

# Foam for Thought: Unlocking the Humane Potential of High Expansion Nitrogen-filled Foam in the Killing of Poultry and Pigs

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# DEPOPULATION

Depopulation is defined as the mass killing of large numbers of animals, typically occurring in response to urgent or emergency situations, including infectious disease outbreaks and both natural and manmade disasters

A depopulation typically refers to the killing of all animals residing at a single location, such as a farm

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# Depopulation

Natural disaster 2018

The need for mass depopulation strategies

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**Animals farmed Environment** • This article is more than 3 years old

## Millions of US farm animals to be culled by suffocation, drowning and shooting

Closure of meat plants due to coronavirus means 'depopulation' of hens and pigs with methods experts say are inhumane, despite unprecedented demand at food banks

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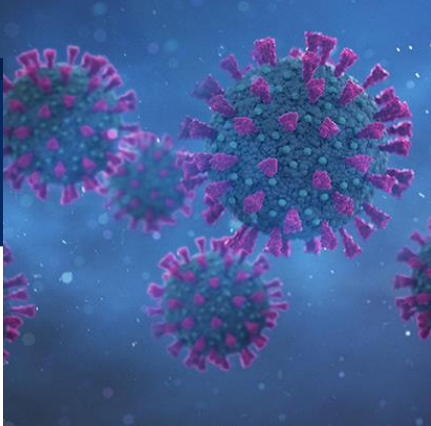
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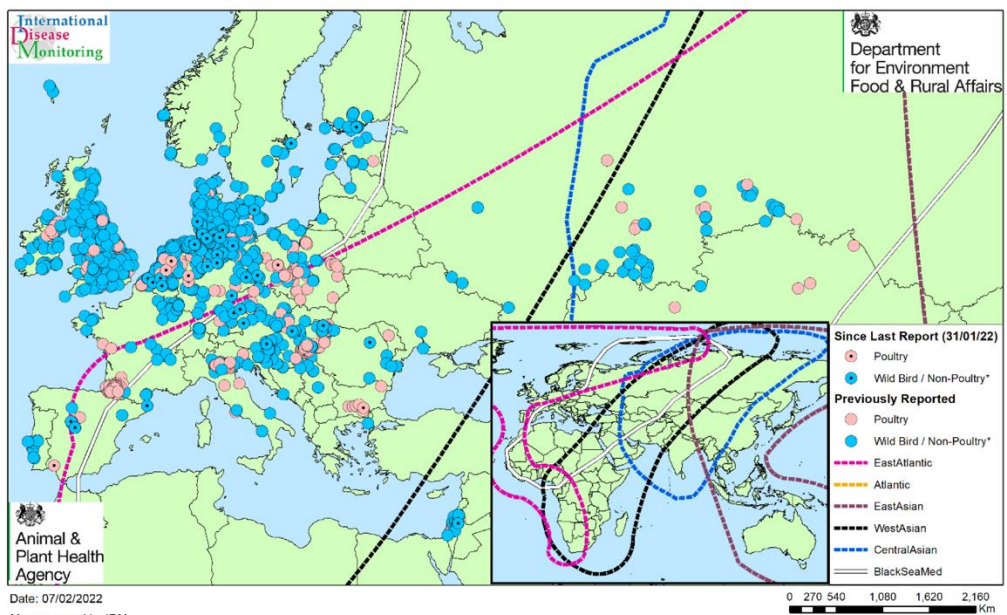
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# Depopulation

