

Negative Air Pressure Cover for Preventing Odor Emission from Earthen Manure Storage

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Species: Swine
Use Area: Manure storage
Technology Category: Cover
Air Mitigated Pollutants: Odor

Description:

Open earthen manure storage basins (EMSB) are the main source of odor from swine operations. Manure storage facilities are not only the most visible odor source on a farm, but odor from manure storage tends to be more persistent in the atmosphere in comparison with odor from barns. Covering manure storages is an effective way of minimizing odor emission. Synthetic plastic covers have been used and shown to be effective in reducing odor emission. In order to ensure the cover is robust enough to withstand wind forces however, the plastic covers become too heavy and expensive to be attractive to the livestock industry. DGH Engineering Ltd. in Manitoba, Canada has developed a unique technology that utilizes negative air pressure (NAP) to anchor lightweight plastic covers capable of withstanding high wind forces. This patented technology is available from Encon Technologies Inc., Manitoba, Canada. The NAP system has been evaluated on several farms. A comparison of odor emissions between a NAP covered and an open EMSB was conducted on two 3000-sow farrowing facilities which were almost identical in design and management. The average emission rate from the NAP covered manure storage was $0.3 \text{ OU s}^{-1} \text{ m}^{-2}$, which is negligible in comparison with the rate from the open manure storage ($20.3 \text{ OU s}^{-1} \text{ m}^{-2}$). Additional benefits of the NAP cover system include the retention of manure nitrogen, thus increasing the fertilizer value of manure; isolating precipitation from the manure, thereby increasing storage volume; and reducing greenhouse gas emissions.

Mitigation Mechanism:

Odor emission from EMSB occurs in three main steps: production of odorous compounds due to anaerobic degradation of organic matter in manure, transport of odorous compounds to the manure surface (bubbling and diffusion); and release of odorous compounds from the manure surface to the atmosphere. A cover forms a physical barrier between the manure surface and the atmosphere to prevent odorous compounds from being released into the atmosphere, thus eliminating or reducing odor emission. An impermeable cover could theoretically eliminate odour emission during storage, although trapped odorous gases may still be released during agitation and land application.

A challenge to using plastic covers on EMSB is to prevent the covers from being damaged by wind forces. The use of *heavy* plastic would allow the cover to withstand wind forces, but the cost becomes unattractive to livestock producers. Heavy synthetic covers require significant foundations that also substantially increase cost. The uniqueness of the NAP cover system is using *lightweight* plastic (e.g., 20 mil reinforced polyethylene) and an air pumping system to create negative pressure to hold the cover down to the manure surface to resist wind forces (fig. 1).

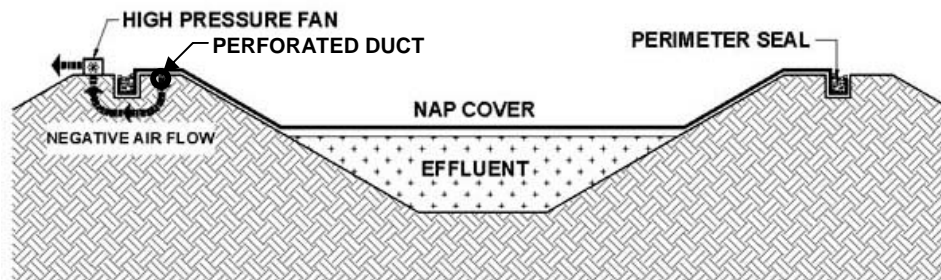


Figure 1. Illustration of negative air pressure cover for earthen manure storage basin (ENCON 2008)

Negative air pressure is created by using small (high pressure, low flow rate) exhaust fans that are connected to the perforated duct placed beneath the cover along the perimeter (fig. 1). Typically, the fans develop a negative static pressure of approximately 62 to 374 Pa (1/4 to 1.5 in of water) under the cover. The impermeable plastic cover virtually

eliminates the transfer of odorous gases from the manure surface to the atmosphere. The fans that create the negative air pressure may, however, release a small amount of odorous air to the atmosphere. The air flow rate of the exhaust fans is very low (about 50 - 70 L/s per fan) and most of this air is leakage of fresh air that occurs at the perimeter seal. The net result is that odor emission is insignificant.

Applicability:

The NAP cover system is effective in reducing odor emission from earthen manure storage basins for swine operations (fig. 2), as well as other types of liquid waste storage facilities. Small and Danesh (1999) performed a subjective assessment of odor around a NAP covered swine manure storage basin. They reported that odor was not detectable during fall, winter and early spring, and a slight odor was detectable downwind and at close proximity to the fan outlets during the summer months. Zhang et al. (2007) conducted a study to compare odour emissions between an open and a NAP covered EMSB for two swine farrowing operations of 3,000-sows which were almost identical in design and management. The NAP covered EMSB had two cells (61 x 51 m primary cell and 61 x 155 m secondary cell). Eight exhaust fans that were used to create negative pressure for holding down the covers (two in the primary cell and 6 in the secondary cell) drew $0.6 \text{ m}^3/\text{s}$ air (about 160 cfm per fan), resulting in an odor emission rate of $3.8 \times 10^3 \text{ OU/s}$, which is about 2% of that from the open EMSB in comparison ($1.7 \times 10^5 \text{ OU/s}$). When the emission rate was expressed as per m^2 of the manure surface, the weighted average rate of the two cells of the NAP covered EMSB was $0.3 \text{ OU s}^{-1} \text{ m}^{-2}$, which is negligible in comparison with the rate from the open EMSB ($20.3 \text{ OU s}^{-1} \text{ m}^{-2}$). Furthermore, the open EMSB contributed 57% to the total odor emission (building plus manure storage), whereas, the NAP covered EMSB contributed only 2%.



