AUSTRALIAN
ENVIRONMENTAL AUDITORS

PFAS CONCENTRATIONS IN LANDFILL LEACHATE IN VICTORIA

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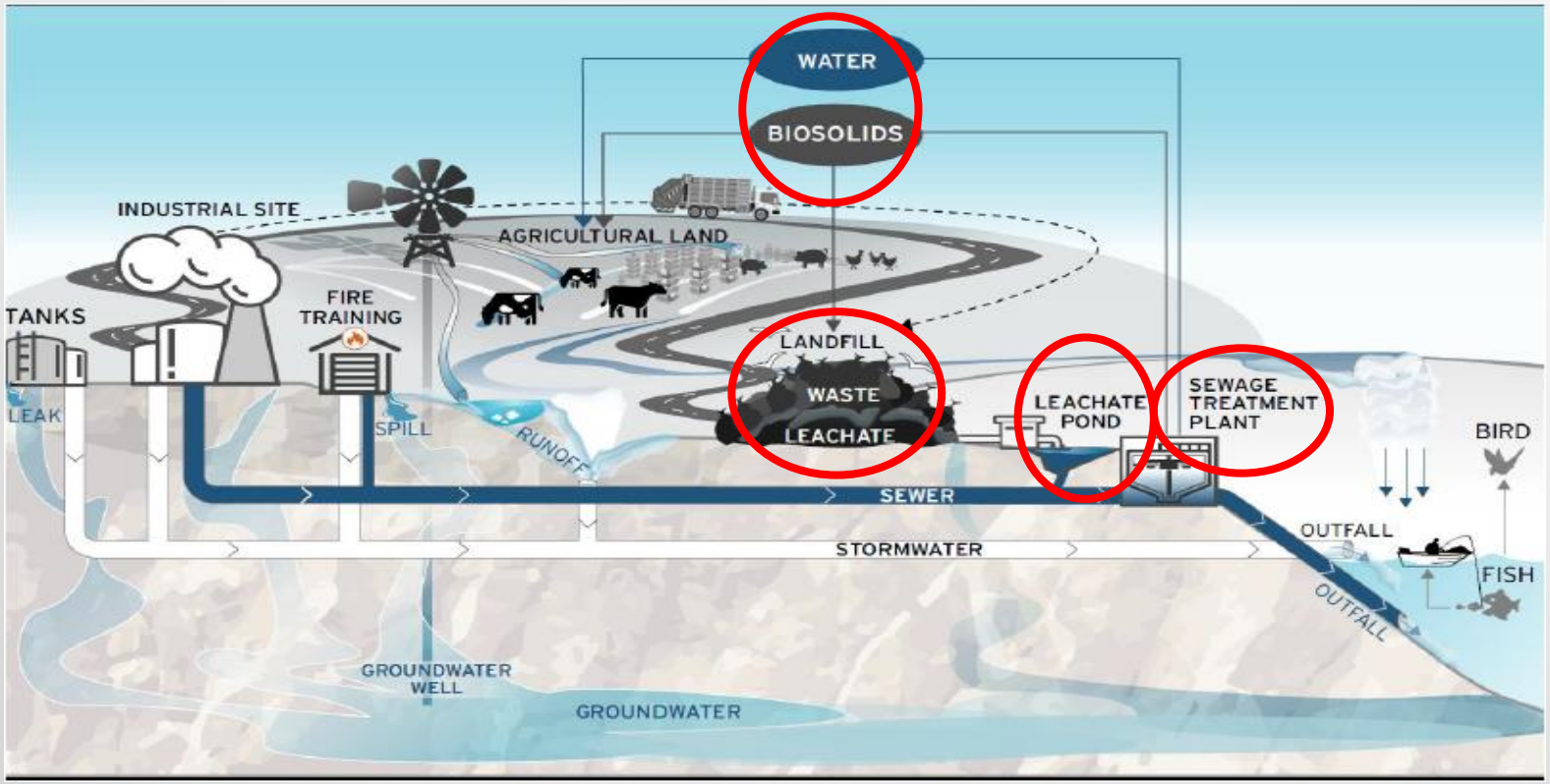
Background


WATER
BIOSOLIDS
INDUSTRIAL SITE
AGRICULTURAL LAND
TANKS
FIRE TRAINING
LANDFILL
WASTE
LEACHATE
LEACHATE POND
SEWAGE TREATMENT PLANT
BIRD
LEAK
SPILL
RUNOFF
SEWER
OUTFALL
STORMWATER
FISH
OUTFALL
GROUNDWATER WELL
GROUNDWATER

Background

- Increased focus by EPA on poor leachate management
  - Updated licence conditions for leachate level control
  - Leachate level control for unlined/partially lined sites derived from Hydrogeological assessment
- Increased disposal of leachate to sewer instead of new lagoons/ponds
- PFAS 'arrived' and leachate in PFAS assumed/thought to be a significant contributor to sewer loading of PFAS.
- At the time of the study (2018/2019) – minimal information on measured PFAS in leachate compared to measured PFAS in wastewater treatment plant influent.
- No reliable evidence that PFAS in leachate was a major contributor to PFAS in wastewater
- How do we balance the need for leachate disposal to sewer vs PFAS in leachate?

