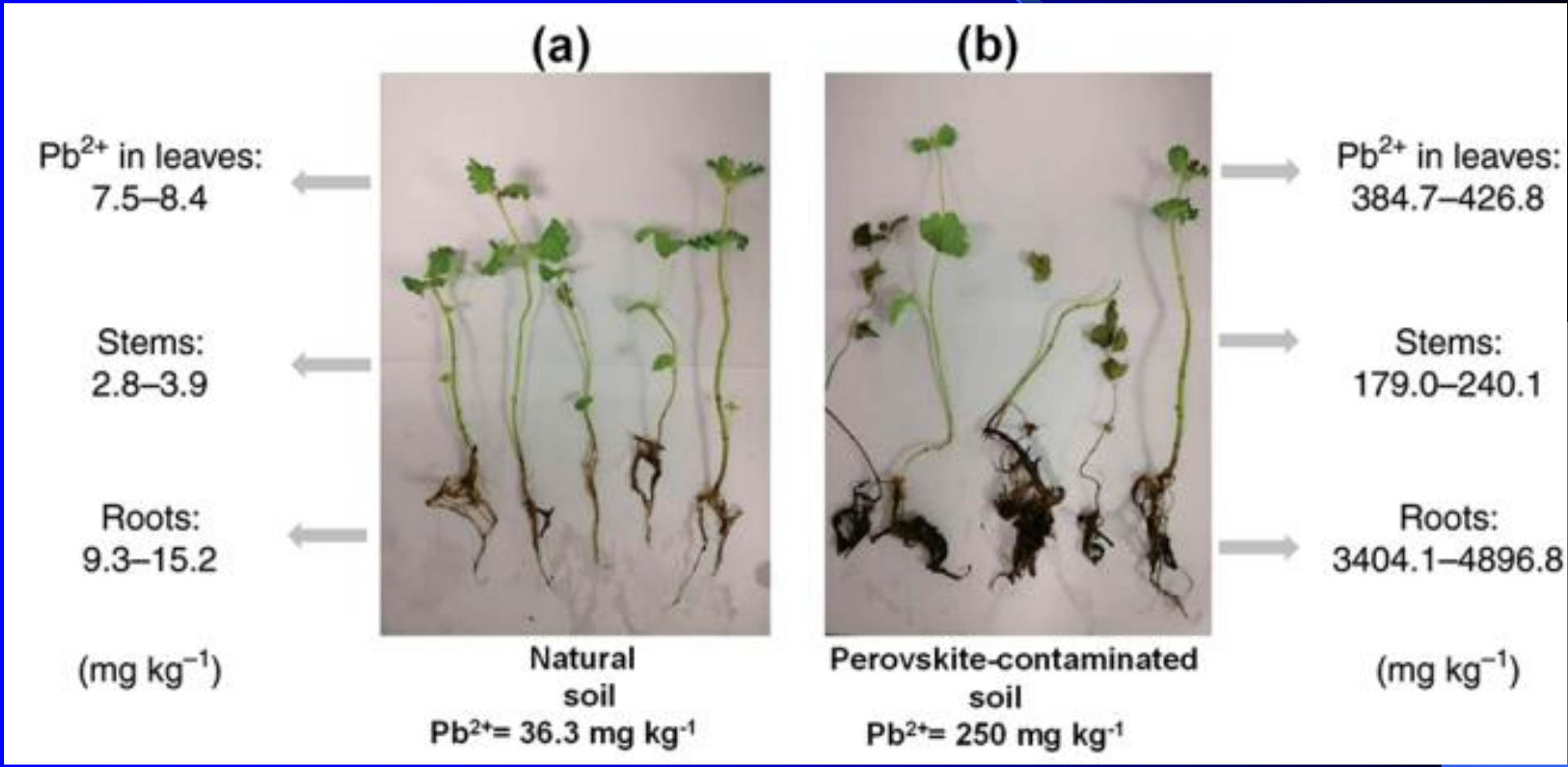
Watc

Bioaccumulation of Zn, Ni, Al, In by brassica plants

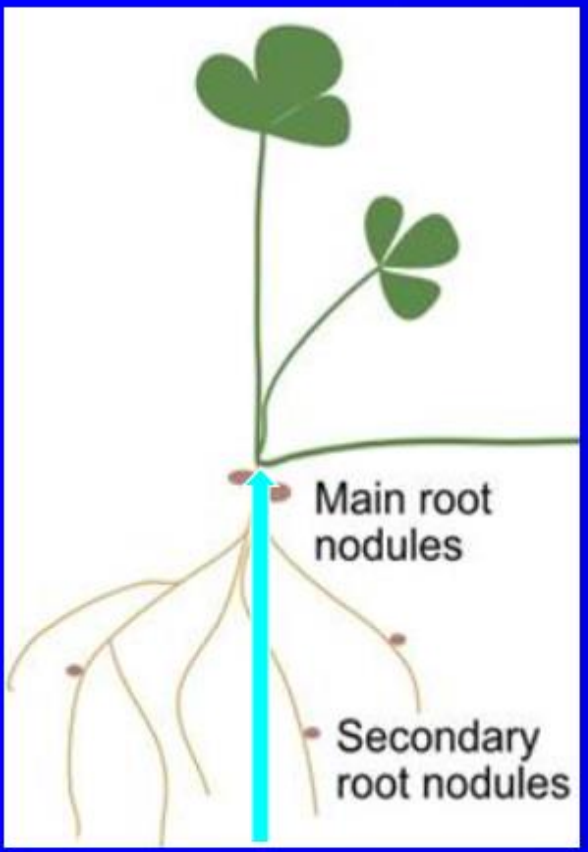


Bioaccumulation of metal halides in plants at USSP-facilities.

a) Lead



Impacts heavy metals on plants at contaminated sites



Aluminium=8,836
Lead =15.3
Nickel=23.5
Copper=8.2
Zinc=22.5

Cadmium=7.4
Lead =85.1
Copper=57.1
Zinc=196.4

1.Metal halides suppress enzyme activity that impacts ability of mycorrhizae to fix nitrogen.
2. Soil nitrogen reduced by 50% over 7 years in Italy

Leachates within food web of terrestrial vertebrates



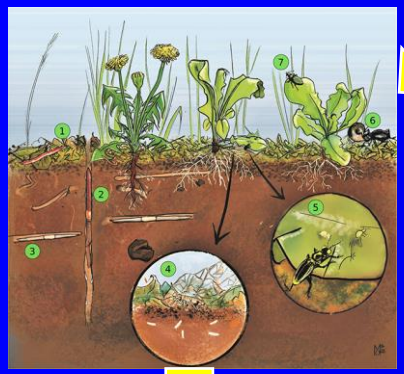








Leachates within food web on farms



Leachates impact soil organisms& micro-organisms

Plant uptake places Pb^2 etc & PFAS in stems & leaves above accepted limits for vegetation