Figure 2. Installed negative air pressure cover system in a swine farrow-to-finish operation

Zhou et al. (2005) conducted field measurements to assess the impact of the NAP cover on downwind odor. Fifteen human odor sniffers were trained to use an 8-point ASTM Odour Intensity Reference Scale (ASTM 1999) to quantify the field odor intensity within a 1-km radius of two 3,000-sow farrowing facilities, one with a NAP EMSB and the other one with an open EMSB. Based on the data from Zhou et al. (2005), Gu et al. (2006) developed predictive equations for downwind odor intensity for the two facilities (fig. 2). Downwind odor intensity from the facility with the NAP EMSB was about 1.5 levels lower than that with the open EMSB at 100 m and the difference was 0.5 intensity levels at 1 km. If the intensity level 3, which describes an odor intensity of *little annoyance*, is used to define the odor annoyance free distance (OAFD) ($I = 3$, $\text{OAFD} = D$ in predictive equations), the NAP cover resulted in an OAFD of 667 m, whereas the open EMSB 926 m. This implies that the NAP cover could reduce the setback distance by 28%.

The cover can also be utilized to capture methane which is a greenhouse gas (GHG). Livestock producers utilizing this technology could potentially sell carbon credits. The methane released from the manure forms large bubbles under the cover. Typically, the large bubbles slowly move with the wind toward the side of the storage, where they are then evacuated by the fan and duct system. This "burping" will normally occur once or twice per day in warm weather (May to September) when the anaerobic bacteria are most active. Since the methane is released from a limited number of fan outlets, it can be easily flared off.

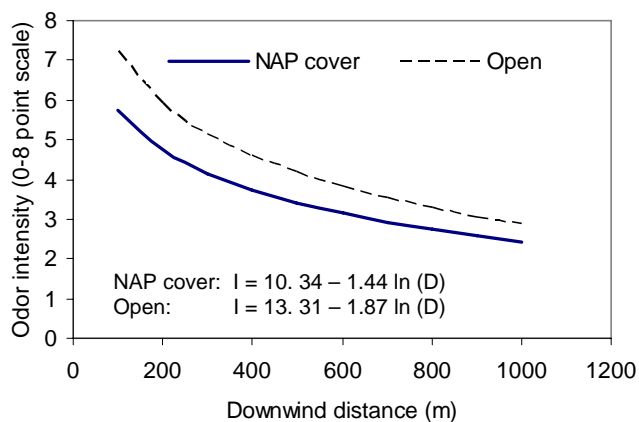


Figure 3. Odor intensity downwind from two 3000-sow farrowing operations. I = odor intensity (0-8 scale); D = downwind distance (m).

Limitations:

The solids in livestock manure require agitation to maintain the solid particles in suspension so that they will be removed with the liquid during pump-out. Traditional agitation involves the use of large tractor powered pumps that are backed into the storage and operated continuously to agitate the manure, while a second pump is simultaneously operated to remove the manure from the storage. This procedure requires that the cover be removed from the storage cells that contain manure solids.

Removing and replacing the cover annually or semi-annually for pump-out increases the wear on the cover and adds labor and time to the pump-out operation. To solve this problem, DGH Engineering has designed an air assisted agitation system that does not require removal of the cover. A grid of small air lines injects air into the bottom of the storage through diffusers located in a one metre grid (fig. 4). A blower (operating at a pressure of approximately 100 kPa) provides the air for agitation. Since this system agitates the complete storage, agitation and solid removal is improved over traditional pump systems and the risk of damage to clay liners is eliminated. The cost of installing and operating the air agitation system is comparable to conventional systems.

To assist with the filling and emptying of the manure storage, separate concrete wet wells are often utilized. Concrete ramps normally installed for conventional pumps can be eliminated with the NAP cover and air agitation system.



Figure 4. Air assisted agitation system in operation

Cost:

The capital cost of the cover varies with the size of the storage; whether the EMSB contains one, two or three cells; the complexity of the installation (existing sites may have various appurtenances) and the location. Typical costs vary from \$10.00 to \$15.00 per m², installed.