Study design

- Pilot sampling round in March 2017. 6 samples from 3 landfills testing for PFHxS, PFOA, PFOS, 6:2 FTS.
- 2018 statewide sampling program of 20 landfills for 29 PFAS (PFBS, PFPeS, PFHxS, PFHpS, PFOS, PFDS, PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, FOSA, MeFOSA, EtFOSA, MeFOSE, EtFOSE, MeFOSAA, EtFOSAA, 4:2 FTS, 6:2 FTS, 8:2 FTS & 10:2 FTS)
- Obtain leachate discharge volumes to sewer per site
- Obtain influent PFAS concentration and flow data for two WWTP's that serve greater metropolitan Melbourne
- Identify unknowns and opportunities for further investigation

Methodology

- Samples obtained from sumps with polypropylene bailers or from leachate pond
- Landfills selected to represent:
  - Leachate age range of 54 years to < 1 month
  - All waste types in Victoria
  - Lined, partially lined, unlined cells
  - Poorly managed leachate, well managed leachate and leachate recirculation
- Samples analysed using LC/MS/MS
- Rationalisation of data – sense check / outliers
- Calculation of PFAS mass from leachate to WWTP's – comparison to total PFAS mass in WWTP's .

QA/QC

- EPA QA/QC standards require that duplicate sample results do not show >20% difference
- 1 blind duplicate showed a 25% difference for PFNA – but, this is noted to be within the 2%-26% LC/MS/MS precision reported by Huset et al (2011)
- 4 of the 6 of split duplicates showed >20% difference
- 1 of these split duplicates showed a 65% difference for PFBS.

Results

Of 29 PFAS analysed for, 15 were identified in landfill leachate:

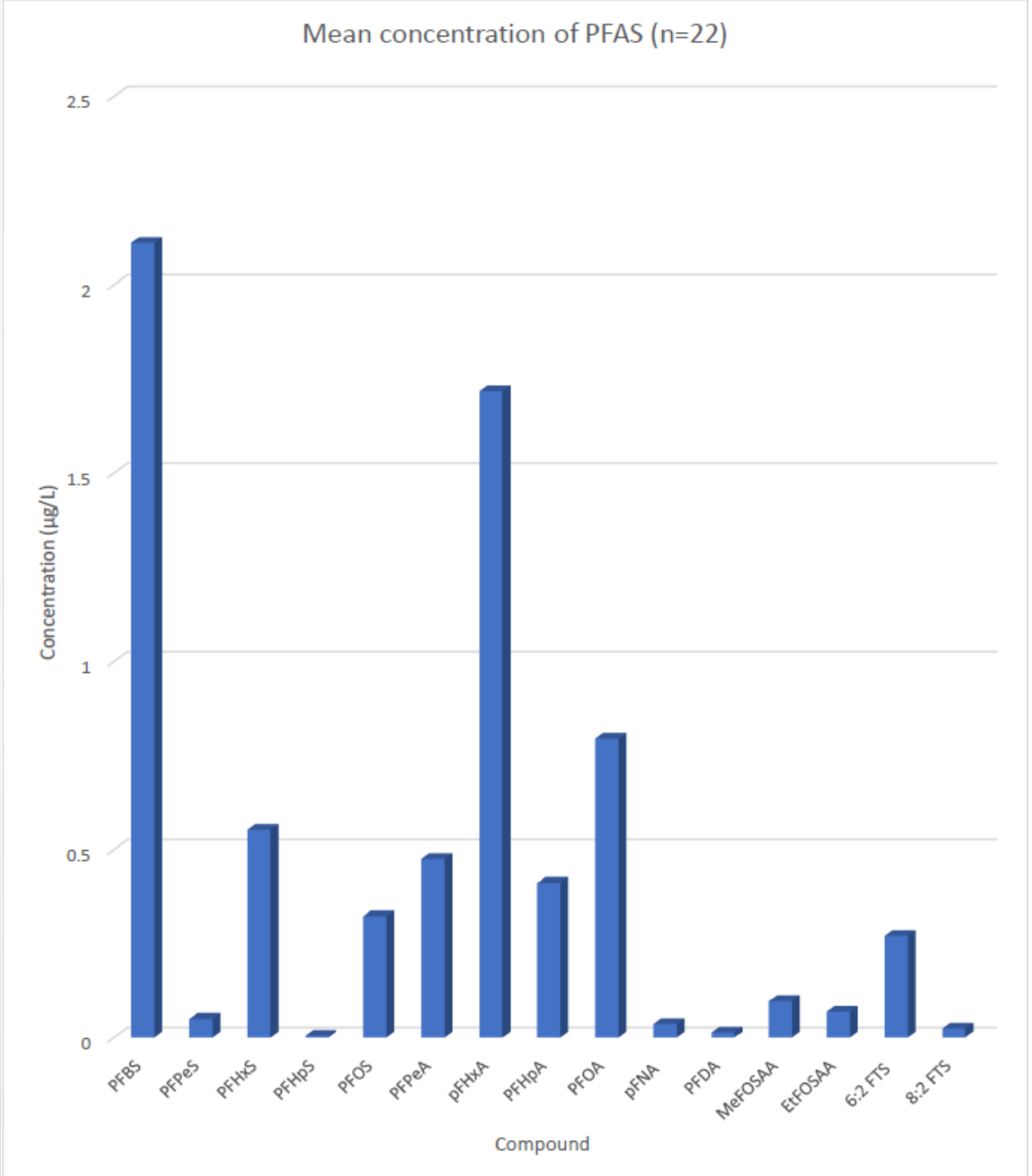
PFBS, PFPes, PFHxS, PFHpS, PFOS, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, MeFOSAA, EtFOSAA, 6:2 FTS, 8:2 FTS