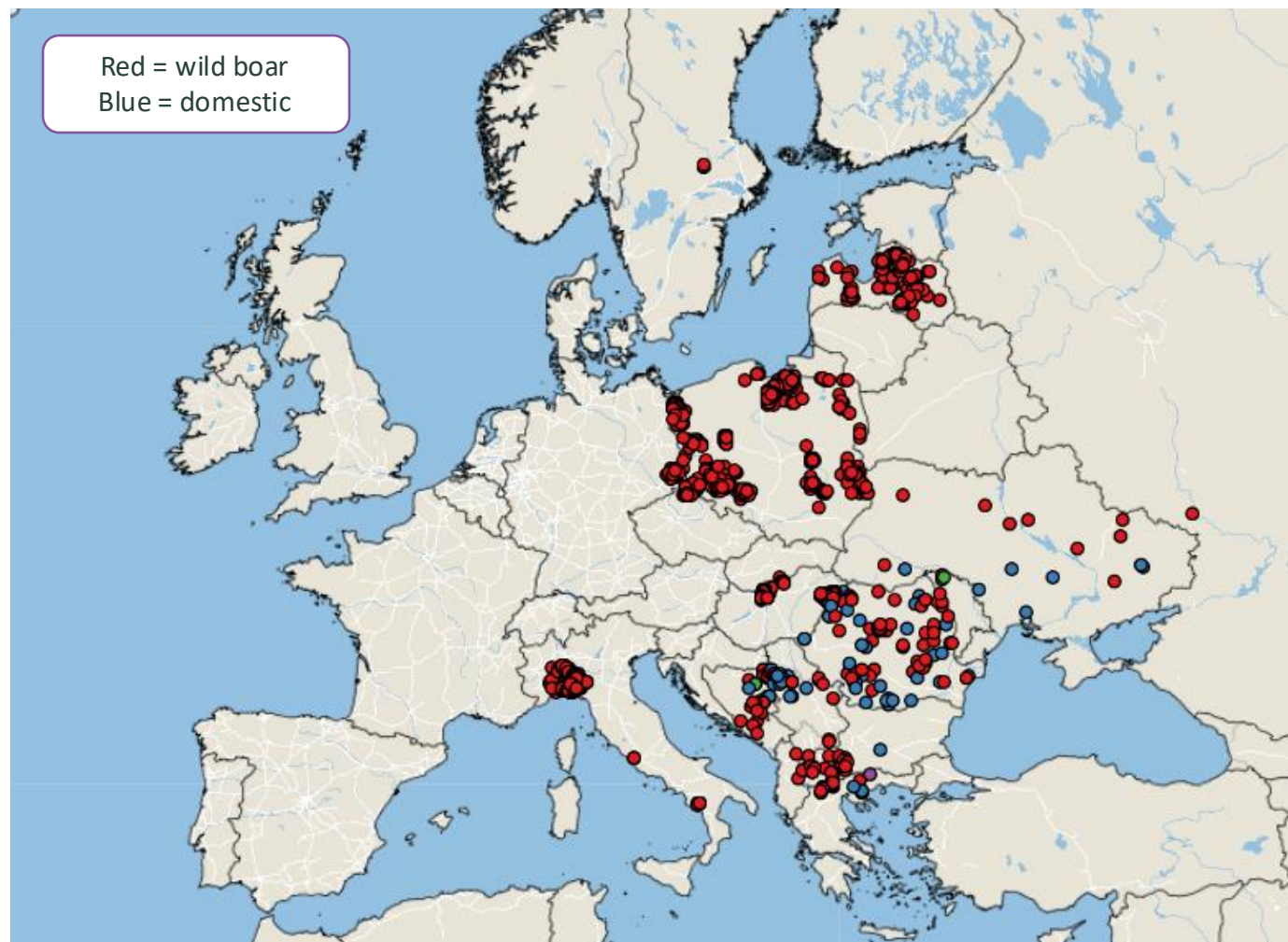
Covid-19 pandemic

The need for mass depopulation strategies



Highly Pathogenic Avian Influenza in Poultry and Non-Poultry\*  
 September 2021 - February 2022  
 Overlay: Migratory Bird Flyways  
 OIE Data Only  
 \*OIE Defined

The need for mass depopulation strategies



# Depopulation

## Latest threat: African Swine Fever

In 2024 alone there have been over 1500 reported outbreaks in wild boar and about 40 outbreaks in domestic pigs

Source: FAO



The need for mass depopulation strategies

## Environment



Humans and their livestock are more likely to encounter wildlife when more than 25% of an original forest cover is lost. Some of these contacts may increase the likelihood of disease transmission.

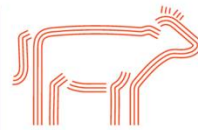


Human actions have severely altered 75% of terrestrial environments and 66% of marine environments.

## Economy



Animal diseases pose a direct threat to the incomes of rural communities that depend on livestock production.



More than 75%<sup>2</sup> of the billion people who live on less than \$2 per day depend on subsistence farming and raising livestock to survive.

# Depopulation

Future threats...

## One Health facts

### World health

**60%**

of pathogens that cause human diseases originate from domestic animals or wildlife.

**75%**

of emerging infectious human diseases have an animal origin.

**80%**

of pathogens that are of bioterrorism concern originate in animals.

