An Evaluation of the Use of Sensors for the Detection of Emissions in Slurry Management

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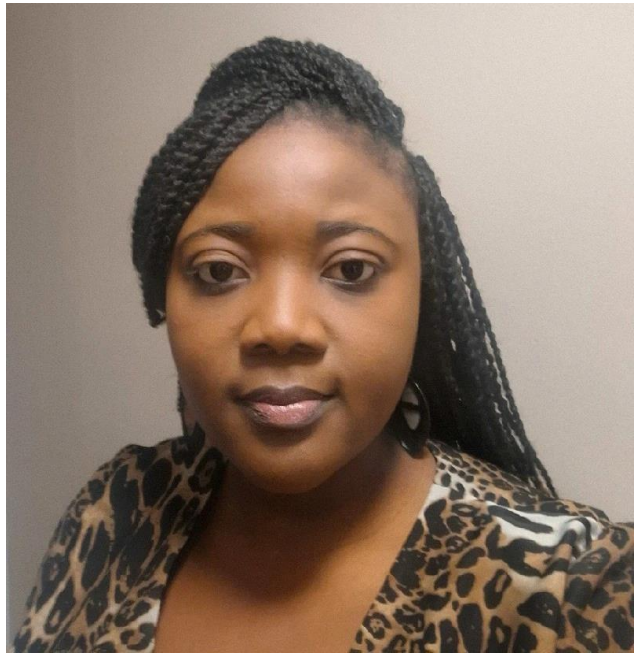

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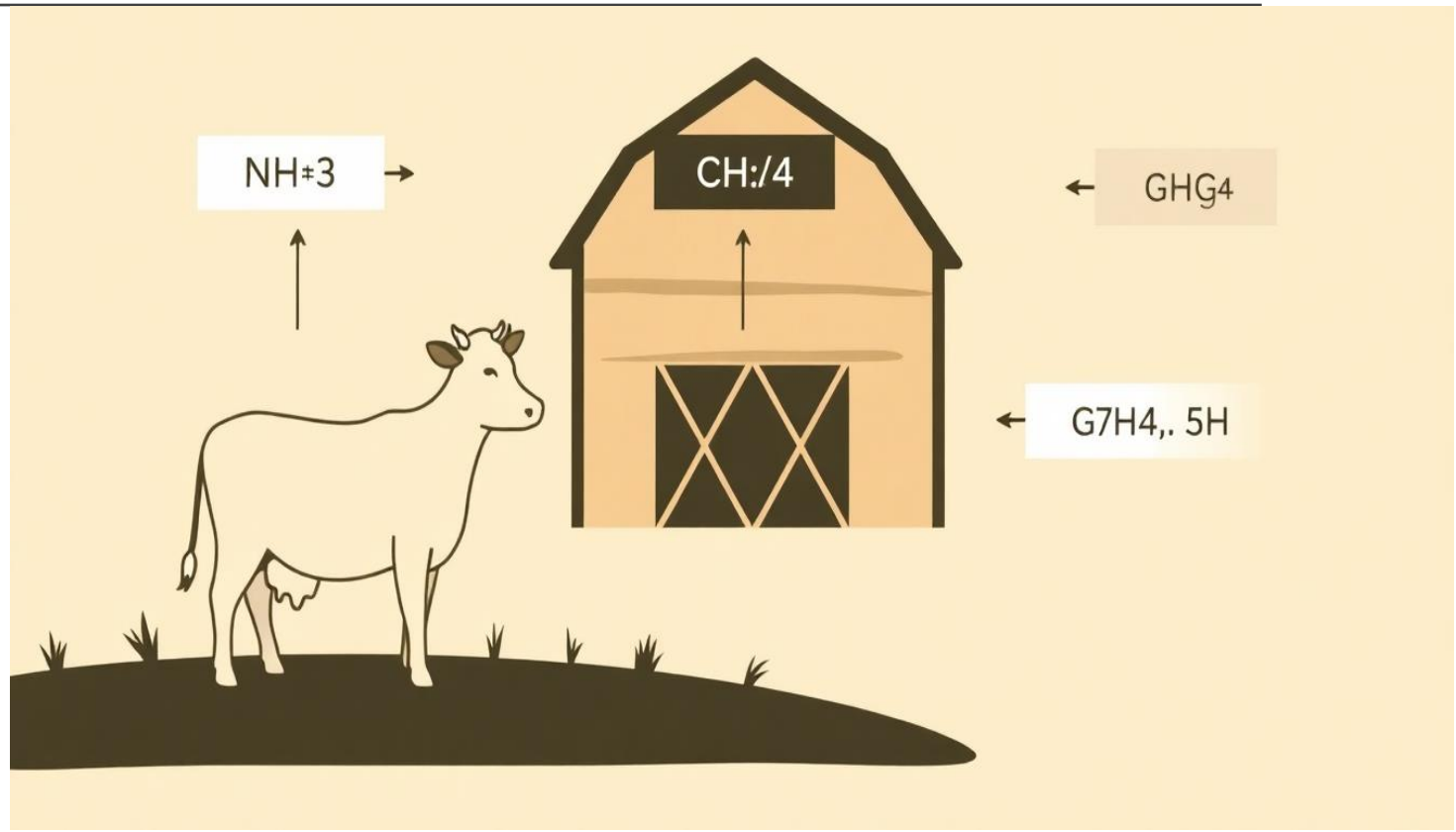
Introduction: The Emissions Challenge