Non-detects:

PFDS, PFBA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, FOSA, MeFOSA, EtFOSA, MeFOSE, EtFOSE, 4:2 FTS, 10:2 FTS

Results

All PFAS found –
mean concentrations (µg/L)



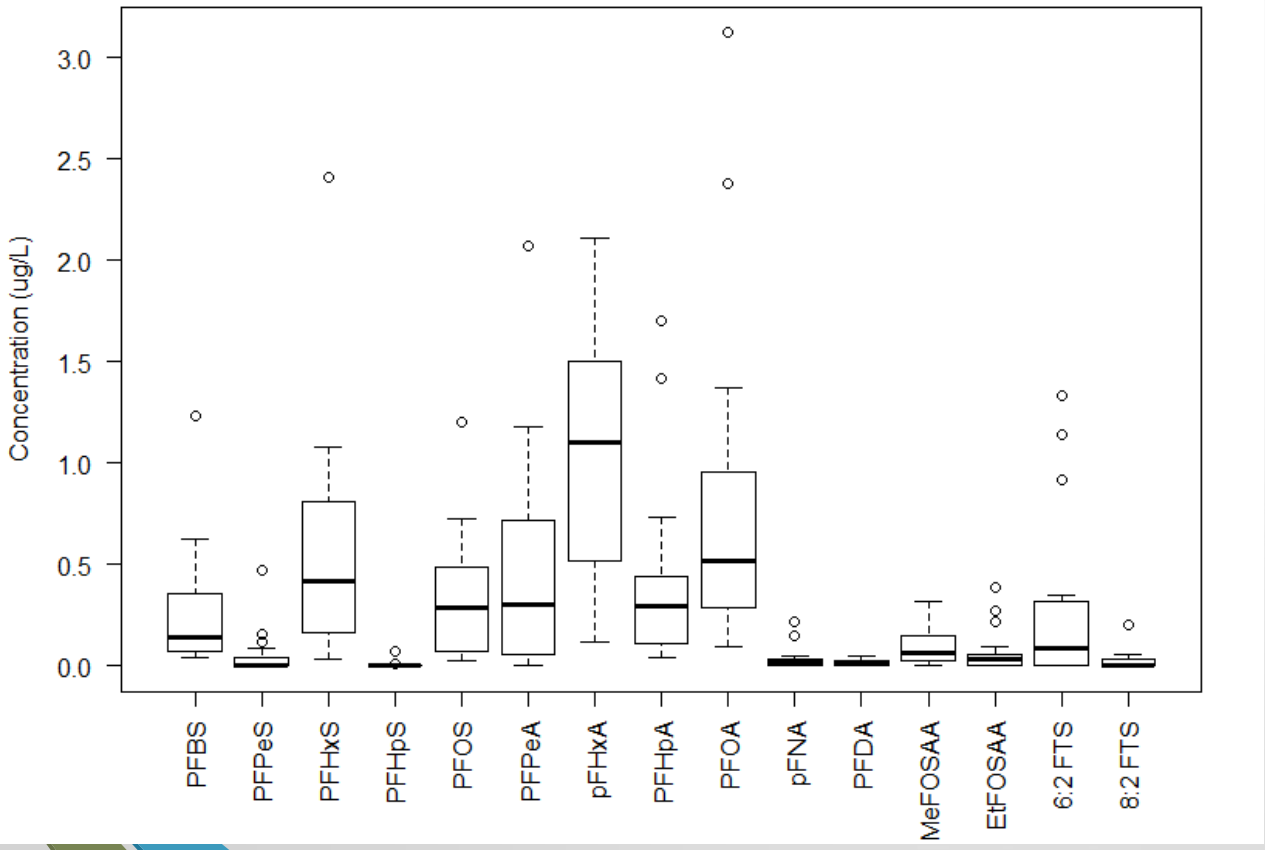
Results

- Dominant PFAS found in leachate
- Account for 91% of total mass found

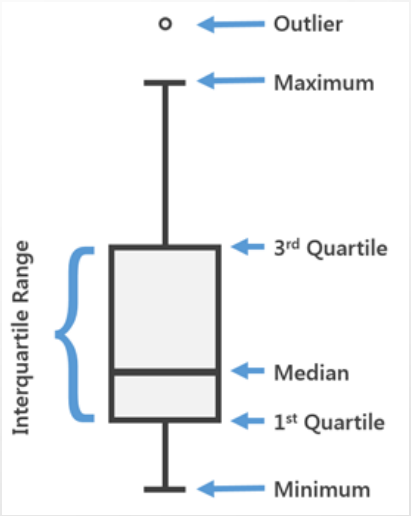
Compound	Mean concentration (µg/l)	Standard deviation (µg/l)	Range (µg/l)
