Mass Euthanasia and Depopulation of Poultry:

HIGHER-WELFARE NITROGEN-BASED METHODS

Mass Euthanasia and Depopulation in Industrial Animal Agriculture

In the United States today, farms that produce eggs or poultry meat are often extremely large, housing tens of thousands—or even millions—of chickens, turkeys, or ducks in one location. While such large-scale, intensive confinement may reduce the cost of producing animal products, it can also cause significant harm to the animals.[1] In addition, major challenges arise when such operations are struck by fatal diseases or other emergencies. In such situations, animals' lives may be ended to alleviate or prevent suffering, slow the spread of a disease, and/or limit economic losses. During the COVID-19 pandemic, for example, more than 10 million chickens were killed due to limited processing capacity. More recently, millions more were killed when two large poultry companies declared bankruptcy.[2, 3, 4, 5]

Many people are familiar with the practice of euthanizing animals to limit their suffering near the end of life. Fewer may be familiar with the practice of "depopulating" massive flocks or herds of farmed animals for disease control or other purposes. Euthanasia (from the Greek *euthanatos*, meaning "easy death") is the act of ending a life in a manner that causes minimal discomfort as an act of mercy—typically when an animal is suffering and has little hope for regaining a good quality of life. "Depopulation," by contrast, refers to killing a large group of animals in response to urgent circumstances.[6]

Some argue that it is acceptable for depopulation methods to involve pain or distress because considerations other than animal welfare—such as the need to act quickly—must take priority during depopulation events.[7, 8, 9] Indeed, at present, depopulation is usually carried out via methods that emphasize ease of implementation, while causing the animals to experience severe and/or prolonged suffering.[10, 11]

However, technology has advanced such that some methods of depopulation are benign enough that they could also qualify as mass euthanasia methods—that is, they can quickly facilitate the death of suffering animals without causing additional pain or distress.

One of the depopulation methods most widely used today, as well as two of the most practical and economical higher-welfare alternatives, are described below.

Bird Flu and the Use of Heatstroke for Mass Killing

Highly pathogenic avian influenza (aka HPAI, or "bird flu") causes suffering and death in chickens, turkeys, and many other animals. Federal policy has long been to rapidly destroy any HPAI-exposed flocks in hopes of preventing further spread and eradicating the disease.[12] Past outbreaks in the United States have been contained following the depopulation of affected farms.

Since 2022, however, HPAI has persisted in the United States despite the depopulation of flocks totaling nearly 200 million birds. The virus has become endemic in wild birds, meaning HPAI infection and subsequent depopulation of poultry flocks are likely to continue indefinitely.[13]

During the current outbreak, a depopulation method known as "ventilation shutdown plus heat" (VSD+) has become a common method of depopulation. VSD+ involves sealing the barn containing the affected animals and adding heat, eventually causing fatal heatstroke.[14] Dying by heatstroke entails prolonged suffering in the form of severe thermal discomfort, pain, anxiety, frustration, exhaustion, and respiratory distress.[15] Most birds die over the course of four or more hours; most barns depopulated with VSD+, however, have survivors who languish for many more hours or days until they are eventually killed by another method.[16]

Because of its negative impact on animal welfare, other countries prohibit VSD+, or the method has been rejected by their poultry industries.[17, 18, 19, 20] In the United States, however, tens of millions of birds are killed annually in depopulations using heatstroke. Large egg operations, which can house millions of birds at a single location, use VSD+ the most.

Nitrogen-based Methods of Depopulation

Methods that use nitrogen (N_2) to euthanize or depopulate flocks of chickens, turkeys, or ducks have emerged as the most promising options to replace VSD+.[21] Properly performed, these methods cause no pain and little or no distress to the animals.[22] N_2-based methods create extremely low oxygen levels ("anoxia") around the animals. Without oxygen, brain function rapidly ceases and consciousness is lost. Involuntary, uncoordinated movements occur in

Left: Through pre-established contracts with suppliers, liquid nitrogen is easily sourced and inexpensive. Right: Controlled distribution of nitrogen gas via a manifold and hoses for whole house gassing.

some birds after they are unconscious or possibly in the moments during which they lose consciousness.[23, 24] As long as oxygen levels decrease at an appropriate rate, and other sources of fear or distress (such as noise or uncomfortable temperatures) are avoided, death via N_2 anoxia is considered a form of humane euthanasia for chickens, turkeys, and ducks.[25] In fact, it may be more humane than other common euthanasia methods; it does not, for example, require restraint (as with lethal injection) and does not cause pain or respiratory distress (as with carbon dioxide gassing).

