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COMMENT

Comment on 'Estimating methane emissions from manure: a suitable case for treatment?'

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Abstract

Ward *et al* (2024 *Environ. Res.* **1** 025003) recently published a paper in this journal (Ward *et al* 2024 *Environ. Res.* **1** 025003) asserting that methane emissions from manure management in the United Kingdom Inventory of Greenhouse Gas emissions could be under-estimated by a factor of four to five. This was based on extrapolation of measurements from two farms located in the south-west of England where manure management is purposely set-up to encourage methane release and capture, for use as a fuel source. We argue that methane thus *extracted* cannot be compared with the quantities *emitted* to the atmosphere on a typical farm which is what the national Inventory seeks to estimate, and show that existing Inventory calculations are consistent with wider literature and typical management practices in the United Kingdom.

Background and commentary

Ward *et al* (2024) recently published a paper in this journal (Ward *et al* 2024) asserting that methane emissions from manure management in the United Kingdom Inventory of Greenhouse Gas and ammonia emissions from Agriculture could be under-estimated by a factor of four to five, on the basis of measurements from two farms located in the south-west of England. It is concerning that the acknowledgement section lists the names of researchers involved in the provision of evidence and preparation of the annual Inventory calculations for the United Kingdom, which could imply that they support the position taken in the paper (named researchers: Dave Chadwick; Laura Cardenas; Sarah Gilhespy; Daniel Sandars). Ward *et al* are wrong on both counts.

The two farms are not shown to be representative of slurry storage facilities and management in the United Kingdom. The demonstration systems are purposely set-up to encourage methane release and capture, for use as a fuel source, and so the quantities of methane *extracted* cannot be compared with the quantities *emitted* to the atmosphere on a typical farm which is what the national Inventory seeks to estimate. There is also a lack of transparency on the methodology used to estimate methane fluxes from the two slurry stores, as insufficient detail was provided about the flow/pumping rates of gas from the stores or the type of methane analyser used, and no information on the relative numbers of production and replacement livestock from which *per* head emission values are derived. The Inventory researchers made the paper authors aware of some of these concerns at the referenced research webinar and a public meeting, in addition to online discussions with inventory researchers.

The methane emissions reported at the two farms are several times higher than has been published in several other farm-scale studies of slurry storage, and the onus was therefore on the authors to publish measurements (such as volatile solids (VSs) content and maximum methane production potential (B_o) of the

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slurry) that would permit a detailed technical review and a physical explanation. Such data were not provided.

Values of the weekly methane production and net slurry flow published by Ward *et al* do allow an estimation of the methane emission rate (having made an allowance for the *minimum* estimated initial stored slurry volume of around 1,200 and 630 m^3) from the two stores which generally ranges between 0.1 and 1.0 kg CH_4 m^{-3} $week^{-1}$ with stored volume weighted averages of 0.43 and 0.74 kg CH_4 m^{-3} $week^{-1}$ (2.53 and 4.40 g CH_4 m^{-3} h^{-1}; derived from supplemental data published at www.ifeaa.com). Emissions are an order of magnitude greater after week 25 when the stores are apparently empty.

For comparison, Vechi *et al* (2023; *n* 2) and Kupper *et al* (2020; *n* 6; table 8) collated measured methane emission rates from untreated and uncovered farm-scale cattle slurry tanks in the range 0.2–2.0 g CH_4 m^{-3} h^{-1} with an overall average of 1.1 g CH_4 m^{-3} h^{-1} (*n* 8) (Sneath *et al* 2006, Maldaner *et al* 2018, Balde *et al* 2016, Husted 1994, Kariyapperuma *et al* 2018). Consistent with the observations of Ward *et al* on the importance of scale of storage and measurement this farm-scale average is higher than the pilot-scale average of 0.49 g CH_4 m^{-3} h^{-1} also reported by Kupper *et al* (2020; *n* 35; table 8). It is also consistent with the average value of 0.9 g CH_4 m^{-3} h^{-1} (2.7 g CH_4 m^{-2} h^{-1}; *n* 7) from slurry tanks in a review of measured emissions from dairy manure management (Owen and Silver 2014; table 2b) that is referenced by Ward *et al* as support for the general under-estimation of methane emissions by the IPCC Tier 2 modelling approach.

The higher methane emission values reported by Ward *et al* are likely to be affected by the physical context, with the slurry (partially) separated, covered and stored for long periods. In particular, covering of the store is known to raise the slurry temperature and methane emission rate. Whereas the majority of cattle slurry in England is stored unseparated in cylindrical steel/concrete tanks or earth banked lagoons (Ipsos MORI 2013) that are uncovered (Defra Farm Practices Survey 2022), and the majority of the slurry is stored through the cooler winter months only. The available farm-scale studies are few in number and the measurements from Ward *et al* add to them rather than replace them.