Perfluorobutanesulfonic Acid (PFBS)	2.11	5.65	0.04 – 23
Perfluorohexanoic Acid (PFHxA)	1.71	1.97	0.11 – 7.74
Perfluorooctanoic Acid (PFOA)	0.79	0.76	0.09 – 3.12
Perfluorohexanesulfonic Acid (PFHxS)	0.55	0.55	0.03 – 2.41
Perfluoropentanoic Acid (PFPeA)	0.45	0.52	ND – 2.07
Perfluoroheptanoic Acid (PFHpA)	0.41	0.43	0.04 – 1.7
Perfluorooctanesulfonic Acid (PFOS)	0.32	0.29	0.02 – 1.2

Results

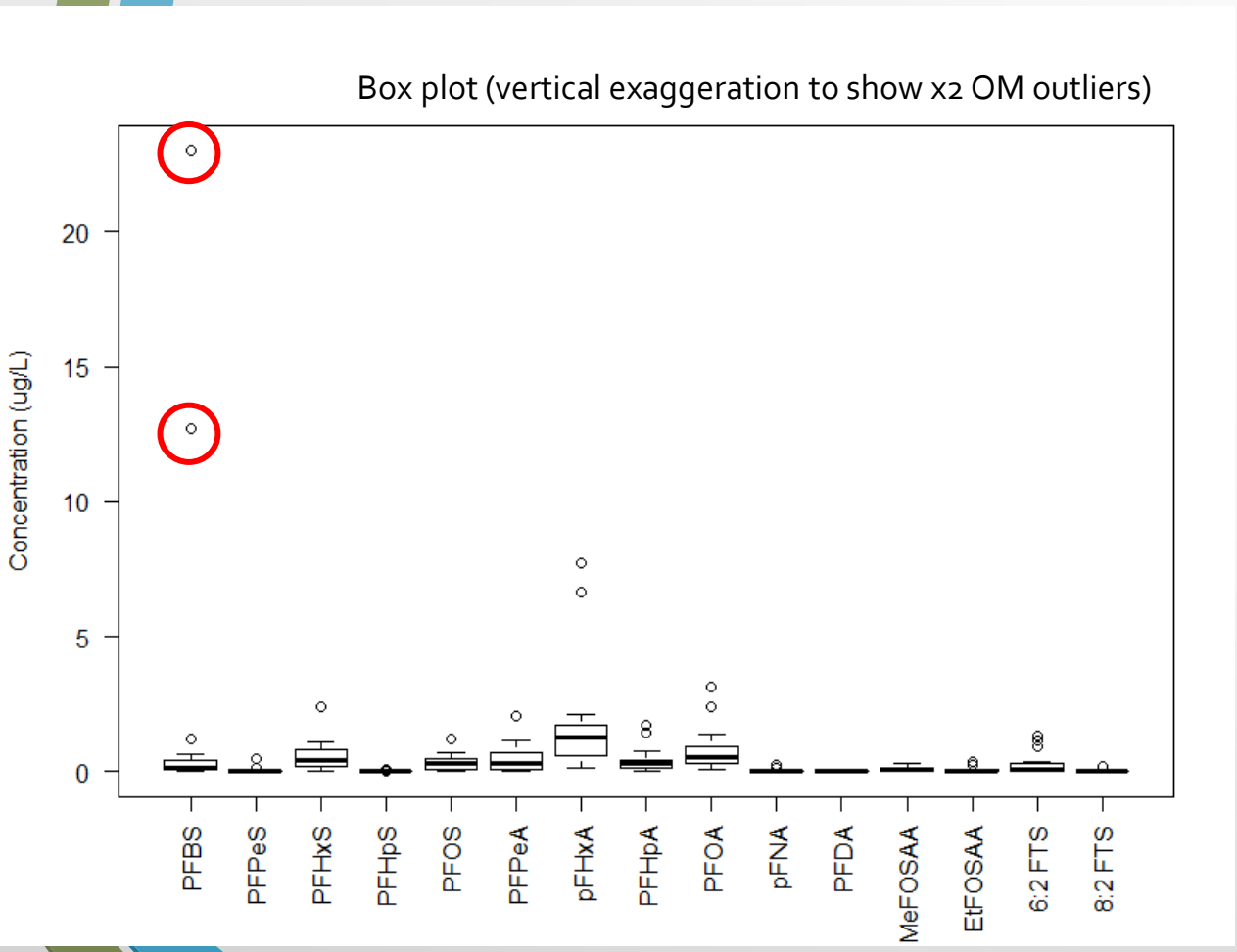
Box plot (no vertical exaggeration)