The need for mass depopulation strategies



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# DEPOPULATION AND ANIMAL WELFARE

- Should the welfare standards required of emergency killing be equivalent to routine slaughter?
  - May not be achievable due to inexperienced operators, time pressure, non-standardised conditions and need to protect human health
  - In the EU, emergency plans expected to ‘achieve a humane death similar to slaughter’
  - Some diseases could cause severe symptoms, and mass culling may be in the animals’ own interests
  - Large numbers of healthy animals are killed in an exclusion zone, providing impetus to choose methods causing the least welfare harm
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# CONSIDERATIONS

- Practicality
  - Availability for rapid deployment
  - Cost
  - Disease transmission risk
  - Welfare consequences
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# CHALLENGES



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# VENTILATION SHUTDOWN



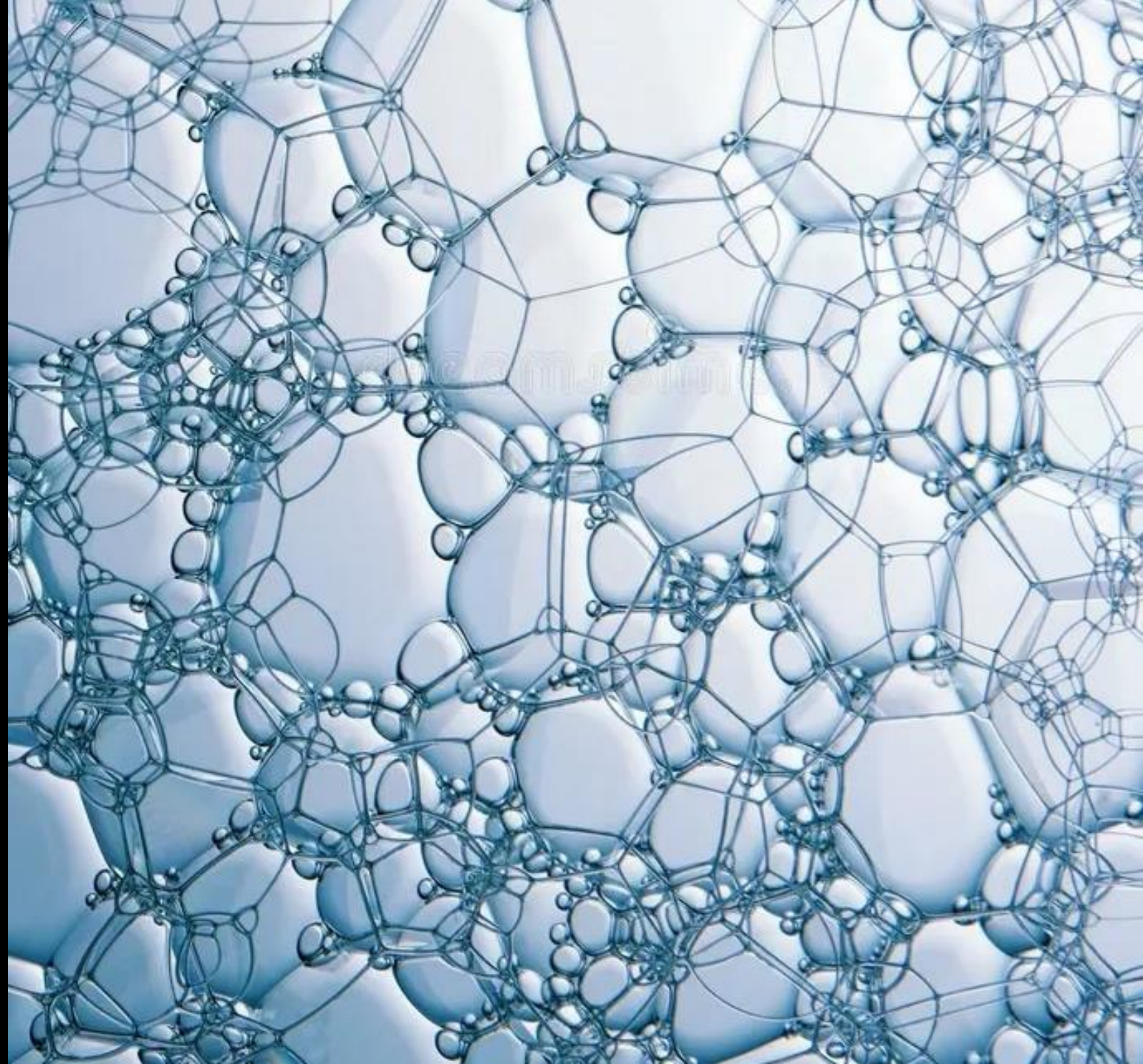
European Food Safety Authority (EFSA) specifically recommends against using VSD methods for depopulation of both poultry and pigs