Clods, changed pH, germination reduced soil compaction, changed C-N ratio

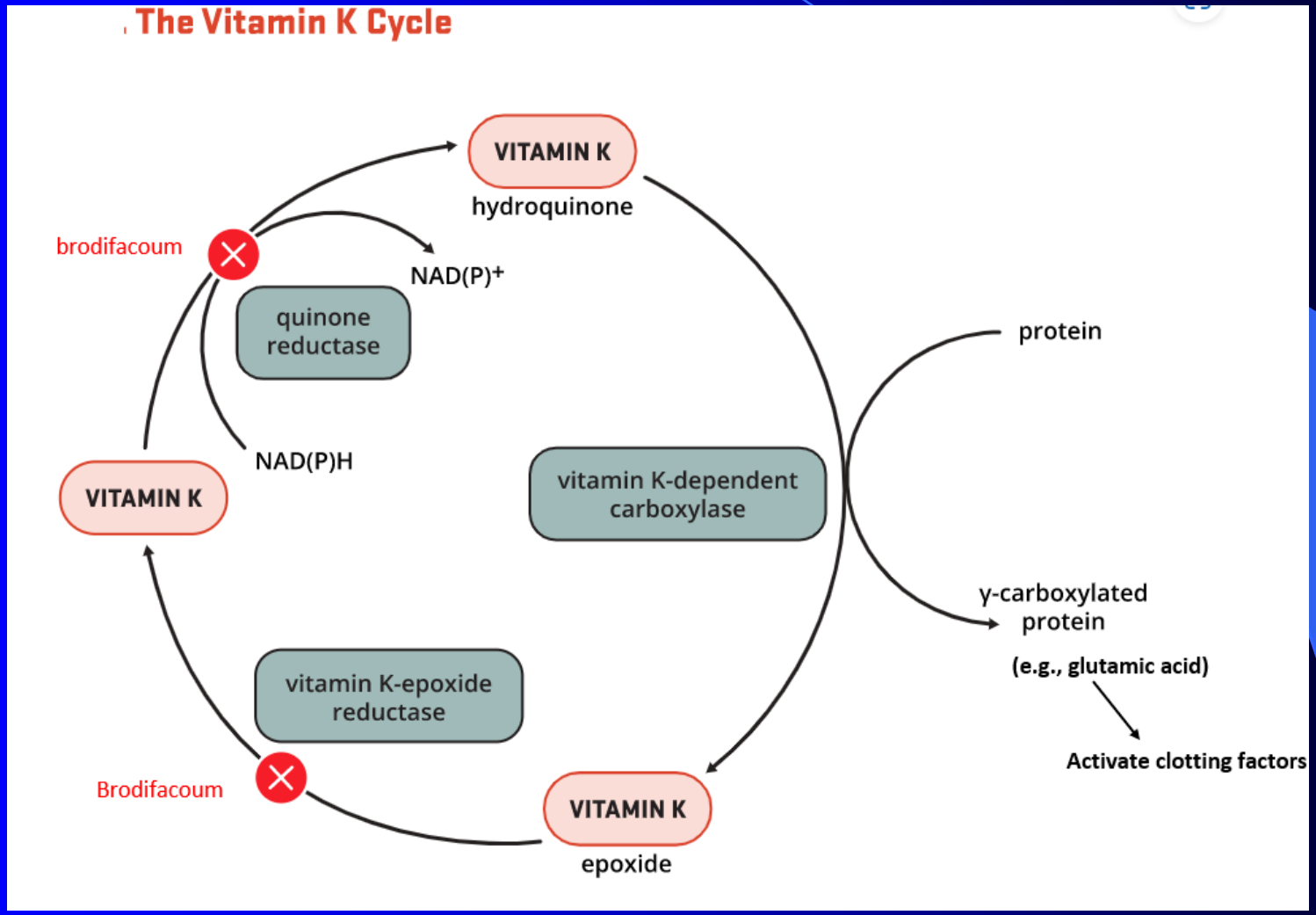
Residues in meat & vegetables we eat

Target organ toxicity & animal welfare issues

Livestock eating contaminated grass have residues in liver, kidney & neurological system

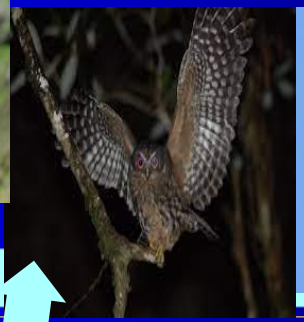
Ecotoxicology

Effect of brodifacoum on molecular processes



Food web (terrestrial vertebrates---Brodifacoum




Trees, shrubs, seeds, [illegible]
reliant on birds for pollination and seed
[illegible]persal;
[illegible]t on people planting missing
spe[illegible]

Invertebrates
(Low abundance)

Insectivores affected by few invertebrates
Fructivores have no fruit some months
Nectar feeders have few flowers & honeydew
Poor Breeding Success

Wasps

Mice

Cats

Stoats



Rats

Possums

Pests controlled

Terrestrial Food web—PFAS & metal halides







Trees, shrubs, seeds, [illegible]
reliant on birds for pollination and seed
persal;
[illegible]t on people planting missing
spe[illegible]

Invertebrates
(Low abundance)