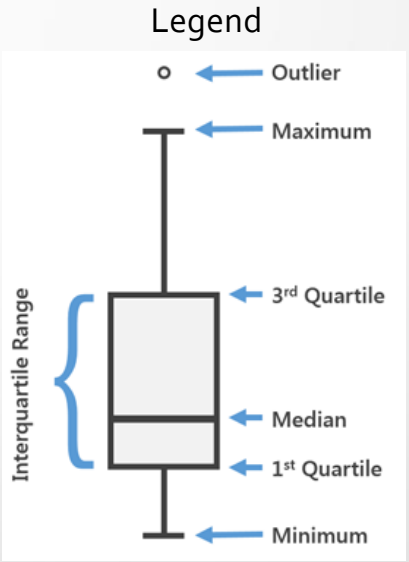


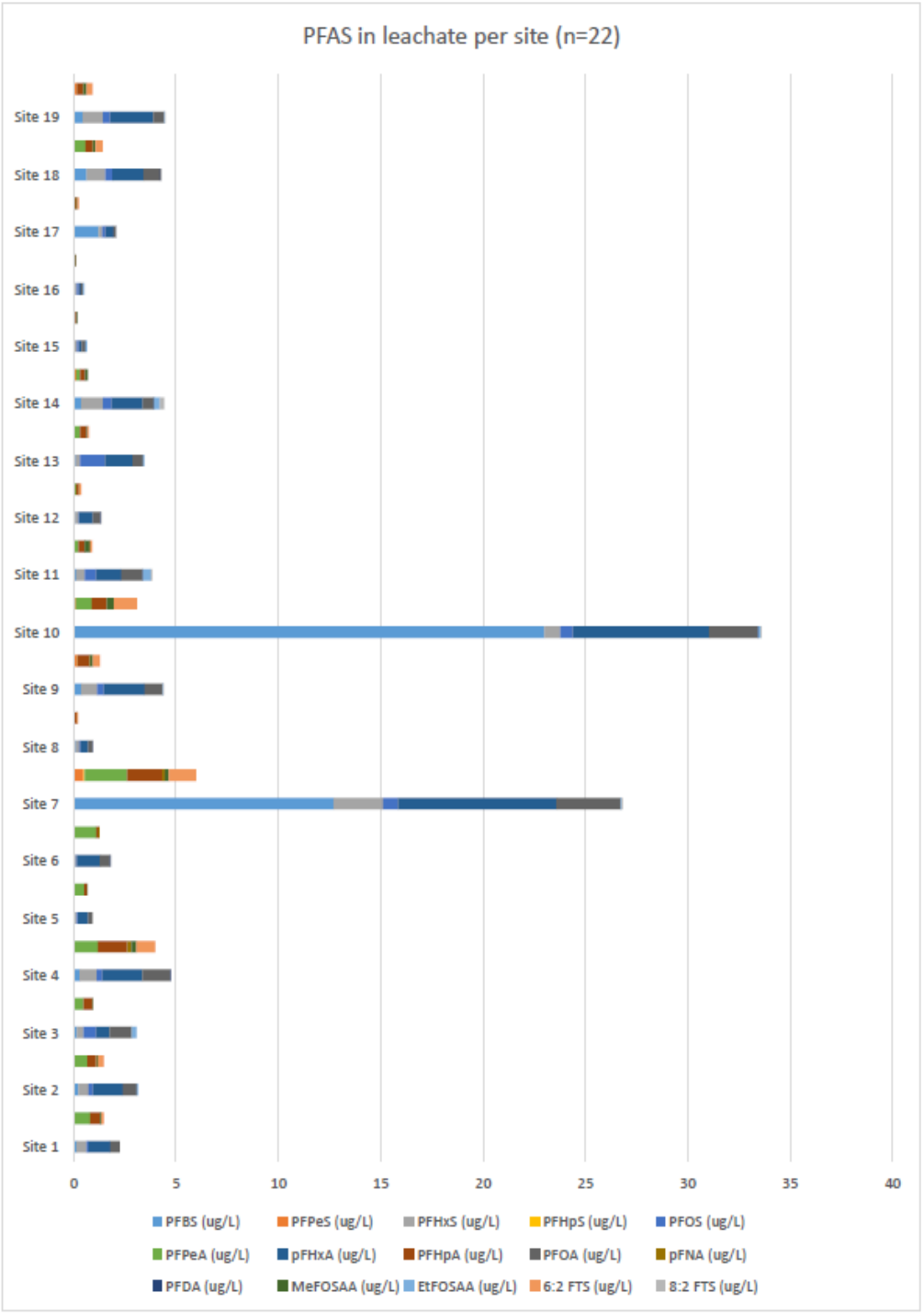
Legend



Results


Box plot (vertical exaggeration to show x2 OM outliers)
Concentration (ug/L)
0
5
10
15
20
PFBS
PFPeS
PFHxS
PFHpS
PFOS
PFPeA
pFHxA
PFHpA
PFOA
pFNA
PFDA
MeFOSAA
EtFOSAA
6:2 FTS
8:2 FTS


Legend
Outlier
Maximum
3rd Quartile
Median
1st Quartile
Minimum
Interquartile Range