Anoxic conditions can be created via containerized gassing units, whole house gassing, or high-expansion nitrogen foam. The latter two methods, detailed below, are more appropriate for depopulating poultry flocks because they require little or no live animal catching or handling.

Nitrogen Whole House Gassing

With nitrogen whole house gassing (NWHG), liquid or gaseous N_2 is released to drop the oxygen level throughout the entire barn.[26] Birds continue to eat, preen, and walk around until the

Wireless equipment is used to monitor barn conditions during nitrogen whole house gassing.

oxygen concentration drops to approximately 7%.[27] At this stage, they briefly become ataxic (wobbly) before losing consciousness. Death occurs soon afterward.

NWHG can be used in poultry houses that either are ventilated mechanically or can be reasonably well sealed. Equipment is available for monitoring barn conditions, including oxygen levels, temperatures, and other parameters essential to ensuring welfare.[28]

High-Expansion Nitrogen Foam

High-expansion nitrogen foam (HENF) consists of lightweight, large-sized foam bubbles that hold N_2 gas and more rapidly displace oxygen from the animal's immediate environment.[29, 30] Only the birds surrounded by foam experience low-oxygen levels; neighboring birds are unaffected. Birds do not appear to be distressed by the foam, particularly if care is taken to ensure it is a comfortable temperature. Unlike water-based foam—another means of depopulation—HENF does not cause the distressing experience of airway obstruction; rather, the birds lose consciousness due to lack of oxygen in the surrounding environment.[31]

A range of HENF systems are available. Some require birds to be placed in a container,[32] while others can be applied to the entire barn.[33, 34] Buildings do not need to be sealed with this method.

High-expansion nitrogen foam uses large, dry bubbles to create an oxygen-free environment.

Transitioning to Higher-Welfare, Nitrogen-Based Methods

Both NWHG and HENF are available and approved for depopulating poultry flocks in the United States.[35] Because N_2 can be easily extracted from the atmosphere and is used in many industries, it is inexpensive and readily available. The US veterinary profession supports a transition toward N_2-based depopulation methods.[36, 37] Unfortunately, however, N_2-based methods have not yet been used for depopulating US poultry flocks affected by HPAI. Meanwhile, numerous poultry farms have repeatedly used VSD+ in response to HPAI infection.[38]

Unlike VSD+, which usually involves little to no advanced preparation or forethought, producers must plan ahead to ensure that N_2-based methods can be rapidly deployed on their operation in an emergency. However, even very large poultry farms can achieve adequate preparedness within a few months.

Preparedness Requirements for All Nitrogen-Based Methods:

- Calculate required amount of N_2 gas
- Enter into contract with N_2 supplier
- Develop standard operating procedures
- Obtain monitoring equipment

Additional Preparedness Requirements for NWHG:

- Obtain manifold and hoses needed to deliver N_2

Additional Preparedness Requirements for HENF:

- Calculate required amount of water and foam concentrate
- Obtain foam-generation equipment and supplies
- Enter into contract with water supplier
- Obtain leaf blowers to disperse foam

Several years into the current bird flu outbreak, HPAI-related depopulation can no longer be considered an unanticipated emergency; it is now a predictable feature of poultry production. Particularly because producers receive taxpayer-funded compensation for both their killed birds and depopulation costs, they have a responsibility to undertake the planning and preparation to ensure that higher-welfare depopulation methods are utilized.

Photos | page 1: Jo-Anne McArthur/Sibanye Trust/We Animals; pages 3-4: Livestock Welfare Strategies