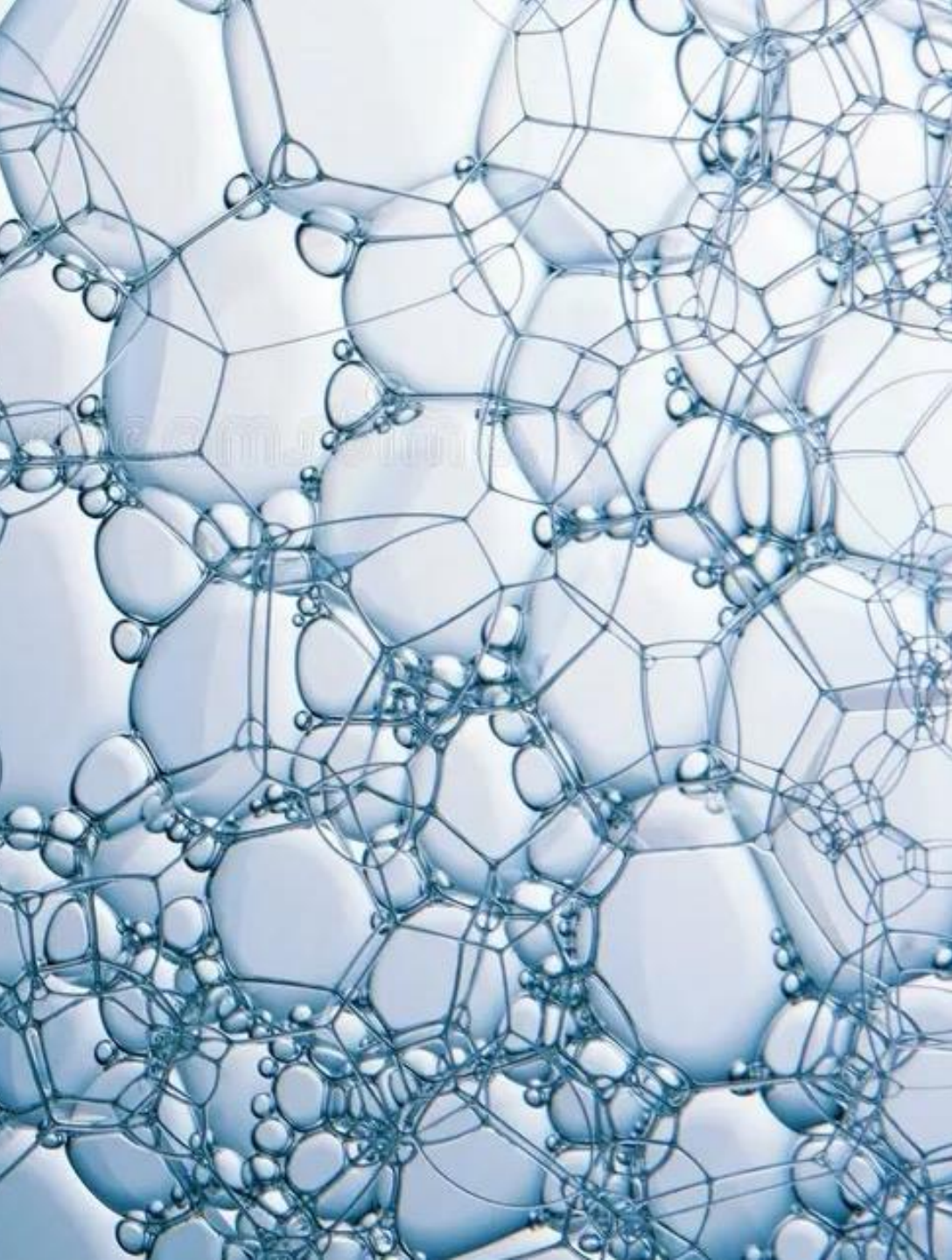
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# FOAM

- Mixture of water, foam concentrate and gas
- Described by expansion ratio – ratio of foam volume formed to volume of solution used
  - Low expansion 2-10:1
  - Medium expansion 20-200:1
  - High expansion >200:1





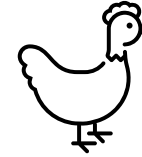
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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM

- Occlusion not acceptable in Europe – welfare concerns
  - Also concerns about shortages of CO<sub>2</sub> – need for an inert gas-based depopulation method
  - High expansion gas filled foam proposed in 2008 – expansion ratio >300:1
  - Aim to envelope the bird with foam, displacing oxygen in the immediate environment
  - Animals exposed to high expansion air filled foam do not die
-

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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



## ENVIRONMENT, WELL-BEING, AND BEHAVIOR

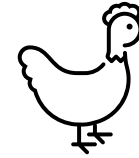
### Physiological and behavioral responses of poultry exposed to gas-filled high expansion foam

D. E. F. McKeegan,<sup>\*1</sup> H. G. M. Reimert,<sup>†</sup> V. A. Hindle,<sup>†</sup> P. Boulcott,<sup>\*</sup> J. M. Sparrey,<sup>‡</sup>  
C. M. Wathes,<sup>§</sup> T. G. M. Demmers,<sup>§</sup> and M. A. Gerritzen<sup>†</sup>

*\*Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary & Life Sciences, University of Glasgow, Glasgow, G61 1QH, UK; †Wageningen UR, Livestock Research, PO Box 65, 8200 AB Lelystad, the Netherlands; ‡Livetec Systems Ltd., West Park Enterprise Centre, Building 52 West Park, Silsoe, Bedford, United Kingdom; and §Royal Veterinary College, University of London, Hatfield, AL9 7TA, UK*

- Designed and built small laboratory scale prototype
- Tested individual birds (broilers, hens, turkeys and ducks)
- Tested CO<sub>2</sub> and nitrogen
- Tested groups of birds under controlled conditions
- Full scale trials funded by DEFRA and the UK poultry industry

# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



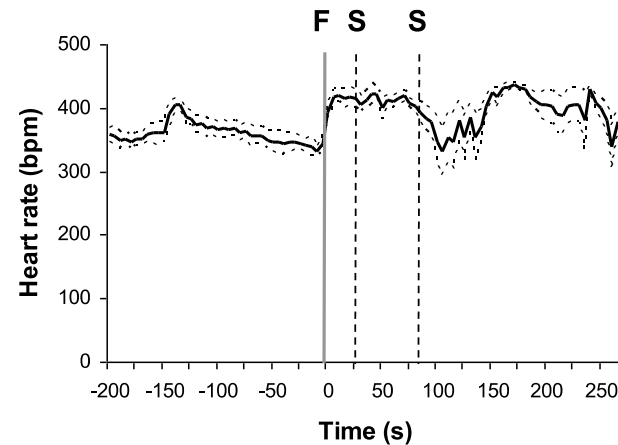
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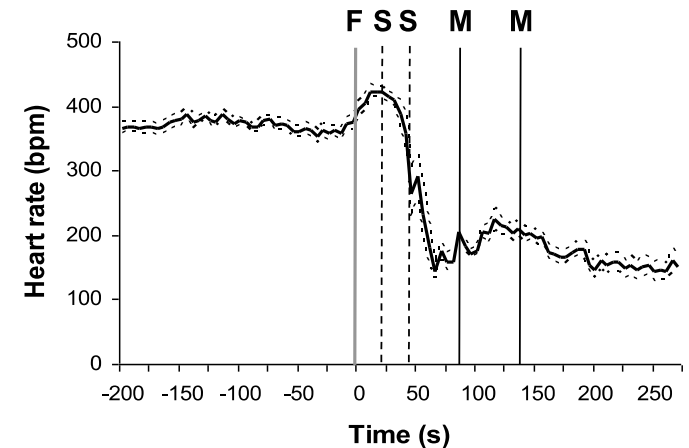
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Air filled foam (control)



F – Foam start

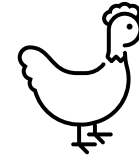
Nitrogen filled foam



S - Submerged

M - Motionless

# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



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Transitional    Suppressed    Isoelectric

Hens  
Mean(± SD)    **9.8 ± 2.8**    **30.1 ± 6.8**    **65.7 ± 11.5**

Broilers  
Mean(± SD)    **8.3 ± 4.4**    **17.6 ± 3.5**    **46.9 ± 8.3**

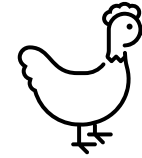
### Time taken (s) to reach EEG phases in relation to submersion