Data rationalisation

- Sites 7 and 10 are anomalies
- Greater mass of dominant PFAS found at these sites
- PFBS exceptionally elevated (light blue line)
- PFBS most dominant PFAS in leachate across whole study due to the results from sites 7 & 10 alone
- Analytical issues with PFBS
- PFBS results from 7 and 10 removed as outliers – not representative of state trends – not used in mass calculation to sewer.
- Other outliers retained in data, as;
  - Were not only ID'd at sites 7 or 10
  - not subject to analytical issues
  - not as extreme as PFBS outliers
  - caution around removing too much data as sample numbers were limited

Victoria vs National trends

- EPA sample results were compared to the Gallen et al 2017 Australian national study on PFAS in landfill leachate
- The 5 dominant PFAS by mass were the same with one possible exception
- PFPeA was identified as dominant in EPA samples – Gallen found that extraction efficiency of PFPeA was too low so it was not reported*
- PFBS outlier removal dropped PFBS to 6th most dominant

PFAS	Average concentration in landfill leachate Gallen et al 2017 (µg/l) (n=97)	Average concentration in landfill leachate EPA VIC 2018 (µg/l) (n=21)
PFHxA	1.7	1.71
PFOA	0.69	0.79
PFHxS	1.2	0.55
PFHpA	0.43	0.41
PFOS	0.31	0.32

*C.Gallen personal communication July 2018

PFAS mass to sewer

- PFAS contribution from leachate calculated by;

* mean PFAS concs' per site x mean annual leachate discharge per site (20.6 ML/yr)

x10 (10 sites discharge leachate)

* mean PFAS concs' per site x median annual leachate discharge per site (9 ML/yr)

x10 (10 sites discharge leachate)

- Median used in addition to mean, as the range is 2.5 – 84.5 ML/yr with 3 sites having significantly greater discharges than the remaining 7.
- PFAS mass to WWTP's (all sources) calculated by multiplying the influent PFAS concs' by the annual volumetric flow of influent into the 2 plants

PFAS mass to sewer

- PFAS concs' in influent of the two WWTP's serving greater metropolitan Melbourne in 2017 was 0.16 to 0.21 µg/L (Coggan et al 2017) (15 PFAS in WWTP analysis suite*)
- Annual PFAS mass to the two WWTP's in 2017 was 49.65 to 65.15 kg/yr – all sources.
- PFAS mass to sewer from landfill leachate using the mean discharge volume of leachate to sewer 1.05 kg/yr
- PFAS mass to sewer from landfill leachate using the median discharge volume of leachate to sewer 0.45 kg/yr
- Leachate contribution to PFAS in sewer at mean discharge volume 1.6 to 2.1%
- Leachate contribution to PFAS in sewer at median discharge volume 0.7 to 0.9%

*Assumed to be same suite as EPA samples. PFOS, PFOA, PFHxS, PFHxA, PFPeA, and PFBA stated as present by Coggan et al 2017.

Conclusions

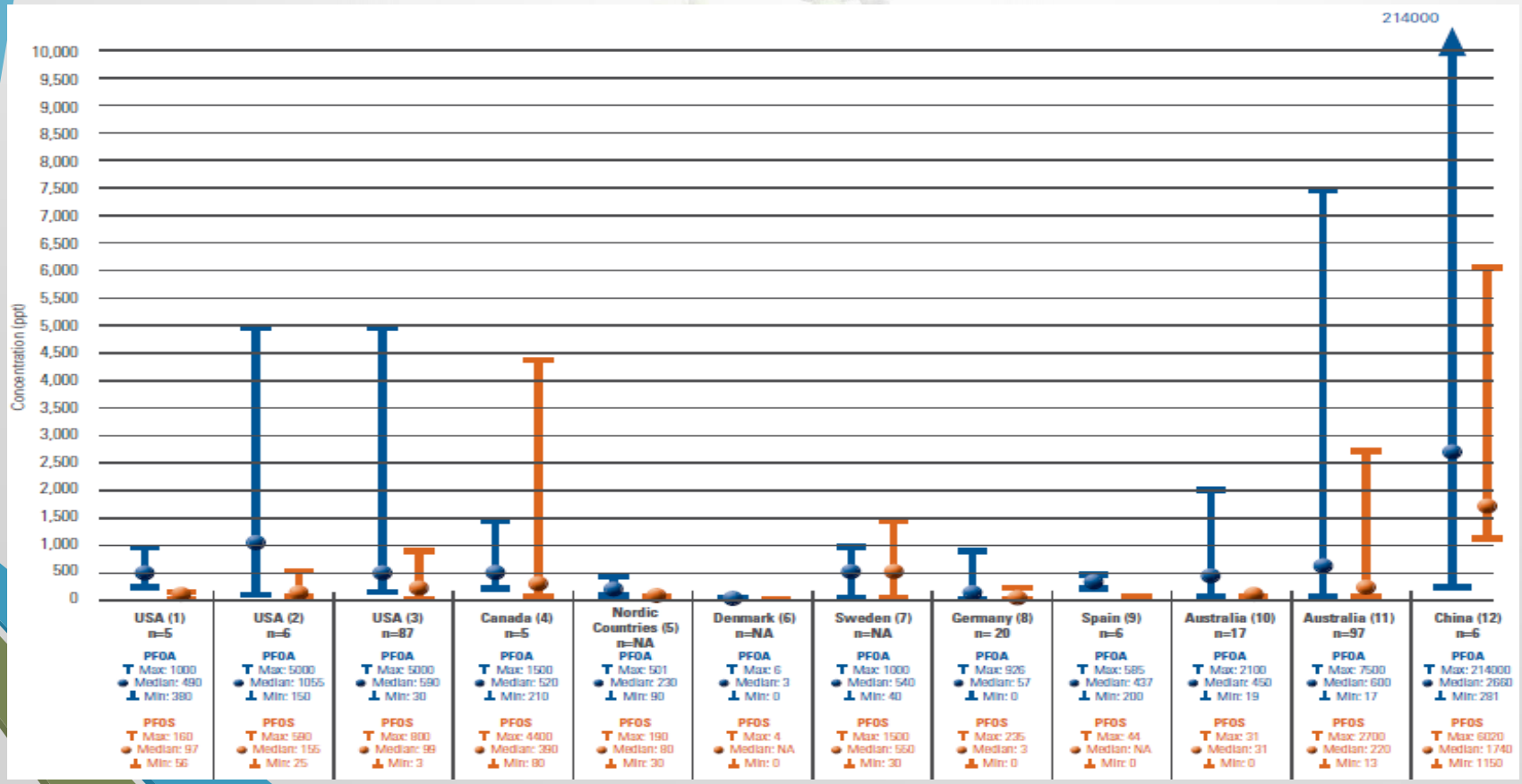
- Leachate contribution to PFAS mass in WWTP's appears minor at this stage