According to UK Inventory calculations, the national average adult dairy cow excretes 118 kg N yr^{-1} and 5.3 kg VS day^{-1} (Brown *et al* 2022). The raw excreta (urine and faeces) volume is 44 l day^{-1} with a calculated dry matter content of 118 g DM kg^{-1}. Measurements of the average dry matter content of slurry as it leaves storage for spreading (78 g DM kg^{-1}; *n* 109; ADAS 2003) indicate that the excreta are typically diluted by wash water and rainfall over yard and store areas by around 50% to give a final managed slurry volume of 66 l^{-1} d^{-1}. The UK Inventory uses the default IPCC 2019 maximum methane production potential (B_o) for dairy cattle slurry of 0.24 m^3 CH_4 kg^{-1} VS excreted, which compares to a measured 0.20 m^3 CH_4 kg^{-1} VS excreted at the start of the storage period (Misselbrook *et al* 2016). By application of the conversion factor for m^3 CH_4 to kg CH_4 (0.67), the maximum methane production potential can therefore be expressed as 311 kg CH_4 hd^{-1} yr^{-1} or 12.9 kg CH_4 m^{-3} managed slurry (*see* equation 10.23 in IPCC 2019). As only around 81% of the dairy cow year is spent in housing or on yards and the remainder at grazing, the estimated maximum methane production from *managed* slurry under optimal conditions is equivalent to 251 kg CH_4 hd^{-1} yr^{-1}. For comparison, the UK Inventory calculates an actual methane emission from the managed slurry produced by dairy cows on farms using slurry storage in above ground tanks and earth banked lagoons of 43 kg CH_4 hd^{-1} yr^{-1}.

The methane conversion factor (MCF) as used in the Inventory calculations expresses the proportion of the maximum production potential that is achieved, given the extent of anaerobic conditions in the slurry store, the ambient temperature of the system and the retention or storage time. The UK Inventory calculations use an MCF of 17% which is confirmed by the ratio of the calculated maximum (251 kg CH_4 hd^{-1} yr^{-1}) and actual (43 kg CH_4 hd^{-1} yr^{-1}) methane production from managed slurry (see IPCC 2019 table 10.16). The UK Inventory MCF value is selected following IPCC guidance and an understanding of typical storage conditions, but can be linked to the literature on farm-scale measurement.

Consider the methane production rates measured by Ward *et al* (2.53 and 4.40 g CH_4 m^{-3} h^{-1}). The estimated average residence time of the stores on the two farms (average slurry fill divided by the total inflow) is 6.1 and 4.8 months. Therefore, the methane emission is approximately equal to 11.1 and 15.2 kg CH_4 m^{-3} of managed slurry. When expressed as percentage of the maximum methane production potential of managed slurry (12.9 kg CH_4 m^{-3}) this implies an MCF of 86% and 118% on the two farms if the assumed VS production rate can be supported (and higher if slurry separation had reduced the quantity of VS input to the store).

Therefore, to achieve the headline figure of 171 kg CH_4 hd yr^{-1} reported by Ward *et al* implies a management system that is optimal for methane production and capture.

The national average installed slurry storage capacity on dairy farms in England is 4.8 months (Ipsos MORI 2013; *n* 467) with an average storage duration of only 3 months assuming batch filling and emptying. Using the literature farm-scale average methane production rate of 1.1 g CH_4 m^{-3} h^{-1} (Vechi *et al* 2023, Kupper *et al* 2020) with this storage duration results in a methane emission of only 2.4 kg CH_4 m^{-3} of

managed slurry. When expressed as percentage of the maximum methane production potential of managed slurry (12.9 kg CH_4 m^{-3}) this implies an MCF of 18% which is close to the UK Inventory value and supports the current emission estimate of 43 kg CH_4 hd^{-1} yr^{-1}. Had the higher methane production rates measured by Ward *et al* been used with the national storage duration then the implied MCF is equal to 42% or 73%. Had the methane production rates measured by Ward *et al* been added to the literature values to produce a new all farm-scale study average of 1.6 g CH_4 m^{-3} h^{-1} (*n* 10) then the implied MCF is 26%.

But to adopt the measurements from Ward *et al* still requires consideration of the context. The estimated MCF on the two farms of 86 and 118% is closer to the IPCC 2019 recommended values of 60%–80% for an anaerobic lagoon where some separation takes place. For emphasis, this and the covering of the store is not yet typical of the majority of slurry management in the UK. Measurements of methane capture under a modified system do not necessarily reflect the methane emissions that occur under a typical system.

Finally, it is also important to acknowledge the existing Inventory verification systems that are in place to sense-check any revisions of emission factors. According to the calculations in the national Inventory, in the year 2022 agriculture contributed a total of 990.9 kt CH_4 to the annual UK total methane emissions of 2019.9 kt CH_4. The contribution from the storage of slurry in above ground tanks or earth banked lagoons was 94.6 kt CH_4 or 4.7% of the total (NAEI 2023). If typical methane emissions from manure management were four to five times greater as implied by Ward *et al* then the annual UK total methane emissions would be in the range 2303.6–2398.2 kt CH_4 or 14%–19% greater than currently estimated. However, independently estimated methane emissions from the UK in the period 2013–2020, by continuous monitoring of atmospheric concentrations and inverse modelling, has reported average annual emissions of $2100^{\pm 90}$ and $2120^{\pm 260}$ kt CH_4 which compare favourably with the Inventory calculations of 2230 kt CH_4 in the same period (Lunt *et al* 2021). Therefore, any increase in the estimated emissions from typical manure management would have to be compensated by a reduction from another source to match atmospheric observations. This is not addressed in the paper.

In conclusion, whilst we wholly support the methane capture process reported on as an effective mitigation strategy, we can show that it was unnecessary to question the accuracy of the current Inventory to advance an opportunity for the methane capture industry and to imply that the named researchers in the Acknowledgements of Ward *et al* (2024) condoned the critique of the UK Inventory or the measurement methods used to support these claims.

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