Behavioural ABM	Proportion of birds displaying behaviour		Mean (±SE) latency (s)	
	N <sub>2</sub> -filled foam	Air-filled foam (control)	N <sub>2</sub> -filled foam	Air-filled foam (control)
<b>Escape attempts</b>	H: 2/12 <sup>a</sup> B: 0/10 <sup>a</sup> , §/8 <sup>a</sup>	H: 1/8 <sup>a</sup> B: 0/10 <sup>a</sup>	H: § <sup>a</sup> B: - <sup>b</sup> , § <sup>b</sup>	H: § <sup>a</sup> B: - <sup>b</sup>
<b>Head shaking</b>	H: §/12 <sup>a</sup> B: §/10 <sup>a</sup> , 0/8 <sup>b</sup>	H: §/8 <sup>a</sup> B: §/10 <sup>a</sup>	H: 2 ± 1 <sup>b</sup> B: 2 ± 1 <sup>b</sup> , - <sup>a</sup>	H: § <sup>a</sup> B: § <sup>a</sup>
<b>Deep inhalation</b>	H: 0/12 <sup>a</sup> B: 0/10 <sup>a</sup> , 1/8 <sup>b</sup>	H: 0/8 <sup>a</sup> B: 0/10 <sup>a</sup>	H: - <sup>b</sup> B: - <sup>b</sup> , 87 <sup>a</sup>	H: - <sup>b</sup> B: - <sup>b</sup>



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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



## ENVIRONMENT, WELL-BEING, AND BEHAVIOR

### Physiological and behavioral responses of poultry exposed to gas-filled high expansion foam

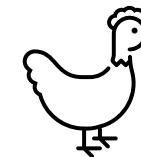
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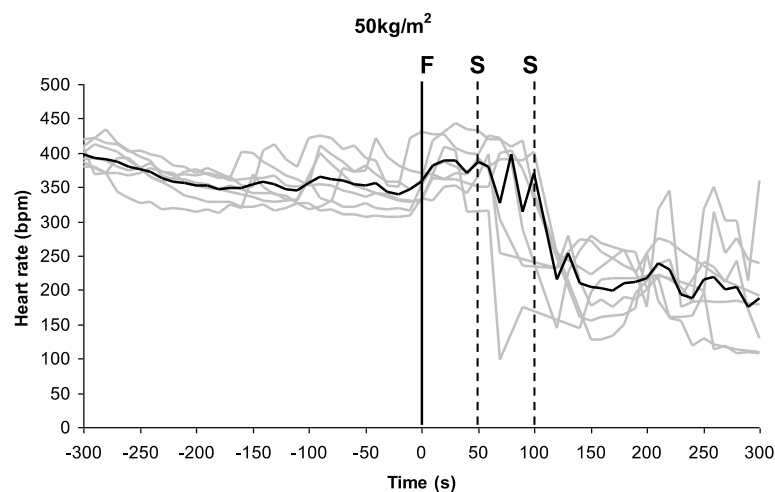


- Immersion in high expansion foam filled with nitrogen or CO<sub>2</sub> achieved a rapid death, with broadly similar responses in all species
- Carbon dioxide was slightly faster acting, little response to immersion in air filled foam
- Behavioural responses included headshaking, loss of posture and vigorous wing flapping characteristic of anoxic death
- Mean time to loss of consciousness was 30s in hens and 18s in broilers

# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



Time to reach EEG phases*	Transitional	Suppressed	Isoelectric
40kg / m <sup>2</sup> Mean ± SD	5.8 ± 2.0	<b>24.1 ± 5.8</b>	39.8 ± 3.0
50kg / m <sup>2</sup> Mean ± SD	4.2 ± 3.3	<b>19.7 ± 6.5</b>	51.7 ± 14.8
Wing flapping	Flap onset (s)*	Number of bouts	Total duration (s)
40Kg / m <sup>2</sup> Mean ± SD	3.8 ± 2.3	3.2 ± 0.8	14.8 ± 5.9
50Kg / m <sup>2</sup> Mean ± SD	5.1 ± 5.0	3.3 ± 1.7	13.9 ± 4.7



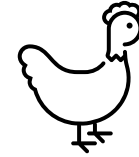
F – Foam start

S - First and last submersion

\*in relation to submersion

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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



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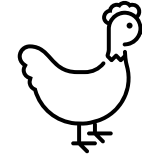
Independent report

## AWC Opinion on the use of high expansion nitrogen foam for culling poultry

Published 24 May 2024

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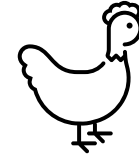
Published 24 May 2024

- Demonstration Trials (March & November 2023) commissioned by APHA
- Conducted in empty poultry sheds and sheds containing live broiler breeders, under field conditions
- Birds displayed minimal distress; some moved mildly in response to the foam, with no significant panic behaviour observed.
- Birds' recumbent and still upon foam contact; footage confirmed complete, humane coverage.
- No evidence of bird smothering or bunching; carcasses were evenly distributed.
- Field trials confirmed technical feasibility and welfare benefits, with foam achieving humane depopulation effectively and efficiently.