- The calculated mass to sewer per site was not multiplied by all landfills in Victoria (approx. 65) to inform the estimated total mass to sewer as;
  - Many do not discharge leachate to sewer
  - Doing so would not be representative of reality as the discharge volume is the variable that affects the mass contribution the most.

- The estimated PFAS mass to sewer from the 10 sites in the study that discharge leachate is considered reasonably representative of the statewide mass as;
  - The 5 largest landfills in the state were in the 10 discharging sites
  - The 5 largest landfills also had the greatest leachate discharge volumes to sewer compared to all others – by an order of magnitude
  - Site inspections indicate in the rest of the state, leachate discharges are significantly less than these 5 largest sites.

Conclusion

- Michigan Waste & Recycling Association March 2019 paper – statewide study
- PFOS and PFOA mass from leachate 'relatively minor' proportion of that found in WWTP influent.
- Very similar methodology to EPA Victoria – but PFOS and PFOA only
- Presented some graphed global PFOS and PFOA results



Discussion – PFAS sources

- PFAS ubiquitous in consumer products – paper, cardboard, textiles, carpet, furniture, food packaging, cookware, electronics.
- These consumer products become MSW waste / kerbside waste
- Only 15% of MSW was diverted or recycled in Victoria in 2016-2017*
- Prominence of shorter chain PFAS. 5 of 7 dominant PFAS in leachate are C4 – C7. With only PFOA and PFOS C8.
- Indicative of phase out of PFOS and PFOA, though still present in significant concentrations compared to the shorter chain PFAS.
- Usage time between product purchase and disposal – reflective of older products with long usage life which may have PFOA/PFOS in e.g. textiles, furniture, carpets
- Newer products with shorter usage life likely produce the shorter chain PFAS e.g. electronics, paper, cardboard, food packaging. PFOS/PFOA not in these products
- But…. these shorter usage life products are mostly recyclable and so are influenced by performance trends in that sector and societal recycling behaviours.
- AFFF and ATC affected fire debris disposal. Disposed of at most landfills sampled.

