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Title: Phosphate dosing of mains water – Novel approaches to water loss reduction through leakage detection and policy

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Detection and tracing of leakage in the environment are essential components of water loss reduction strategies. Industry standard techniques for tracing leaks include analysis of chlorine and trihalomethane concentrations, but levels of these determinands can fall below detection limits due to their volatile nature[1]. Consequently additional tools to trace leakage in the environment are a useful step to move towards minimum losses. Dosing of mains water with phosphate (P) has been shown to be highly effective in reducing concentrations of lead in drinking water to current public health standards. In the UK, > 95% of water supplies are dosed at c. 1 mg P/L[2]. In the USA over half of supplies are dosed, and other countries (e.g. Ireland) are considering dosing for plumbosolvency reduction. Given the extent of dosing, this paper considers the following questions:

- Could the phosphate added to mains water be a useful tracer of leakage?
- Can phosphate dosing be incorporated into leakage policy to reduce water losses?

Recent work has shown the ratio of the stable isotopes of oxygen (^{18}O and ^{16}O) in the phosphate molecule (termed $\delta^{18}O_{PO4}$) to be a potentially useful tracer of P in the environment[3]. We assessed the potential benefit of this novel isotope technique for leakage tracing by undertaking a programme of mains water sampling across England and Wales. 40 samples were taken across all the major water companies in addition to the source phosphoric acid used in dosing. The water samples fall into two categories based on the different source acids used, with 70% of the samples were dosed with acid Type A. As illustrated in Figure 1, Type A waters have a relatively distinctive isotopic fingerprint in comparison to other P sources, such as fertilizer or sewage treatment effluent. This suggests that P in leakage from mains water dosed with Type A acid can be distinguished from other P sources. There is potential for this technique to be incorporated into the standard suite of leakage tracing methods.

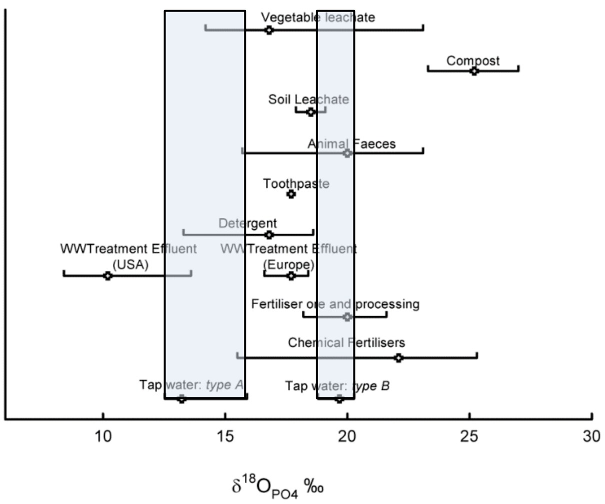

Figure 1 The isotopic fingerprint ($\delta^{18}O_{PO4}$) of phosphate dosed tap water in England and Wales relative to other sources of phosphate.

Whilst phosphate added to mains water may be potentially useful tool for tracing leaks, there are also significant cost implications. We used phosphate rock price trends, estimates of dosing concentrations and national leakage rate data to quantify the cost of phosphate lost to the environment from leakage in England and Wales. The total cost between 1994 – 2014 is estimated to be c. $9 million, with current annual operational costs in 2015 estimated to be $1 million per year. With limited alternatives to phosphate dosing[4] and increasing costs of source phosphate rocks[5], the commercial cost of P leakage is likely to continue to increase.

Phosphate lost from leakage has additional environmental costs through potential eutrophication. We quantified the environmental significance of the loss of P from leakage in the Thames catchment, England. We used historic leakage rates[6], dosing concentrations and extents[7] to derive the total flux of P and compared this to published sewage treatment discharges[8]. In 2011 the flux of P from mains leakage is estimated to be c. 40% of current sewage treatment discharges. With future improvements to wastewater treatment the importance of mains leakage will increase.

