A Review of Manure Injection to Control Odor and Ammonia Emissions during the Land Application of Manure Slurries

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Species: Swine, Dairy, and Beef
Use Area: Land Application
Technology Category: Manure Injection
Air Mitigated Pollutants: Ammonia, Odor

Description:

Manure slurry injection provides a significant reduction in odor and ammonia emissions from the land application of manure when compared to conventional surface broadcasting of manure. Release of odor and ammonia during land application can be reduced by more than 90% compared to conventional application methods (Ohio State University, 2007). Manure can be successfully injected in both conventional tillage and no-till systems with currently available equipment. Current equipment options and costs are presented in this paper for both drag-hose and tanker systems. The positive and negative aspects of each system type will be discussed. Additionally the cost to have manure injected by professional commercial applicators will also be discussed.

Research by Hanna et al., (2000) compared the odor and ammonia volatilization mitigation capabilities of various types of manure injection techniques to slurry that was surface applied (broadcasted). Air samples were taken immediately after application, the day after, and five days after application. The samples were analyzed using a dynamic olfactometer and a four-member panel. Odor level was determined in odor units, or the average number of dilutions required to obtain undetectable odor (the threshold odor level). Ammonia concentration was measured with a Sensidyne ammonia tube (SKC, Inc., Eighty-four, Pennsylvania). Odor and ammonia tests were run for both fall and spring application. Ammonia was below the detection limit (0.2 ppm) for all but two (measured at 0.6 and 1.3 ppm) of the 72 samples taken. Table 1 contains some of the odor data presented by Hanna.

Table 1. Odor* measured from application of swine slurry on soybean residue (Hanna et. al. 2000)

	Fall Application			Spring Application	
Application	At Application	One Day After	Five Days After	At Application	One Day After
Broadcast	807	876	63	140	40
Narrow Knife Injection	185	52	43	61	44
Sweep Injection	94	60	43	35	16
Chisel Injection	256	113	43	33	43

*Odor units are the number of clean air dilutions required to reach the threshold odor level for a panel of four observers.

This research shows broadcasting manure requires approximately 4 to 5 times the fresh air dilutions required to reach the threshold level compared to the number of dilutions required for injected manure, indicating the large odor reduction provided by injection compared to broadcasting. In a different study odor intensity from broadcasting at 400 meters downwind was found to be similar to that of injection at only 50 meters (Berglund and Hall, 1987).

Mitigation Mechanism:

A variety of tools are available to inject slurry but all perform similarly. The tool (a narrow knife, a sweep, chisel plow or chisel ripper) slices through the soil to create a sub-surface cavity approximately 13-23 cm (5-9 inches) deep (Puck, 2008). The slurry is injected through tubes directly into the cavity behind the tool. This provides immediate mixing of slurry and soil as well minimizing exposed slurry and residue cover disturbance. By minimizing slurry exposure to air, odor is reduced significantly and ammonia volatilization is mostly avoided.

Applicability:

Injection application can be used with any slurry or liquid type manure which is greater than 85% and 90% moisture content for swine and dairy waste respectively (AMWFH, 2007). Injection is used extensively for swine slurry and liquid dairy manure but can also be used to apply captured beef feedlot runoff. Additionally, most injection tools leave enough crop residue to accommodate no-till cropping schemes. Hanna et al. (2000) found that injection tools left soybean crop residues 75-85% intact.

Limitations:

Compared to conventional broadcast of manure, injection has a few limitations. Injection generally requires as much as 30% more tractor horsepower than broadcast because of the added weight and drag of the injection tools in the soil, especially in hilly terrain (Puck, 2008). Injection may not be desirable in forage or pasture/sod fields where the producer does not with to disturb soil. In this case, broadcasting may be required. Injection tools and the hydraulic systems required to lift the tools from the ground will wear requiring more maintenance than a broadcast system.

Cost:

Generally, injection is more costly than broadcast application. Injection requires more tractor horsepower and more equipment (injection tool bars). Because tool bars are pulled through the soil, wear and maintenance is greater with injection systems. Tables 2 and 3 give the cost of commercial drag hose slurry injection and broadcast respectively in $/gal and $/L. Figures 1 and 2 show the cost of commercial drag hose slurry injection and broadcast respectively in $/acre with increasing transfer distance. Cost increases as application rate decreases and as distance from the manure storage site increases. Puck Custom Enterprises (PCE) applies a mileage charge of $.001/gal/mile for every mile over one from the manure storage site (Puck, 2008). The increase in cost as application rate decreases is due to wear on the application equipment. At lower application rates, field speed is increased causing wear (and eventually maintenance) on the equipment to increase.