The annual cost per pig marketed for typical 5,000 and 10,000 head swine finisher operations is estimated to be \$1.40 and \$1.13, respectively, per pig marketed. The following assumptions were used in determining these costs:

Lifespan of cover:	10 years
Interest rate:	8 percent
Maintenance and Repairs:	3 percent of capital cost
Energy cost:	6 cents per kilowatt-hour
Barn efficiency:	2.8 pigs marketed per pig place

The fans used to maintain the negative pressure are ¼ kilowatt centrifugal blowers that run continuously. A large EMSB typically utilizes four to six fans.

Offsetting the cost of the cover is the value of the nitrogen retained by the cover. A 5,000 head swine finisher operation will excrete approximately 50,000 kg of nitrogen annually. Nitrogen losses from a NAP covered EMSB are negligible. Losses from uncovered storages vary widely but are reported to vary between 30 to 50 percent (Agricultural Guidelines Development Committee 1998). Assuming a loss of five percent for a NAP covered EMSB and 40 percent for an open EMSB, approximately \$20,000.00 of nitrogen can be retained annually, based on a nitrogen cost of \$1.10 per kilogram. The nitrogen saved is approximately equivalent to the cost of the cover.

In comparison with permeable EMSB covers, such as straw, an additional economic advantage of the NAP cover is the potential gain in storage capacity due to the isolation of precipitation. With a NAP cover, precipitation remains on top of the cover as clean, uncontaminated water until it is pumped off. In a large portion of the Great Plains region of North America, evaporation is approximately equal to precipitation, therefore a NAP cover has no advantage compared to an uncovered EMSB. However, with a straw cover, all precipitation enters the storage through the porous straw. Evaporation, however, is negligible through the heavy mat of straw. In the example of the 5,000 head finisher barn, approximately 2500 m³ of storage capacity can be gained where the annual precipitation excluded is 300 mm. EMSB construction costs vary widely but a value of \$10.00 per m³ is typical. In the eastern maritime regions of North America, annual precipitation can exceed 1000 mm; the value of the storage volume saved will nearly pay for the cover in these areas.

Implementation:

The NAP technology is patented in both Canada and the United States. It is available exclusively through Encon Technologies Inc., St. Andrews, Manitoba, Canada. Encon only supplies installed covers therefore all design and construction details are proprietary.

In general, the cover material varies from 0.4 to 0.7 mm and is a low density polyethylene. The cover is either permanently anchored in an earthen trench, which is typical for second cells that do not contain manure solids requiring agitation; or it is anchored with sand bags in trenches for removal of the cover. The cover material is treated for ultraviolet light and has a life span of approximately 10 years or greater.

Technology Summary:

Impermeable synthetic covers block the transfer of odorous compounds from the manure surface to the atmosphere, thus eliminating or reducing odor emission from earthen manure storage basins. DGH Engineering Ltd. in Manitoba, Canada, has developed a unique technology that utilizes negative air pressure (NAP) to anchor lightweight plastic covers to ensure the cover is robust enough to withstand wind forces. The NAP cover system uses small exhaust fans to create a negative pressure between the synthetic cover and the manure surface in order to hold down the cover, thus preventing wind damages to the cover. Odor emission from the NAP cover is negligible. The capital cost of a NAP system from Encon Technologies Inc., Manitoba, Canada is approximately \$10 to \$15 per square metre, with a service life of ten years or more. The value of the nitrogen retained by the cover is approximately equivalent to the cost of the cover. Other benefits can include additional storage volume gained from eliminating precipitation and the reduction of GHG emissions.

Additional Resources:

Additional information on the NAP cover system can be obtained from www.enconcovers.com or by contacting Doug Small of DGH Engineering Ltd., (204) 334-8846.

References

- Agricultural Guidelines Development Committee. 1998. Farm Practices Guidelines for Hog Producers in Manitoba. Published by Manitoba Agriculture, Food, and Rural Initiative, Winnipeg, MB, Canada.
- ASTM. 1999. E544-75: Standard Practices for Referencing Suprathreshold Odour Intensity. Annual Book of ASTM Standards. Philadelphia, Pa.: American Society of Testing and Materials.
- ENCON. 2008. *Negative Air Pressure (NAP) Cover Systems*. Available at www.enconcovers.com. Accessed 22 March, 2008.
- Guo, H., Y. Li, Q. Zhang, and X. Zhou. 2006. *Comparison of Four Setback Models with Field Odour Plume Measurement by Trained Odour Sniffers*. Canadian Biosystems Engineering 48:6.39-6.48.
- Small, D. and S. Danesh. 1999. *Development of a Negative Air Pressure Cover System for Swine Earthen Manure Storages In Manitoba*. Report submitted to Manitoba Livestock Manure Management Initiative. DGH Engineering Ltd., Winnipeg, MB.
- Zhang, Q., X. J. Zhou, N. Cicek, and M. Tenuta. 2007. *Measurement of Odour and Greenhouse Gas Emissions in Two Swine Farrowing Operations*. Canadian Biosystems Engineering 49:6.13-6.20.
- Zhou, X, Q. Zhang, and H. Guo. 2005. *Measuring Odor Plumes in Two Swine Farrowing Operations*. ASAE Paper No. 054042, Am. Soc. Agric. Eng., St. Joseph, MI.

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