Endnotes

1. Pew Commission on Industrial Farm Animal Production. Putting Meat on the Table: Industrial Farm Animal Production in America. **2008.** https://www.pew.org/~/media/legacy/uploadedfiles/phg/content_level_pages/reports/pcifapfinalpdf.pdf
2. Brosch, C.; Cartanza, G. COVID-19 Acutely Impacted the Delmarva Poultry Industry in Early 2020. *Del. J. Public Health* **2021**, *7*, 38–39.
3. Kevany, S. (2020, May 19). Millions of US farm animals to be culled by suffocation, drowning and shooting. *The Guardian*. https://www.theguardian.com/environment/2020/may/19/millions-of-us-farm-animals-to-be-culled-by-suffocation-drowning-and-shooting-coronavirus
4. Oatman, R. Former Pure Prairie Poultry chickens depopulated. *MEAT+POULTRY*, **2024**. https://www.meatpoultry.com/articles/31000-former-pure-prairie-poultry-chickens-depopulated
5. Grajeda, A. Arkansas chicken growers sue poultry execs for damages from closure, depopulated flocks. *Arkansas Advocate* **2024**. https://arkansasadvocate.com/2024/09/25/arkansas-chicken-growers-sue-poultry-execs-for-damages-from-closure-depopulated-flocks/
6. AVMA. *AVMA Guidelines for the Depopulation of Animals: 2019 Edition*. https://www.avma.org/sites/default/files/resources/AVMA-Guidelines-for-the-Depopulation-of-Animals.pdf
7. AVMA. *AVMA Guidelines for the Depopulation of Animals: 2019 Edition*. https://www.avma.org/sites/default/files/resources/AVMA-Guidelines-for-the-Depopulation-of-Animals.pdf
8. Anonymous. 'Depopulation' Takes Spotlight In Avian Influenza Epidemic. PBS Wisconsin News. **2016**. https://pbswisconsin.org/news-item/depopulation-takes-spotlight-in-avian-influenza-epidemic/
9. USDA-APHIS-VS. National Animal Health Emergency Management System (NAHEMS) Guidelines: Mass Depopulation and Euthanasia. **2015**. https://www.aphis.usda.gov/sites/default/files/mass_depop_euthan_0.pdf
10. Reyes-Illg, G.; Martin, J.E.; Mani, I.; Reynolds, J.; Kipperman, B. The Rise of Heatstroke as a Method of Depopulating Pigs and Poultry: Implications for the US Veterinary Profession. *Animals* **2023**, *13*, 140. https://doi.org/10.3390/ani13010140
11. USDA-APHIS. 2022–2023 Highly Pathogenic Avian Influenza Outbreak: Summary of Depopulation Methods and the Impact on Lateral Spread. https://www.aphis.usda.gov/sites/default/files/hpai-2022-2023-summary-depop-analysis.pdf
12. USDA-APHIS-VS. Highly Pathogenic Avian Influenza Response Plan: The Red Book. **2017**. https://www.aphis.usda.gov/sites/default/files/hpai_response_plan.pdf
13. American Association of Avian Pathologists. Vaccination for H5N1 2.3.4.4b High Pathogenicity Avian Influenza: Questions and Answers. https://aaap.memberclicks.net/assets/NewsRelease/Vaccination%20Fact%20Sheet%20-%20AAAP.pdf
14. USDA-APHIS. HPAI Response: Ventilation Shutdown Plus (+) Policy. **2022**. https://www.aphis.usda.gov/sites/default/files/ventilationshutdownpolicy.pdf
15. Reyes-Illg, G.; Martin, J.E.; Mani, I.; Reynolds, J.; Kipperman, B. The Rise of Heatstroke as a Method of Depopulating Pigs and Poultry: Implications for the US Veterinary Profession. *Animals* **2023**, *13*, 140. https://doi.org/10.3390/ani13010140
16. USDA-APHIS. 2022–2023 Highly Pathogenic Avian Influenza Outbreak: Summary of Depopulation Methods and the Impact on Lateral Spread. https://www.aphis.usda.gov/sites/default/files/hpai-2022-2023-summary-depop-analysis.pdf
17. Canadian Food Inspection Agency. (2022). Planning for Alternative Depopulation Options during a Highly Pathogenic Avian Influenza Outbreak in Canada.
18. Council Regulation (EC) No 1099/2009 of 24 September 2009 on the Protection of Animals at the Time of Killing. EUR-Lex. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009R1099
19. The Welfare of Animals at the Time of Killing (England) Regulations 2015. legislation.gov.uk. Available online: https://www.legislation.gov.uk/uksi/2015/1782/contents/made. [Note that similar regulations are in effect in Northern Ireland, Scotland, and Wales. Complete citation information available upon request]
20. Animal Health Australia. Operational manual: Destruction of Animals (version 5.0). Australian Veterinary Emergency Plan (AUSVETPLAN), edition 5. **2026**. Canberra, ACT. https://animalhealthaustralia.com.au/wp-content/uploads/dlm_uploads/2026/01/AUSVETPLAN_Operational-Manual_Destruction-of-Animals-v5.0.pdf
21. Hill, J. A Better Means to a Humane Ending? Nitrogen Anoxia for the Mass Depopulation of Livestock, **2025**. Recording: https://www.youtube.com/watch?v=8ats0zN_gY4 Presentation slides: https://www.vafaw.org/_files/ugd/231617_f76db69528b0489facb1a880a25fb4fb.pdf
22. McKeegan, D. Mass Depopulation. In *Advances in Poultry Welfare*; Elsevier, 2018; pp 351–372. https://doi.org/10.1016/B978-0-08-100915-4.00017-8
23. Poole, G.H.; Fletcher, D.L. A Comparison of Argon, Carbon Dioxide, and Nitrogen in a Broiler Killing System. *Poultry science* **1995**, *74*, 7: 1218–1223.
24. Gent, T. C.; Gebhardt-Henrich, S.; Schild, S.-L. A.; Rahman, A. A.; Toscano, M. J. Evaluation of Poultry Stunning with Low Atmospheric Pressure, Carbon Dioxide or Nitrogen Using a Single Aversion Testing Paradigm. *Animals* **2020**, *10* (8), 1308. https://doi.org/10.3390/ani10081308

