

How does Air Filtration fit into Porcine Reproductive and Respiratory Virus Regional Control and Eradication Strategies?

Laura Batista, François Pouliot, Valerie Dufour and Michel Morin

Centre de développement du porc du Québec inc., 2795, boul. Laurier, bureau 340, Québec, QC, G1V 4M7; *Email*: lbatista@cdpqinc.qc.ca

■ Introduction

The economical impact of porcine reproductive and respiratory syndrome (PRRS) has been recognized worldwide. In 1990 Polson et al. (1990) estimated losses at US\$236 per sow due to infertility, abortions, stillbirths and neonatal mortality. More recently, Neumann et al. (2005) reported a total cost of \$560 million due to PRRS in growing pigs: \$250 million (45%) was due to declines in average daily gain and feed efficiency in growing pigs; \$243 million (43%) resulted from mortality in growing pigs; \$63 million (12%) was attributed to reproductive losses; estimates in this study were based on feed costs of \$0.286 per kg. Since the study was conducted, feed costs have increased by 50-65%, partly as a result of market demand for corn by ethanol manufacturers (Funderburke, 2007), therefore, PRRSV actual economic impact is currently higher (Zimmerman 2008).

Globally the swine industry has recently been hit by new diseases such as PRRS, PCVAD, and new variants of influenza virus. Consequently, veterinarians have developed different means for individual farms or groups to eradicate diseases; however the risk of re-infection remains high even with the best current practices of biosecurity. This has led to a consensus that more coordinated, or 'regional', approaches must be taken to combat PRRS and other emerging swine diseases.

Clearly, the objective of today's prevention programs is either to stop the introduction of different pathogens, particularly PRRSV, into negative herds or

the introduction of new pathogens and of new strains into PRRSV-infected herds (Dee et al., 2001). As of today, we know that animals and semen are the primary sources of PRRSV but other sources of infection may also be important (Desrosiers, 2002 and 2004a,b). Torremorell et al. (2004) reported that over 80% of new infections in a commercial system in the US were due to area spread from neighboring units, the movement of pigs in PRRSV infected transports, and the lack of compliance to the biosecurity protocols. Dee et al. (2004a) demonstrated that simple hygiene measures were adequate to inactivate PRRSV and stop transmission. Also, this group have described protocols involving cleaning, washing, disinfection and drying that were effective at inactivating PRRSV on transport vehicles (Dee et al. 2004b,c; 2005a,b; 2007; and Dee and Deen, 2006a,b).

■ Regional Control and Eradication Strategies

As already mentioned, there is growing consensus among the veterinary community that coordinated regional efforts will be necessary to effectively combat diseases like PRRS, and other emerging diseases of swine, rather than isolated efforts on individual farms which are often frustrated by the reappearance of a disease.

Table 1. General characteristics of diseases requiring regional vs. individual approaches to control (adapted from Hanson and Hanson, 1978)

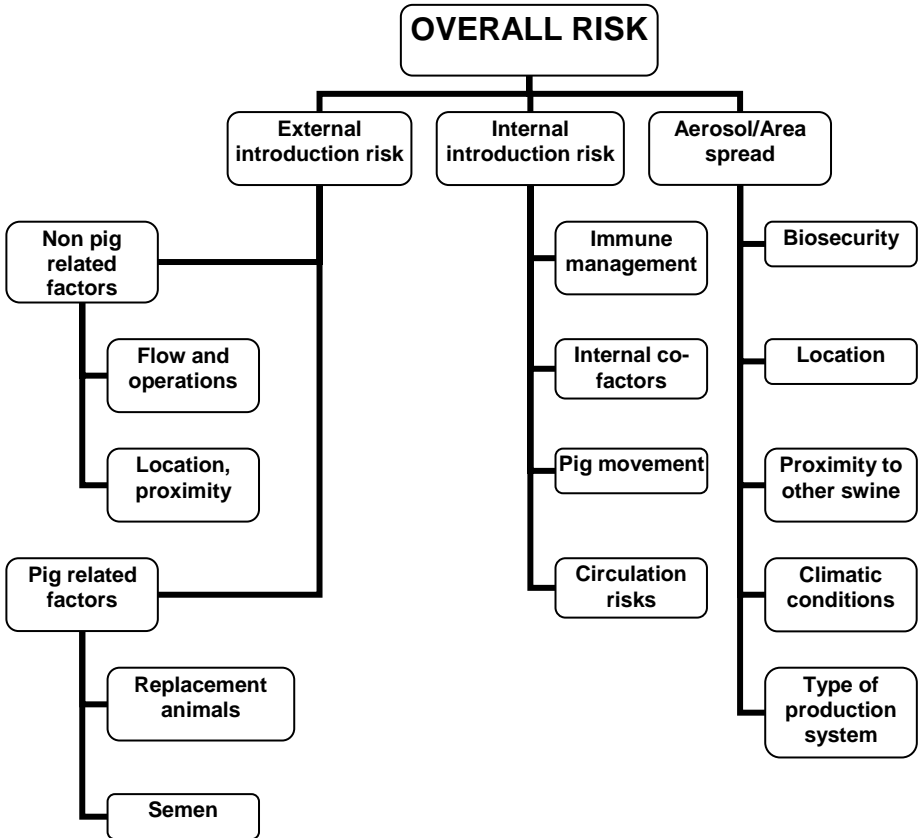
Regional Control	Individual Herd Control
<ul style="list-style-type: none"> ● Disease readily bypasses standard biosecurity barriers ● Rate of spread is too fast to permit intervention before entire herd becomes infected ● Apparently healthy carriers disseminate the disease ● Disease causes high morbidity and high mortality ● Vaccine or treatment is only poorly to moderately effective ● Disease constitutes a public health risk 	<ul style="list-style-type: none"> ● Spread of disease is stopped by standard biosecurity barriers ● Rate of spread is slow enough to permit intervention before entire herd becomes infected ● Carriers of disease can be detected at the farm ● Disease causes low to high morbidity with low or no mortality ● Highly effective vaccine or treatment is available ● Disease does not constitute a public health risk