Table 2. Commercial slurry injection cost for drag hose application one mile from the site (Puck, 2008).

Gallons/acre	Inch-acres	Liters/hectare	$/gal (1 mile)	$/L (1 mile)
3000	0.11	28037	$ 0.019	$ 0.0050
4000	0.15	37383	$ 0.017	$ 0.0044
4750	0.17	44392	$ 0.015	$ 0.0038
5500	0.20	51401	$ 0.014	$ 0.0037
7000	0.26	65420	$ 0.014	$ 0.0036
9000	0.33	84111	$ 0.013	$ 0.0034
12000	0.44	112148	$ 0.012	$ 0.0032

Table 3. Commercial slurry broadcast cost for drag hose application one mile from the site (Puck, 2008).

Gallons/acre	Inch-acres	Liters/hectare	$/gal (1 mile)	$/L (1 mile)
3000	0.11	28037	$ 0.010	$ 0.0026
4000	0.15	37383	$ 0.010	$ 0.0026
4750	0.17	44392	$ 0.010	$ 0.0026
5500	0.20	51401	$ 0.010	$ 0.0026
6000	0.22	56074	$ 0.0085	$ 0.0022
9000	0.33	84111	$ 0.0085	$ 0.0022
12000	0.44	112148	$ 0.0085	$ 0.0022

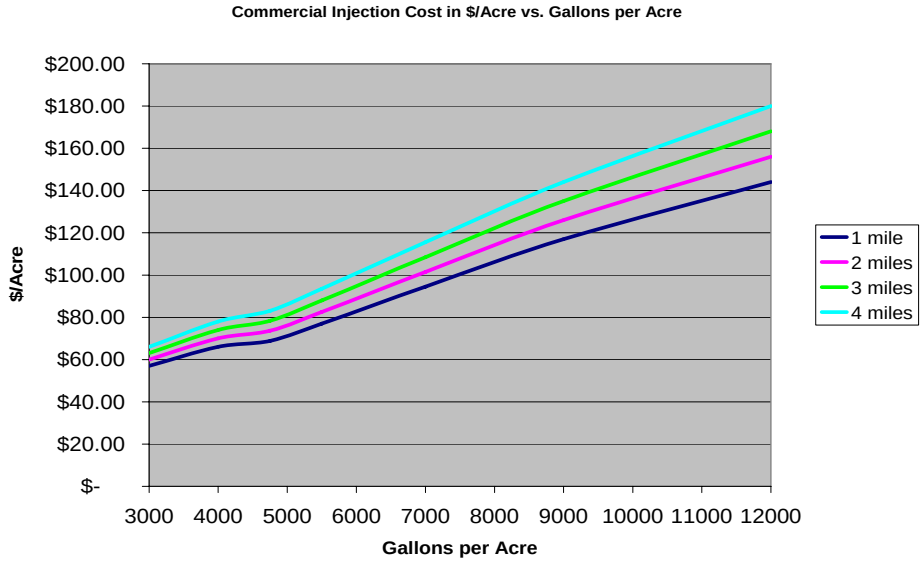

Figure 1. Commercial injection cost for drag hose application (Puck, 2008).