Ireland's Agricultural Emissions

99% of national Ammonia (NH_3) emissions

37.8% of national Greenhouse Gas (GHG) emissions

Methane (CH_4) from slurry alone accounts for 10.6% of agricultural GHGs



Technological Advancement and Emissions Control

Explosion of technological advancement and use in agriculture

Sensor technology enables the Internet of Things (IoT).

Determination of nutrient content of slurry

Use of sensors for the quantification of emissions

Source: https://www.niubol.com/Product-knowledge/What-are-the-sensors-used-in-precision-agriculture.html

Research Focus & Methodology

Research Questions

How can sensors be used to reduce or mitigate ammonia or GHG emissions in slurry management?

What are the advantages and disadvantages of using advanced sensor technologies for this purpose?

Research Method

Narrative literature review

Sensor Applications Across the Slurry Lifecycle

1. Production

Monitoring air quality (NH_3, CO_2, H_2S) in animal houses to maintain animal health and optimize the farm environment.

2. Storage

Real-time monitoring of gas concentrations during storage to minimize nitrogen loss and reduce emissions.

3. Field Application

Understanding processes at the soil-air interface to optimize application timing and minimize nutrient loss.

Findings: Sensors in Animal Housing

IoT sensors continuously detect NH_3, CO_2, and H_2S, linking emissions to housing structures and management practices.

Electrochemical (EC) sensors show acceptable accuracy for on-field odour quantification.

Challenge: Improving sensor sensitivity for accurate detection at very low concentrations.

Findings: Sensors in Slurry Storage

Sensor networks provide data for predictive models of CH_4 and NH_3 emissions.
Sensor location is critical for accuracy (e.g., 1.8m above floor level proved more stable).
Advanced tech like FTIR and UAV-mounted sensors offer multi-gas and spatial analysis capabilities.

Image Source: Vanotti, M. (2012). *Development of Clean Technologies for Management of Wastes from Pig Production and their Environmental Benefits.* Available at: https://en.engormix.com/pig-industry/swine-management/development-clean-technologies-management_a35474/ [Accessed 15 Dec. 2025].

Findings: Sensors in Field Application

Microscale Analysis

Reversible optodes can create 2D images of NH_3, O_2, and pH microenvironments at the soil-air interface with high spatial resolution (<100 µm). This provides a deeper understanding of the chemical drivers of NH_3 emissions upon manure application.

Holistic Monitoring

Systems like 'Agri-Guard' aim to bridge the gap by integrating multiple sensors (CO_2, CH_4, NH_3, etc.) into a unified system. However, fragmented, isolated systems remain a common challenge.