Researchers around the world have been working actively to understand mechanisms of transmission of PRRS, and on evaluating new options for improving prevention and farm biosecurity. These are most notably related to transport biosecurity, insect borne transmission, and most recently options for air filtration.

Biosecurity has become more significant in trying to deal with PRRS than it has been for other swine diseases. Disease control programs rely on accurate epidemiologic surveillance, access to appropriate tools for diagnosis and control, and adequate financial and human resources. Interventions that support regional control programs include implementation of effective regional and local biosecurity, quarantine of infected herds (and suspicious and contact populations), restrictions on animal movement, possible herd depopulation, with cleaning and disinfection and implementation of an adequate vaccination program to reduce pathogen excretion and therefore area spread in a region.

As of today, around the world there are many projects based on regional control and possible future eradication of PRRSV such as the ones in Chile, Rice and Ramsey County in Minnesota (led by Bob Morrison), France, Mexico and the AASV North American PRRS Eradication Task Force. These projects use geographical information systems (software for mapping and analysis of geographic information) to share information about farm PRRS status, including use of a web-site displaying county maps and related information (Davies 2007). Moreover, risk assessment is an integral part of these programs and allows the understanding of risk factors associated with PRRS virus breaks in negative or naïve breeding herds, and the understanding of what factors and conditions contribute to some farms having a large number of severe PRRS breaks while others have few, therefore providing insights on how to better manage and control PRRS. Expectations of this analysis are that it will reduce the list of biosecurity practices into a handful that are truly significant for producers and veterinarians to focus on (Polson and Holtkamp 2008). Finally, regular meetings with local producers addressing the issues of confidentiality, access to data, potential litigation, etc. that come with the use of modern information technology are recognized as a vital factor in improving local communication and fostering motivation of producers to attempt PRRS elimination.

Figure 1. Risk assessment of pathogen introduction (adapted from Polson et al. 2006)



■ **Where does air filtration fit in control and future PRRSV eradication programs?**

Throughout the swine industry, extensive efforts have been made to protect genetic and commercial swine herds from infection with different pathogens. However, local spread of certain pathogens such as PRRSV between farms still occurs due to aerosol transmission (Dee et al. 2006c). To reduce the risk of airborne spread, swine producers around the world are beginning to implement systems to filter the air entering their facilities. France was the first country that reported the use of air filtration in nucleus herds and boar studs. Since 1996, Cooperl- Hunaudaye, implemented air filtration in 11 herds that were populated with PRRSV negative animals after the system was installed.

These herds are situated in Brittany, the most populated swine area in France; all have preserved their PRRSV negative status since then. As of today a considerable number of artificial insemination centers and farms in Europe, Quebec and the United States have implemented this technology since, in spite of extreme biosecurity rules, they experienced among others PRRS outbreaks without finding a logical explanation (Desrosiers, 2004a).