Insectivores affected by few invertebrates
Fructivores have no fruit some months
Nectar feeders have few flowers & honeydew
Poor Breeding Success

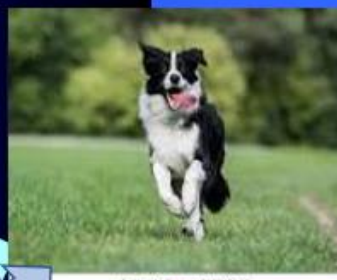
Weathering

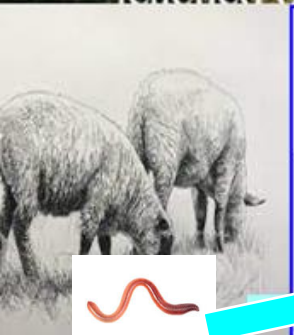
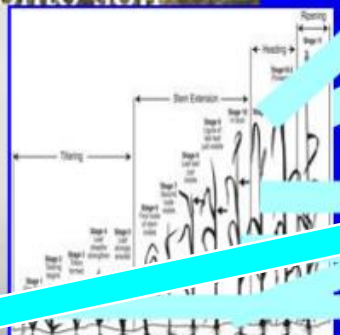
Heavy metals /PFAS
leached onto soil

Mice

Cats

Stoats



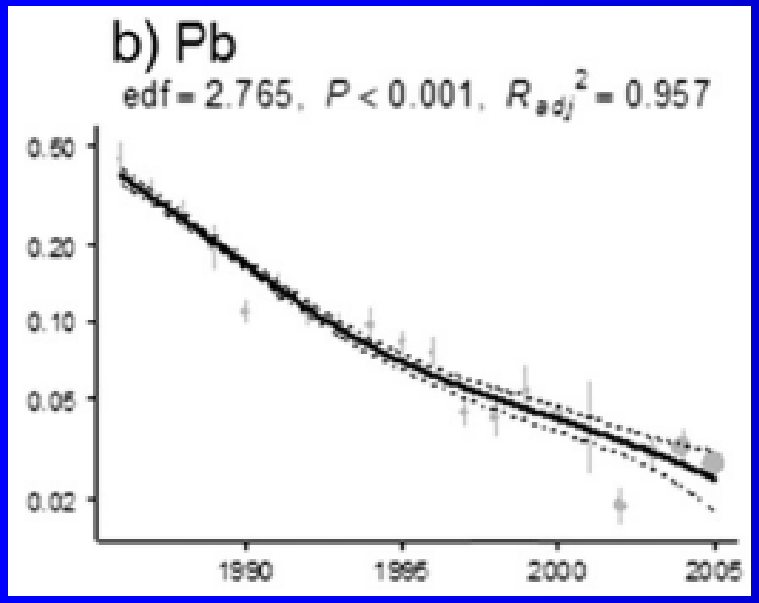



Finches

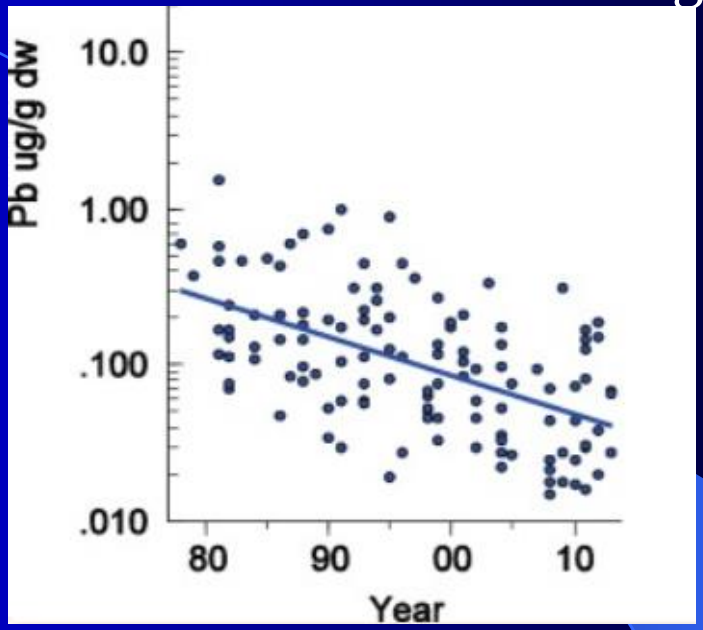
Passerines


Heavy metals in birds of prey

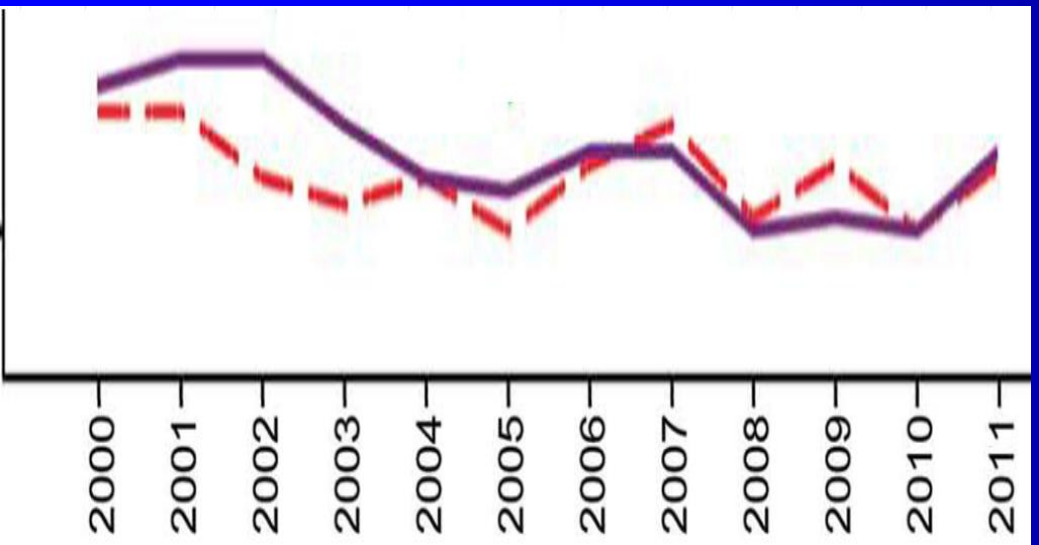
Pb Norway <1% solar energy



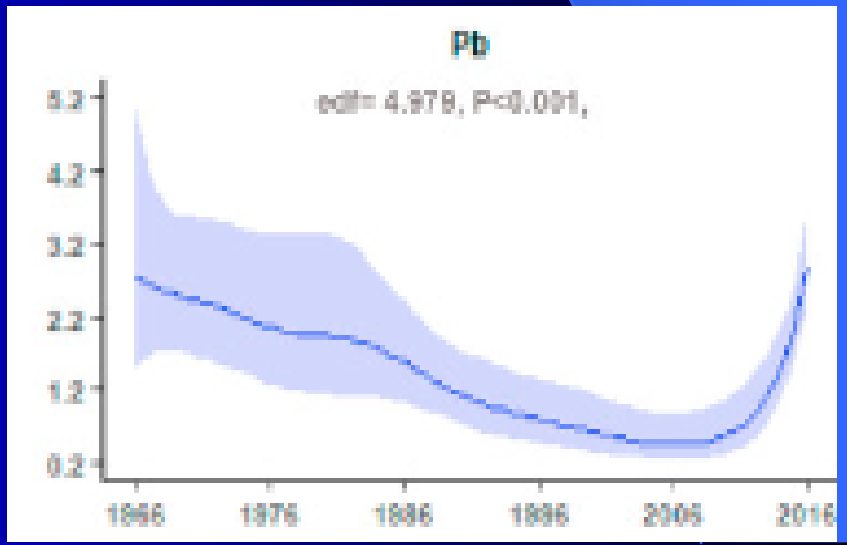
Pb Sweden <1% solar energy



Pb Italy = 22% solar energy



Pb Spain = 43% solar energy



Impacts of metal halides & PFAS on birds

Metal halides and PFAS impact birds through:

(1) Emaciation and death by starvation;
(2) Thin egg shells with breakage during incubation,
(3) Embryo feeding on contaminated albumen;
(4) Fewer chicks fledged,
(5) Immune system compromised, increased susceptibility to disease;
(6) behavioural changes;
(7) Progressive decline in populations.

a) It is inhumane, so creates issues with animal welfare;
b) It reduces fertility;
c) It reduces biodiversity.