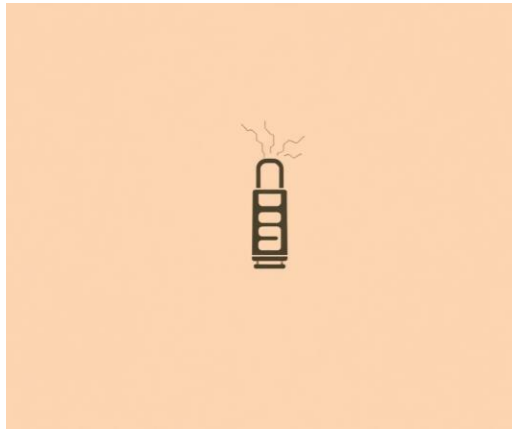
Discussion: From Descriptive to Prescriptive Analytics

Image Source : Analyticsinsight

Advantages of Sensor Technology in Slurry Management

Real-Time Monitoring

IoT sensors enable immediate, data-driven decisions on optimal slurry application timing and housing management.

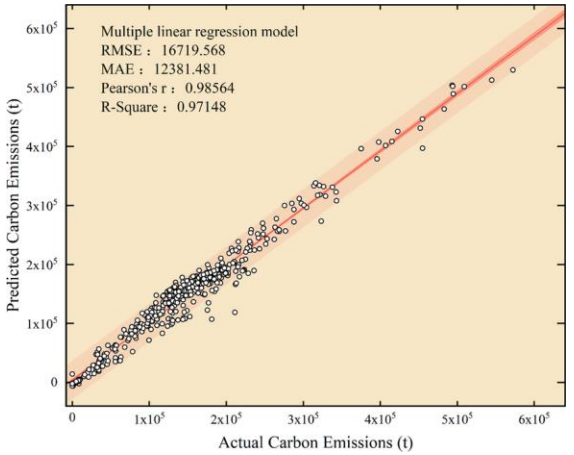


Enhanced Detection

EC and FTIR sensors can detect multiple gases (NH_3, CH_4, CO_2), providing a comprehensive view of emissions.

Spatiotemporal Precision

Drones and high-resolution imaging enable precise mapping of emission hotspots and variability over time.



Improved Quantification

Accurate data is critical for developing and validating predictive models and mitigation strategies.

Disadvantages and Current Challenges

Limited Slurry Characterization

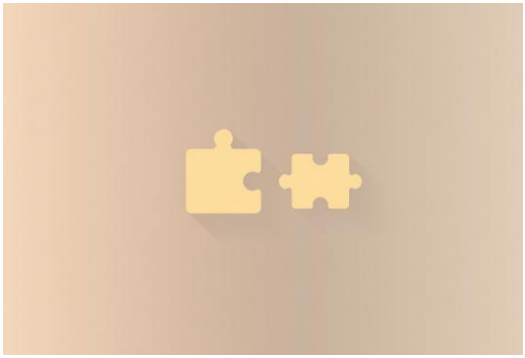
Most sensors cannot measure key slurry properties like pH, dry matter, or nutrient content in-situ.

Sensitivity & Durability

Sensors can have long response times, short operational lives, and struggle with low gas concentrations (e.g., N_2O).

Cost and Maintenance

Advanced technologies like FTIR are costly to operate and maintain, limiting their widespread adoption.



Fragmented Systems

Lack of integration between different sensor platforms prevents a holistic, unified view of farm emissions.

The Path Forward

Future Research Needs

Develop robust, reliable, and durable sensors calibrated for harsh slurry environments.

Address challenges of sensor fouling, data accuracy, and cost.

Shift focus from descriptive to predictive analytics to enable proactive decision-making.

Incorporate predictive models to simulate scenarios (e.g., extreme weather) and prevent emissions before they occur.

Image Source: Leitrim Live ed., (2024). *Local organics project receives major Government funding*.

Conclusion

Sensors add significant value to smart agriculture through real-time monitoring and improved quantification. However, their use is largely focused on descriptive analysis. Limitations in capability, cost, sensitivity, and system integration still hinder their full potential as predictive tools for efficient slurry management.

Image Source: FieldBee.com (2020). *Precision Farming Technologies to Increase Profits*. Available at: https://www.fieldbee.com/blog/precision-farming-technologies-to-increase-profits [Accessed 15 Oct. 2025].