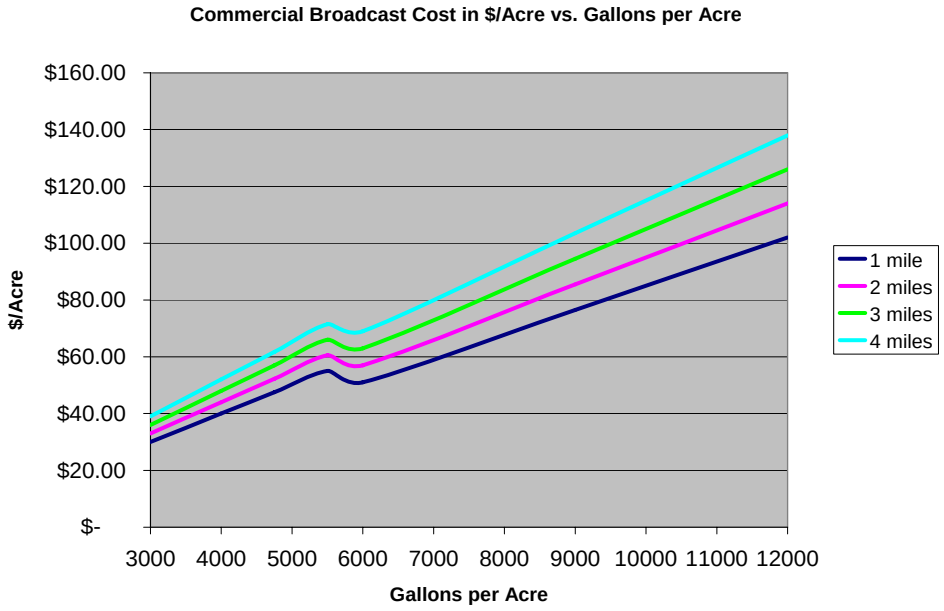

Figure 2. Commercial broadcast cost for drag hose application (Puck, 2008).

Tables 3 and 4 give ownership and maintenance cost data for tanker wagon and drag hose injection systems respectively. In Tables 5 and 6, the operational cost is compared to the cost of commercial application for wagon and drag hose injection systems respectively. The ownership and operational cost for both systems is represented graphically in Figures 3 and 4. It should be noted that the estimates include the purchase of tractors required to operate the systems. Costs will we less if the producer already owns adequate tractor power but the maintenance and operation costs will remain because they are specific to the systems. Additionally, if the producer already owns a tanker wagon and wishes to retrofit it with an injector bar the cost will be reduced. The cost for wagons in Table 3 includes the wagon and injector bar. Wagons can be retrofitted with a 6.7m (22 ft), five tool injection tool bar for approximately $12,000 (Puck, 2008).

Table 3. Tanker wagon injection system ownership and maintenance cost (Puck, 2008)*.

	Capital (1 wagon)**	Capital (2 wagons)	Capital (3 wagons)	Maintenance (1 wagon, $/year)***	Maintenance (2 wagons, $/year)	Maintenance (3 wagons, $/year)
Used 220 HP tractor (wagon)	$50,000	$100,000	$150,000	$4,000	$8,000	$12,000
Used 100 HP tractor (pump/agitator)	$15,000	$15,000	$15,000	$1,200	$1,200	$1,200
Load stand	$500	$500	$500	$40	$40	$40
4800 gallon tanker with injection tool bar	$41,500	$83,000	$124,500	$3,320	$6,640	$9,960
Agitator pump	$12,000	$12,000	$12,000	$960	$960	$960
Total	$119,000	$210,500	$302,000	$9,520	$16,840	$24,160

* Values are estimates from Puck Custom Enterprises, a commercial manure application business utilizing wagon and drag hose systems.
** Values are based on estimates for new equipment unless otherwise stated.
*** Yearly average for 5 years of operation.

Table 4. Drag hose injection system ownership and maintenance cost, (Puck, 2008)*

	Capital cost**	Maintenance cost/year***		
Boom Truck (with feeder pump and high pressure pump)	$100,000		$8,000	
Hose Cart	$19,950		$1,596	
Used 240 HP MFWD tractor (tool bar)	$95,000		$7,600	
Used 130 HP tractor (hose cart)	$25,000		$2,000	
Used 100 HP tractor (agitation pump)	$10,000		$800	
22', 7 knife, injection tool bar with flowmeter	$31,000		$2,480	
ATV (for checking hose)	$4,000		$320	
1/4 mile 5" drag Hose	$12,210		$977	
1 mile 6" transfer hose	$42,240		$3,379	
Agitator pump	$12,000		$960	
Total	$351,400		$28,112	

* Values are estimates from Puck Custom Enterprises, a commercial manure application business utilizing wagon and drag hose systems.
** Values are based on estimates for new equipment unless otherwise stated.
*** Yearly average for 5 years of operation

Table 5. Wagon injection system operation cost compared to commercial application cost (Puck, 2008)*.