Aquatic ecosystems

Run-off of water containing leachates

Water that contains heavy metals and PFAS runs off paddocks and down to Lake Ellesmere

All heavy metals and PFAS pushed into drains are highly toxic to aquatic organisms. Included are: Al, Cd, Pb, Zn, Cr, Ni, As, Cu, Ag….all were classified as 9.1A substances (i.e., highly toxic to aquatic organisms). Silica is classified as 9.1B (fine granules).

PFAS in water bioaccumulate in fish to the extent that eating just one fish is the equivalent of drinking PFAS-contaminated water for a month (Barbo *et al.* 2023)

Bioaccumulation of heavy metals in carp

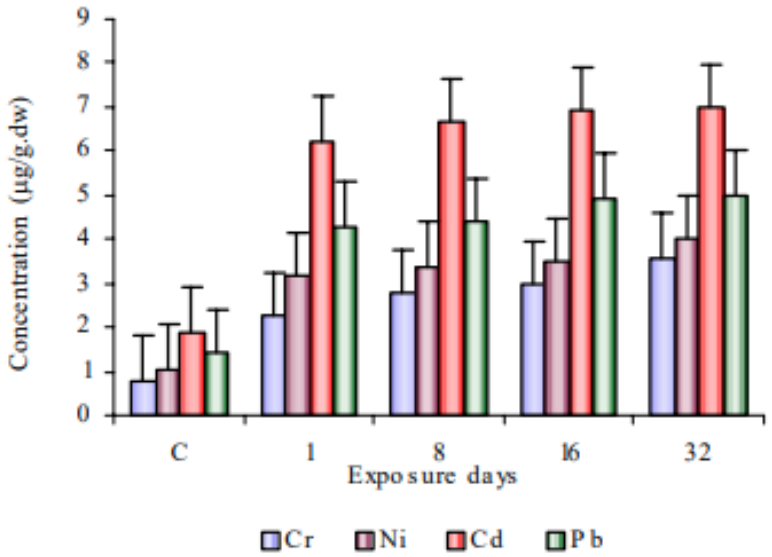


Fig. 1: Accumulation of heavy metals in gills

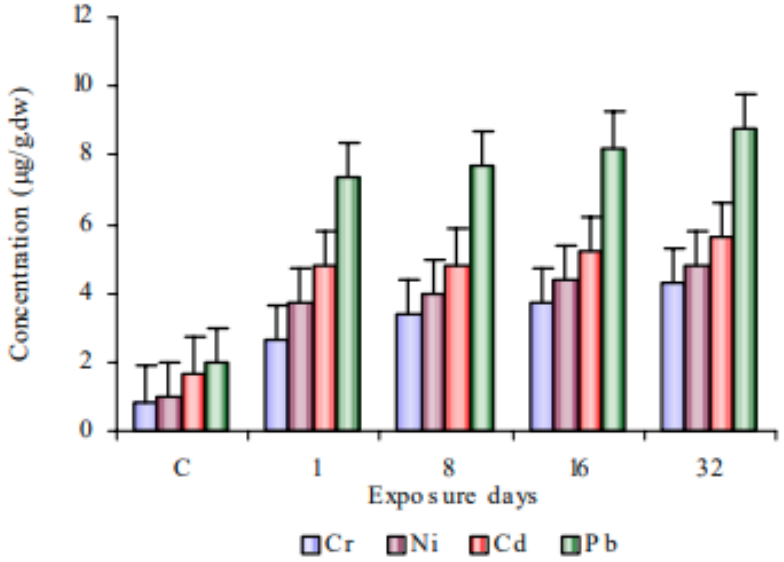


Fig. 2: Accumulation of heavy metals in liver

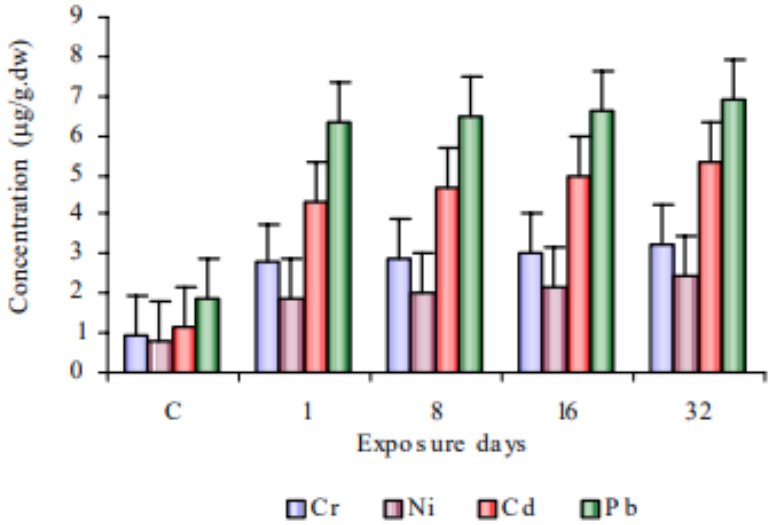


Fig. 3: Accumulation of heavy metals in kidney

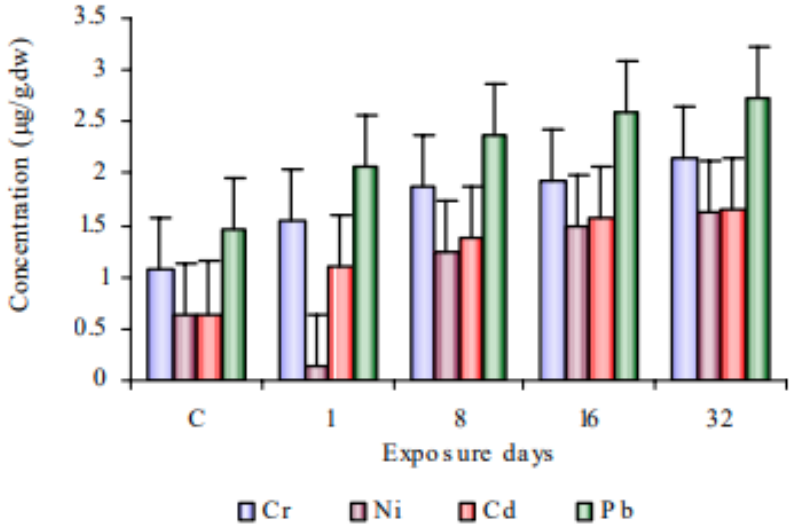


Fig. 4: Accumulation of heavy metals in flesh

Effect of metal halides on herons

Table 11. Metal accumulation in various prey species of waterbirds, Veeranam Lake, Tamil Nadu, India (Values are mean and SE; ppm).

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	$p < 0.001$

Table12 Level of metals in the different organs of the black-crowned night heron, Veeranam Lake, Cuddalore, District, Tamil Nadu [Values are mean and SE; ppm (N = 3)].

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

Summary of "Risk=Hazard x Exposure"

- Leachates are an integral part of solar technologies
- Are very significant during weather events and fire;
- Impact of leachates on soil micro-organisms >> "minor"
- Impact of leachates on soil nutrients (nitrogen, carbon) >> "minor"
- Impacts of pollutants in air in the event of a fire >> "minor"

  Large fire may result in a 'contaminated site' at Brookside
- Impacts on surface water >> "minor"

  Consents to discharge stormwater must be revoked
- Impact on aquatic ecosystems (fish, waterfowl) >> "minor"
- Impact on vertebrate ecosystems >> "minor"

The purpose of the **Resource Management Act 1991** is to:

2b) safeguard the life-supporting capacity of air, water, soil, and ecosystems.

2c) avoid, remedy, or mitigate any adverse effects of activities on the environment.