In the UK water loss targets are set by calculating the Sustainable Economic Level of Leakage (SELL). The SELL is the level of water loss at where it would cost more to make further reductions in leakage than produce the water from another source, taking into account benefits derived from both water savings and social/environmental improvements. To date these calculations have included the environmental benefits of reduced water abstraction and chemical consumption due to lower leakage levels, but have not considered loss of P. Figure 2 illustrates how the environmental impact of P losses from leakage could be incorporated into the SELL calculation through an additional environmental cost function. Implementation of policy instruments to incorporate this additional cost into the calculation would lower the SELL value towards minimum losses.

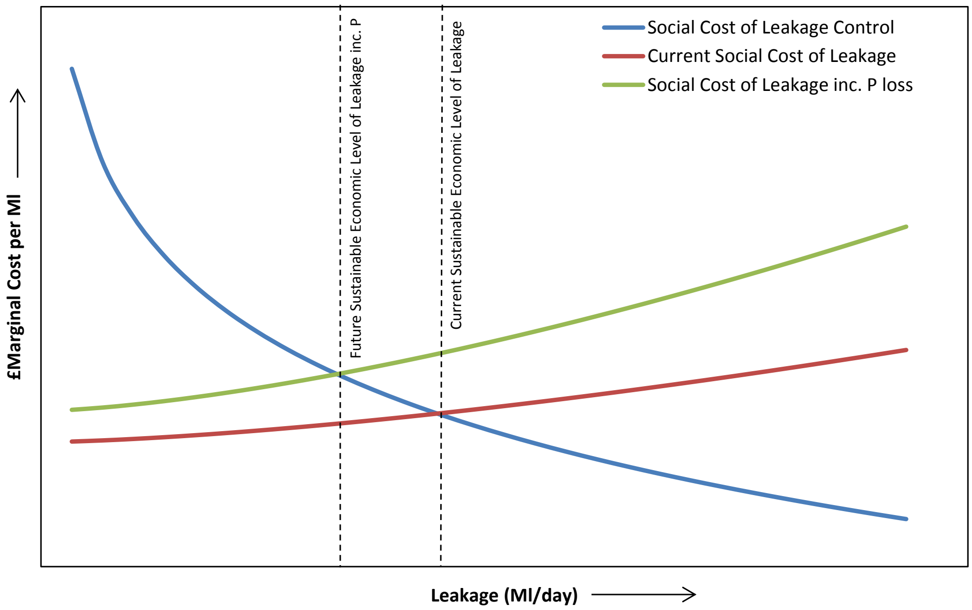

Figure 2: An example calculation of the sustainable economic level of leakage including and excluding additional environmental costs associated with leakage of phosphate (P)

References

1. Pavelic, P., P.J. Dillon, and B.C. Nicholson, *Comparative Evaluation of the Fate of Disinfection Byproducts at Eight Aquifer Storage and Recovery Sites.* Environmental Science & Technology, 2006. **40**(2): p. 501-508.
2. CIWEM. *Lead in Drinking Water*. 2011; Available from: http://www.ciwem.org/policy-and-international/policy-position-statements/lead-in-drinking-water.aspx.
3. Gooddy, D.C., et al., *An isotopic fingerprint for phosphorus in drinking water supplies.* Environmental Science & Technology, 2015.
4. UK Water Industry Research Ltd, *Alternatives to Phosphate for Plumbosolvency Control* 2012, UK Water Industry Research Ltd: London.
5. Elser, J.J., et al., *Regime shift in fertilizer commodities indicates more turbulence ahead for food security.* PloS one, 2014. **9**(5).
6. Thames Water, *Water Resources Management Plan 2015-2040*. 2013, Thames Water Utilities Ltd: Reading, UK.
7. Comber, S., et al., *Phosphate treatment to reduce plumbosolvency of drinking water also reduces discharges of copper into environmental surface waters.* Water and Environment Journal, 2011. **25**(2): p. 266-270.
8. Haygarth, P.M., et al., *Sustainable phosphorus management and the need for a long-term perspective: The legacy hypothesis.* Environmental science & technology, 2014. **48**(15): p. 8417-8419.