■ Available Filtration Systems

High-efficiency Particulate Air (HEPA) Filtration

This system operates with positive-pressure ventilation; incoming air is passed through a series of filters of decreasing pore size in conjunction with a centrifugal turbine. These systems use filters that are capable of blocking the passage of particles 0.3 μm or more in diameter. Dee et al. 2005c evaluated a HEPA-based commercially available air filtration system. Aerosol transmission was observed in 6 of the 20 replicates in the non-filtered facility, whereas all pigs remained PRRSV-negative in the filtered facility. While the results with HEPA filtration are extremely promising, the cost of installing such a system in a commercial swine facility still remains quite high, around \$1500-2000 USD per boar/sow.

Other Options to Air Filtration

Since the reported diameter of bioaerosols (0.5 to 100 μm) exceeds the pore size of HEPA filters, Dee et al. 2006c questioned if similar results could be obtained with the use of low-cost alternative methods, such as residential furnace filters or ultraviolet (UV) light, particularly UVC irradiation (wavelength 200 to 280 nm). Transmission of PRRSV was observed in 9 of the 10 control replicates, 8 of the 10 UVC-irradiation replicates, 4 of the 10 low-cost-filtration replicates, and 0 of the 10 HEPA filtration replicates. Therefore, HEPA filtration was significantly more effective on reducing aerosol transmission of PRRSV than the other methods evaluated in this study.

DOP 95

Extending their research further, Dee et al 2006d, tested HEPA filtration, bag filtration, 2X-low-cost filtration, and a filter derived from dioctylphthalate (DOP) found to have an efficiency $\geq 85\%$ and $< 95\%$ for particles 0.3 to 1.0 μm in diameter. Aerosol transmission of PRRSV occurred in 0 of the 10 HEPA-filtration replicates, 2 of the 10 bag-filtration replicates, 4 of the 10 low-cost-filtration replicates, 0 of the 10 95%-DOP, 0.3- μm -filtration replicates, and all 10 of the control replicates. The HEPA and 95%-DOP were further evaluated; infection was not observed in any of the 76 HEPA-filtration replicates but was

observed in 2 of the 76 95%-DOP, 0.3- μm replicates and 42 of the 50 control replicates.

Darwin Reicks (2006, 2007 and 2008), a veterinarian from the Swine Vet Center in St. Peter, Minnesota has been a leader in implementing and perfecting this technology in the field. Installation cost of this filter is around \$0.80 USD per weaned pig over a 10 year period.

A New Filtering Kit developed in Quebec, Canada

Noveko Inc., a Canadian company specialized in research, design, manufacturing and distribution of patented air filtration products recently developed an innovative filter combination which integrates a viricide, bactericide and fungicide at the molecular level in the fiber of the filter material. The initial evaluation of this filter was done by Dr. Laura Batista, DVM, Ph.D., from the Faculté de médecine vétérinaire de l'Université de Montréal (FMV) and the team of the Centre de développement du porc du Québec inc. (CDPQ; Quebec Swine Development Centre) (**Table 2**). Briefly, an adaptation of the experimental design and scale model of a commercial swine finisher barn (**Figure 2**), described by Dee et al. 2005a, 2006a and 2006b, was used for this experiment. Two rectangular aluminum chambers (an aerosolization (no.1) and a recipient chamber (no. 2) where a naïve pig was placed) were connected by a stainless steel rectangular duct where the filter (filter A) was placed. During the development of the project a new combination of viricide, bactericide and fungicide was developed and also tested (filter B).

Figure 2. Diagram of the experimental device (Batista et al. 2008)

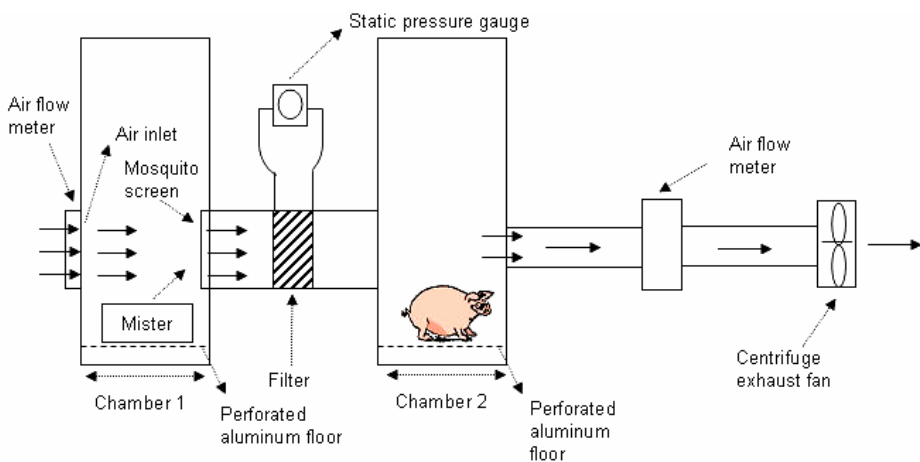


Table 2. Success filtration rate (%) and number of negative PRRSV swabs on recipient chamber (no. 2) after aerosolization and pigs on day 14 after aerosolization of PRRSV for filters A and B (Batista et al. 2008)