***sustainability Victoria 2018 – but 43% MSW recovered in 2018/2019 (Sustainability Victoria 2020).**

Discussion – sites 7 & 10

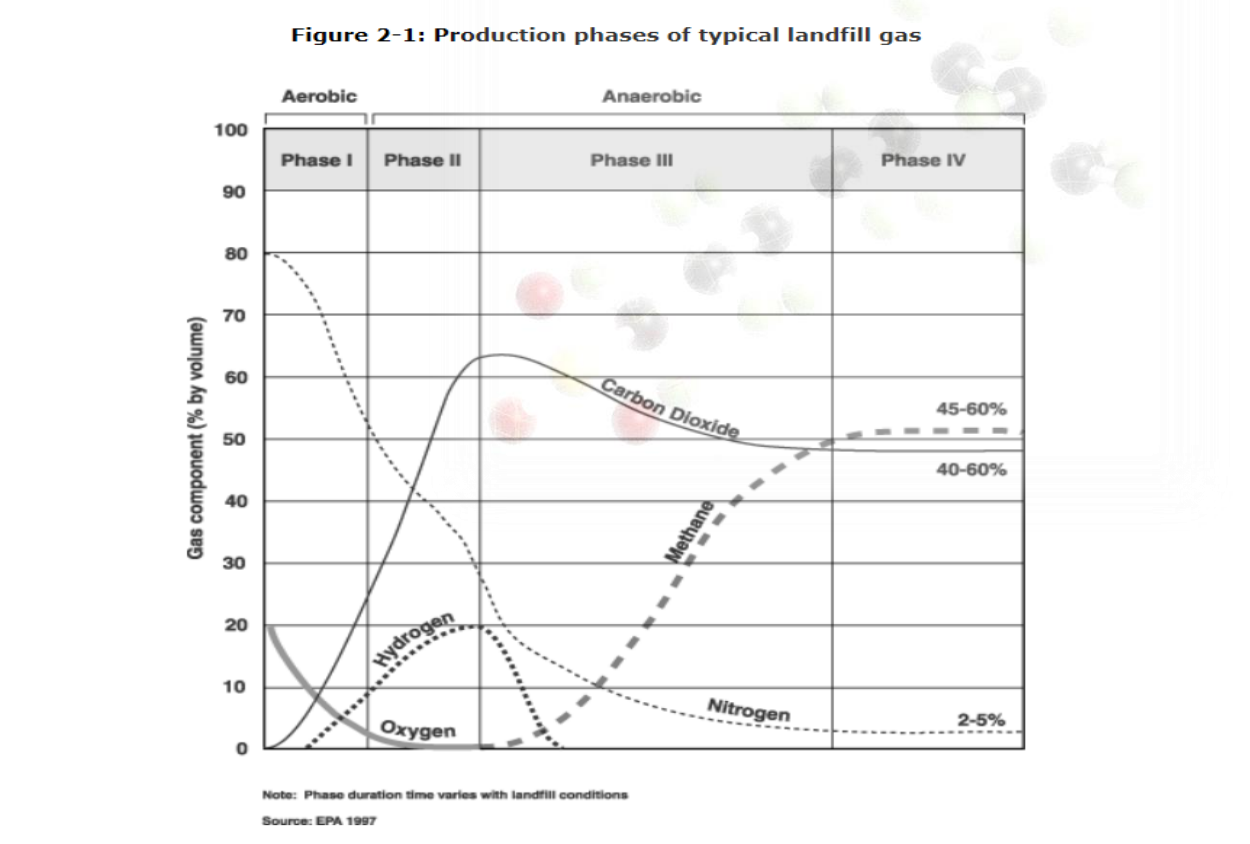
- Extremely high concentrations of PFBS in these leachates
- PFHxS, PFHxA, PFOA, PFPeA also significantly higher than other sites sampled
- Sites 7 & 10 accepted shredded vehicle interiors, paper manufacture waste and sludge from WWTP ponds.
- Site 7 – leachate sample represented multiple disposal areas with these wastes present
- Site 10 – leachate sample was obtained from the leachate pond, represents all cells with these wastes present
- Both sites recirculate leachate – possible effects ???

Influence of leachate composition

- Wang et al 2015 reports significant sorption of PFAS onto solid organic matter in sewage sludge.
- As leachate contains significant solid organic matter sorption is likely an important mechanism influencing PFAS in leachate
  - treatment removing solids and could influence PFAS occurrence – temporal variance
  - Considerations for sampling – filtered vs unfiltered
- 24 hr precipitation reported by Benskin et al 2012 as important factor controlling PFAS occurrence in leachate.
- 24 hr precipitation is site specific – influences leachate generation rate – which will influence leaching rate and dilution factor
- Rehabilitation practices will moderate the importance of 24 hr precipitation

Influence of leachate composition

- Benskin et al 2012 also report pH as an influence on PFAS occurrence in leachate.
- Leachate pH changes over time in leachate



Wrap up and further work

- The sampling and analysis of leachate in Victoria strongly indicates that contribution of PFAS from leachate to WWTP is minor at 0.7% – 2.1%
- The % contribution is a conservative estimate as it includes the mean data which is heavily influenced by 5 large sites with significant discharge volumes.
- Limited number of landfill sampled (n=21)
- Limited number of PFAS (15) in analysis suite
- To gain a more accurate figure of the PFAS contribution to WWTP;
  - Each landfill that discharges leachate to sewer should be subjected to ongoing PFAS sampling to build up site specific trends
  - Leachate discharge volumes to sewer should be recorded regularly for each site
  - The PFAS mass calculation should be site specific based on these numbers

Wrap up and further work

- EPA Victoria Interim Position Statement on PFAS October 2020 (Publication 1669.4) incorporates the outcome of this study.

Landfill leachate discharge to sewer

EPA's position is that leachate discharges to sewer (including trade waste) should not be generally restricted on the basis of PFAS content. Landfill sites and the water treatment industry should be vigilant and work collaboratively to identify where specific sites warrant further consideration, such as when a site's leachate has unusually elevated concentrations of PFAS and discharges a high volume of this leachate to sewer.

- Whether any PFAS limits are applied is a matter for water authorities
- An option to bypass the PFAS to sewer issue is to build more leachate storage/evaporation lagoons, but….
- PFAS in lagoon sludge – returned to landfill at desludging?
- PFAS flux via typical landfill liners is not fully understood
  - – one study using bentonite indicates minimal attenuation in low K / high CEC materials
  - - Rowe et al 2020 found low diffusion of PFAS through LLDPE with EVOH core.

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Thank You :)

Questions?

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