Gallons applied per year (millions)	Maintenance ($/year)**	5 year amoritization capital cost, 6.5% ($/year)	Fuel cost, $3.00/gal ($/year)	Labor ($/year)***	Insurance ($/year)	Total ownership cost ($/year)****	Commercial application cost, $.0135/gal ($/year)*****
1	$9,520	$28,636	$3,000	$1,953	$6,500	$49,609	$13,500
4	$9,520	$28,636	$12,000	$7,813	$6,500	$64,468	$54,000
8	$16,840	$50,654	$24,000	$15,625	$6,500	$113,619	$108,000
11	$16,840	$50,654	$33,000	$21,484	$6,500	$128,478	$148,500
15	$24,160	$72,672	$45,000	$29,297	$6,500	$177,629	$202,500
20	$24,160	$72,672	$60,000	$39,063	$6,500	$202,394	$270,000

* Values are estimates from Puck Custom Enterprises, a commercial manure application business utilizing wagon and drag hose systems.
** Yearly average for 5 years of operation.
*** Based on $15/hour/worker, 1 laborer per wagon, 2 loads/hour/wagon, plus 25% for equipment transport and downtime labor.
**** It is assumed 1 wagon is used for less than 8 million gallons, 2 wagons for 8 -15 million gallons, and 3 wagons for over 15 million gallons.
***** Average (application rate, transport distance) commercial application cost of drag hose injection.

Table 6. Drag hose injection operation cost compared to commercial application cost, (Puck, 2008)*.

Gallons applied per year (millions)	Maintenance ($/year)**	5 year amoritization capital cost, 6.5% ($/year)	Fuel cost ($3.00/gal, $/year)	Labor*** ($/year)	Insurance ($/year)	Total ownership cost ($/year)	Commercial application cost, $.0135/gal ($/year)****
1	$28,112	$84,559	$2,250	$750	$12,500	$128,171	$13,500
2.5	$28,112	$84,559	$5,625	$1,875	$12,500	$132,671	$33,750
5	$28,112	$84,559	$11,250	$3,750	$12,500	$140,171	$67,500
10	$28,112	$84,559	$22,500	$7,500	$12,500	$155,171	$135,000
15	$28,112	$84,559	$33,750	$11,250	$12,500	$170,171	$202,500
20	$28,112	$84,559	$45,000	$15,000	$12,500	$185,171	$270,000
25	$28,112	$84,559	$56,250	$18,750	$12,500	$200,171	$337,500

* Values are estimates from Puck Custom Enterprises, a commercial manure application business utilizing wagon and drag hose systems.
** Yearly average for 5 years of operation
*** Based on 2 laborers, $15/hour/laborer, 40,000 gallons/hour efficiency (60,000 gallons/hour minus 33% for set-up, transportation, and maintenance).
**** Average (application rate, transport distance) commercial application cost of drag hose injection.