Filter	Recipient chamber (no. 2)*	Pig (Day 14)**
A	70%*** (7/10)	70% (7/10)
B	100% (0/20)	95% (1/20)

*by real time q-PCR, ** by real time q-PCR and ELISA

*** percent success filtration rate, and a/b= negative swabs or pigs/no. of repetitions

Further evaluation of filter B was done by Dr. Scott Dee (2008c) at the Swine Disease Eradication Center of the University of Minnesota (**Table 3**). Compared to other filters on the market, this filter is very flexible in its use and installation (it comes in rolls of a very flexible, washable and easy to maintain material), and not only does it block the passage of bioaerosols due to its filtering effect, but it also has the ability to neutralize pathogens as they come in contact with the antimicrobial agents embedded in the filter fiber (Dee 2008c). After review and analysis of these encouraging results, a commercial kit was developed by CDPQ and Noveko's team to practically implement filter combination B of Batista's et al. 2008 and Dee's 2008c research into swine farms. The filtration system kit is contained in a convenient frame having three levels of filtration: level 1 (insect screen) removes large particles and is easy to clean. Level 2 has three layers of the patented filter material containing viricide, bactericide and fungicide cocktail. This level removes fine dust particles and initiates the filtration and neutralization process and reduces the number of times level 3 needs to be cleaned. Finally, level 3 contains 7 layers of the filtering and neutralizing material. (**Figure 3**). The cost per inventoried sow per year over a period of 10 years is around 26- 27 \$CAN.

Table 3. Number of positives/tested and swine bioassay (Dee 2008c)

PRRSV in air	20 layers	15 layers	10 layers	Swine Bioassay
10^7	0/10 (+)	0/10 (+)	4/10 (+)	neg
10^6	0/10 (+)	0/10 (+)	0/10 (+)	neg
10^5	0/10 (+)	0/10 (+)	0/10 (+)	neg
10^4	0/10 (+)	0/10 (+)	0/10 (+)	neg
10^1 - 10^3	0/10 (+)	0/10 (+)	0/10 (+)	neg

Figure 3. Filtration case showing the three levels of filtration



■ **Applying Air Filtering Technology in the Field**

Remember, air filtration is not the magic bullet; it is one more gadget in our biosecurity toolbox. Before thinking of investing in air filtration you definitely have to have “basic” biosecurity in place (Polson & Holtkamp, 2008). Filtration will not correct erroneous or absurd biosecurity strategies, nor will it assure compliance to other strategies by involved personnel, transport, etc. Also, we need to remember that in order to control regional transmission, control of transmission and excretion of PRRSV in the growing herds is key, due to their size and shedding rate (Dee 2008a). So, filtering artificial insemination centers and breeding stock farms is easy to justify, however, as John Dee recently said, maybe filtering or scrubbing outgoing air should be a thinkable option for regional control strategies. The strategy of Dee (2008b) has proven to be effective and feasible

We need to understand that there is not a “one size fits all” solution; each farm has its own requirements, and we need to work on a case by case strategy. Some of the past challenges of available filtering systems (DOP95) were the restriction of the filter on airflow or that at hot temperatures, it produced too much restriction, therefore filters needed to be removed or cool cell tunnel ventilation needed to be installed (Reicks 2007), in other cases costly retrofitting was required (Reicks 2008). However, more flexible filtering options are now available, when used wisely in conjunction with other strategies, these make air filtration an extremely useful tool to impede or diminish aerosol transmission of PRRSV. This was first shown several years ago by the French and confirmed by recent USA and Canadian experiences. These approaches offer a higher success rate for control and future eradication PRRSV and other pathogens.

■ Conclusions

As Peter Davies (2007) has mentioned several times;

If the industry aspires to deal with some of today's disease problems (particularly PRRS), we need to systematically identify the major obstacles and seek the solutions. The feasibility of controlling the complex diseases we face now and into the future will increasingly depend on uptake of improved technology.

Air filtration is an example of how technological advances can alter the feasibility and cost-effectiveness of implementing a regional control program. However the biggest question is not whether new technologies can assist us in the challenge of disease control in the swine industry; it is whether we are ready to embrace them (Davies 2007).