25. AVMA. *AVMA Guidelines for the Euthanasia of Animals: 2020 Edition*. https://www.avma.org/sites/default/files/2020-02/Guidelines-on-Euthanasia-2020.pdf

26. Hill, J. Evaluation of Nitrogen Whole House Gassing for the Mass Depopulation of Poultry., 2024. Recording: https://poultryinnovationpartnership.ca/presentation/evaluation-for-adopting-nitrogen-in-whole-barn-gassing-during-the-mass-depopulation-of-poultry/. Powerpoint: https://poultryinnovationpartnership.ca/wp-content/uploads/2024/12/Webinar-9_3_2024-compressed.pdf

27. Australian Eggs. Validation of Modified Atmospheric Nitrogen Euthanasia (MANE) in Australian layers. **2025**.

28. Datapro. Whole House Gassing System Developed by Cortex Agritechnology. https://www.vafaw.org/_files/ugd/231617_1d3340bd07a34d4b829c551400351561.pdf

29. McKeegan, D. Mass Depopulation. In *Advances in Poultry Welfare*; Elsevier, **2018**; pp 351-372. https://doi.org/10.1016/B978-0-08-100915-4.00017-8

30. United Kingdom Animal Welfare Committee. Opinion on the Use of High Expansion Nitrogen Foam Delivery Systems for depopulation of poultry flocks affected by notifiable disease in the UK **2024**. https://www.gov.uk/government/publications/awc-opinion-on-high-expansion-nitrogen-foam-for-culling-poultry/awc-opinion-on-the-use-of-high-expansion-nitrogen-foam-for-culling-poultry

31. Raj, A. B., Smith, C., & Hickman, G. (2008). Novel method for killing poultry in houses with dry foam created using nitrogen. *The Veterinary record, 162*(22), 722–723. https://doi.org/10.1136/vr.162.22.722

32. HEFT. The C3: System for large-scale euthanasia of livestock **2025**. https://heftinternational.com/c3/

33. Agricultural Emergency Services Incorporated. Nitrogen Foam. https://www.agemergency.com/home

34. Livetec Systems. Nitrogen Foam Delivery System. https://www.livetecsystems.co.uk/resource-hub/nitrogen-foam-delivery-system-nfds-product-guide/

35. Animal Welfare Institute. Higher-Welfare Farmed Animal Depopulation Methods: Information and Sources **2025**. https://awionline.org/sites/default/files/uploads/documents/awi-higher-welfare-farmed-animal-depopulation-methods.pdf

36. United States Animal Health Association. Resolution: Accessibility of Nitrogen-Based Depopulation Methods for Response to Highly Pathogenic Avian Influenza. **2025** https://usaha.org/wp-content/uploads/2025/11/2025-Res-24-AnimalWelfare.pdf

37. Sign-on letter to American Veterinary Medical Association. **2025**. https://b198cd96-ba6b-426f-ad3d-a1c0bdb58e43.filesusr.com/ugd/73e29d_698cd7499a4a49779ada8f8d832f456c.pdf

38. Granger, A. Letter from the Animal Welfare Institute to USDA APHIS Policy and Program Development regarding Comments on Interim Rule Pertaining to Conditions for Payment of Indemnity and Compensation for Highly Pathogenic Avian Influenza (Docket No. APHIS-2023-0088). March 3, 2025. https://awionline.org/sites/default/files/uploads/documents/comments-aphis-hpai-indemnity-interim-rule.pdf

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AWI seeks to advance the welfare of animals raised for agricultural purposes–on the farm, during transport, and at slaughter. We support plant-based food choices and higher-welfare options when animal products are consumed and work to ensure accuracy and transparency in animal-product marketing claims pertaining to the welfare of farmed animals.

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