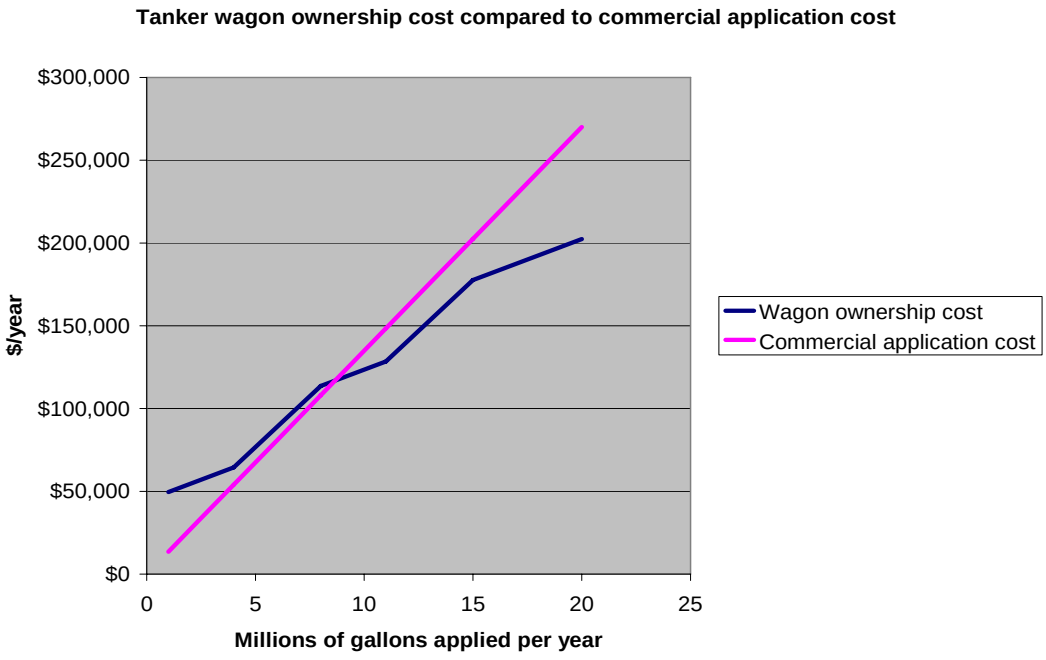

Figure 3. Tanker wagon injection system ownership and operation cost compared to commercial application cost (Puck, 2008).

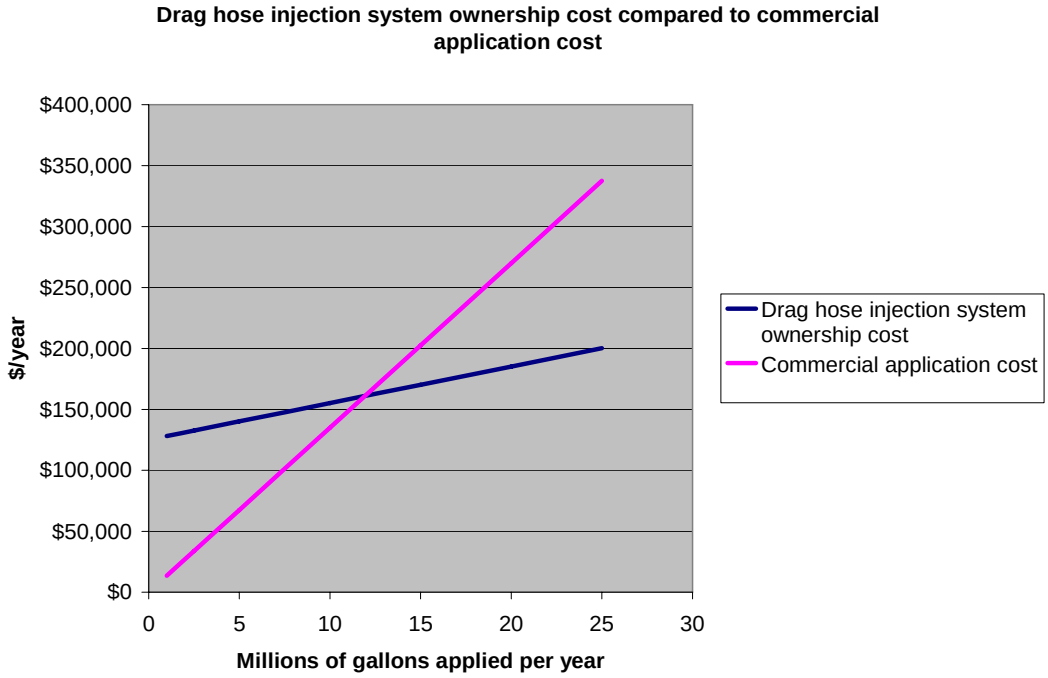

Figure 4. Drag hose injection system ownership and operation cost compared to commercial application.

Implementation:

Injection equipment can be purchased from many different vendors. If a producer currently uses a tanker wagon to broadcast slurry, most wagons can be retrofitted with an injection toolbar. If large amounts of slurry are to be applied (greater than 5 million gallons) a drag hose injection system may offer the best performance. It should be noted that with drag hose injections systems the slurry flow is continuous and that surface spillage will occur on end rows while turning around. The spillage should be incorporated to avoid odor and ammonia volatilization associated with surface application.

Additional Resources:

More information can be found through Puck Custom Enterprises (PCE).

Puck Custom Enterprises
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www.puckenterprises.com

Acknowledgments:

The majority of manure handling equipment information was provided by Puck Custom Enterprises (PCE). PCE has been a commercial application business in western Iowa for over 27 years. Currently, PCE owns and operates several drag hose systems as well as tanker wagons to apply over 100 million gallons of swine, dairy, and beef feedlot slurry per year.

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