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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



  
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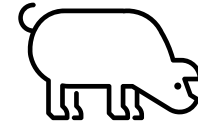
Published 24 May 2024

- ✓ EEG data – time to LOC
- ✓ Behavioural data – time to LOC + minimal signs of aversion
- ✓ Pathology data – no occlusion of airways
- ✓ Tested in multiple

- High-expansion nitrogen foam is an effective and welfare-advantageous method for culling poultry, particularly in disease control scenarios (e.g., avian influenza).
- Offers benefits over CO<sub>2</sub> whole-house gassing (WHG) and containerized gassing units (CGUs) due to reduced bird handling.
- Proven effective for litter-based broilers, breeders, meat turkeys, and ducks.
- Field trials needed for alternative housing types and other bird species.
- Foam should ideally form a wave from both ends of the shed to ensure even coverage and prevent bird bunching.
- Government authorization for use in emergency disease control.

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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



Article

## Responses of Pigs to Stunning with Nitrogen Filled High-Expansion Foam

Cecilia Lindahl <sup>1,\*</sup>

, Erik Sindhoj <sup>1</sup>

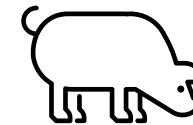
, Rebecka Brattlund Hellgren <sup>2</sup>, Charlotte Berg <sup>2</sup> and Anna Wallenbeck <sup>2</sup>


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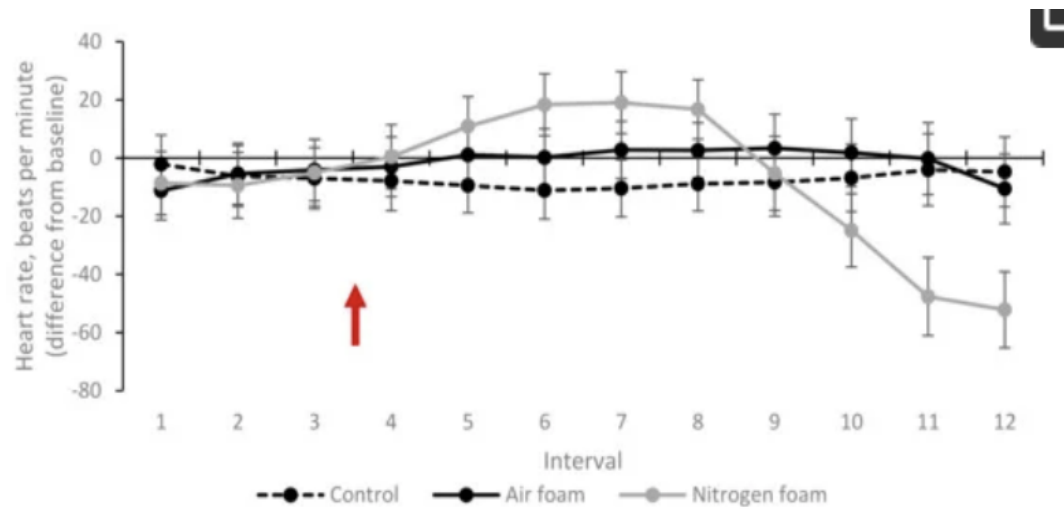



Article  
**Responses of Pigs to Stunning with Nitrogen Filled High-Expansion Foam**

Cecilia Lindahl <sup>1,\*</sup>  
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 , Rebecka Brattlund Hellgren <sup>2</sup>, Charlotte Berg <sup>2</sup> and Anna Wallenbeck <sup>2</sup>

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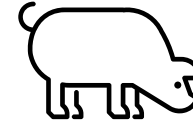
Behavioural ABM	Proportion of pigs displaying behaviour	
	N <sub>2</sub> -filled foam	Air-filled foam (control)
Escape attempts	16/20 <sup>a</sup>	16/20 <sup>a</sup>
Deep inhalation	0/20 <sup>a</sup>	0/20 <sup>a</sup>
Clonic convulsions	20/20 <sup>a</sup>	0/20 <sup>a</sup>
High-pitch vocalisations	19/20 <sup>a</sup>	9/20 <sup>a</sup>



- High-expansion nitrogen foam is an effective method for culling pigs
- Behavioural LOC in ~58s
- 80% of pigs performed escape attempts
- 95% of pigs performed high-pitch vocalisations
- Startle responses when exposed to gas pulse
- Elevated HR indicative of stress response

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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



Article

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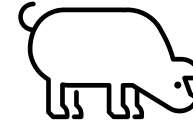
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- ✗ EEG data – time to LOC
- ✓ Behavioural data – time to LOC
- ✗ minimal signs of aversion
- ✗ Pathology data – occlusion of airways (?)
- ✓ Tested in pigs (15-41 kg) only



# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



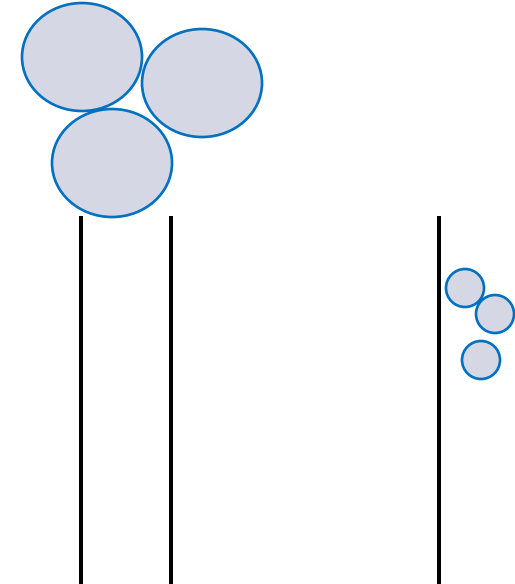


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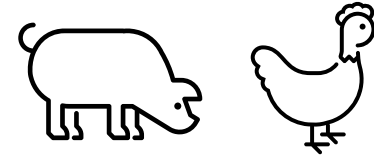
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Why size of bubbles matters?



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# HIGH EXPANSION N<sub>2</sub>-FILLED FOAM



Adopted: 3 June 2024

DOI: 10.2903/j.efsa.2024.8855

SCIENTIFIC OPINION

EFSA JOURNAL

## The use of high expansion foam for stunning and killing pigs and poultry

EFSA Panel on Animal Health and Welfare (AHAW) | Søren Saxmose Nielsen | Julio Alvarez | Dominique Joseph Bicout | Paolo Calistri | Elisabetta Canali | Julian Ashley Drewe | Bruno Garin-Bastuji | Jose Luis Gonzales Rojas | Christian Gortázar | Mette S. Herskin | Miguel Ángel Miranda Chueca | Barbara Padalino | Helen Clare Roberts | Hans Spoolder | Karl Stahl | Antonio Velarde | Christoph Winckler | Arvo Viltrop | Jessica Martin | Mohan Raj | Alexei Vyssotski | Yves Van der Stede | Marika Vitali | Aikaterini Manakidou | Virginie Michel



- **Animal Welfare Compliance:** High expansion N<sub>2</sub>-filled foam meets or exceeds EU welfare standards for pigs and poultry in depopulation scenarios. However, its use is limited to specific animal categories and conditions.
- **Welfare Hazards:** Works by displacing oxygen with nitrogen, creating an anoxic environment. Welfare risks arise from the initial foam contact, with pigs and poultry showing discomfort (e.g., head shaking, escape attempts) before the nitrogen release.
- **Equivalence to Other Methods:** Provides comparable welfare protection to high-concentration CO<sub>2</sub> exposure, though data on animal responses remain qualitative, due to significant lack of quantitative data.
- **Technical Requirements:** For effective application, must maintain specific parameters like foam expansion ratio and exposure times (5 minutes for poultry, 7 minutes for pigs).
- **Limitations in Data:** Data gaps include insufficient evidence linking neurological and behavioural indicators of unconsciousness, especially for species like ducks and turkeys and pigs >40kg

# Thank you!

 @JessMartinLab

 Jessica.Martin@ncl.ac.uk



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The Royal (Dick) School  
of Veterinary Studies



Biotechnology and  
Biological Sciences  
Research Council



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for the Replacement  
Refinement & Reduction  
of Animals in Research