In the long term the greatest challenge will be to foster producer participation, which will ultimately determine the usefulness of any initiative to support regional disease control. Finally, common sense ***also must*** be part of the equation. As of today we have plenty of knowledge and understanding on pathogen transmission and how to prevent it, importance of geographical location, and implementation of effective and not “psychological” biosecurity strategies such as air filtration. So let's use available, sound information and help our producers on the battle against PRRSV and other economically important pathogens; let them be successful and profitable and may the swine industry shine again!

■ References

- Batista L., Pouliot F, Dufour V, Morin M. 2008. Evaluation of commercial filters to avoid or reduce reproductive and respiratory syndrome virus aerosol transmission. IPVS, Durban, South Africa, p.138.
- Davies P. 2007. Regional control of swine disease, new tools for the future? MN Pork Congress
- Dee S.A., Torremorell M., Rossow K.D., Mahlum, C, Otake S, Faaberg K 2001. Identification of genetically diverse sequences (ORF5) of porcine reproductive and respiratory syndrome virus in a swine herd. Can J Vet Res 65:254-260.
- Dee SA, Deen J, Pijoan C. 2004a. Evaluation of four intervention strategies to prevent the mechanical transmission of porcine reproductive and respiratory syndrome virus. Can J Vet Res 68:19-26.
- Dee SA, Deen J, Otake S, Pijoan C. 2004b. An experimental model to evaluate the role of transport vehicles as a source of transmission of

- porcine reproductive and respiratory syndrome virus to susceptible pigs. *Can J Vet Res* 68:128-133.
- Dee S, Deen J, Burns D, Douthit G, Pijoan C. 2004c. An assessment of sanitation protocols for commercial transport vehicles contaminated with porcine reproductive and respiratory syndrome virus. *Can J Vet Res* 68:208-214.
- Dee S, Deen J, Burns D, Douthit G, Pijoan C. 2005a. An evaluation of disinfectants for the sanitation of porcine reproductive and respiratory syndrome virus-contaminated transport vehicles at cold temperatures. *Can J Vet Res* 69:64-70.
- Dee S, Torremorell M, Thompson B, Deen J, Pijoan C. 2005b. An evaluation of thermoassisted drying and decontamination for the elimination of porcine reproductive and respiratory syndrome virus from contaminated livestock transport vehicles. *Can J Vet Res* 69:58-63.
- Dee S, Batista L, Deen J, Pijoan C. 2005c. Evaluation of an air-filtration system for preventing aerosol transmission of porcine reproductive and respiratory syndrome virus. *Can J Vet Res* 69:293-298.
- Dee SA, Deen J. 2006a. Evaluation of an industry-based sanitation protocol for full-size transport vehicles contaminated with porcine reproductive and respiratory syndrome virus." *J Swine Health Prod* 14:307-311.
- Dee SA, Deen J. 2006b. Evaluation of an industry-based sanitation protocol for transport vehicles contaminated with porcine reproductive and respiratory syndrome virus." *J Swine Health Prod* 14:126-132.
- Dee, S.A., Batista, L., Deen, J. and C. Pijoan. 2006c. Evaluation of systems for reducing the transmission of Porcine reproductive and respiratory syndrome virus by aerosol. *The Canadian Journal of Veterinary Research*, 70(1) : 28-33.
- Dee SA, Deen J, Cano JP, Batista L, Pijoan C 2006. Further evaluation of alternative air-filtration systems for reducing the transmission of Porcine reproductive and respiratory syndrome virus by aerosol. *Can J Vet Res*. 2006 Jul; 70(3):168-75
- Dee SA, Torremorell M, Thompson R, Cano JP, Deen J, Pijoan C. 2007. Evaluation of the thermo-assisted drying and decontamination system for sanitation of a full-size transport vehicle contaminated with porcine reproductive and respiratory syndrome virus." *J Swine Health Prod* 15:12-18.
- Dee SA 2008a. Controlling environmental excretion of PRRSV from infected. *Pigletter* 28:2a.
- Dee SA 2008 b. "Disinfected cool cells: A new use for and old product?" *Pigletter* 28:5a.
- Dee SA 2008c. New approaches to aerosol biosecurity. Carlos Pijoan International Symposium. St. Paul, MN
- Desrosiers R. 2002. Aerosol spread of the PRRS virus: why it is too early to say no. *Int Pigletter*,22:21-23.
- Desrosiers R. 2004a. Epidemiology, diagnosis and control of swine diseases. *AASV Proc.*, 9-37.

- Desrosiers R. 2004b. Transmission of pathogens: we, veterinarians, should change our tune! *International Pigletter* 2(4):No.2c.
- Funderburke D. 2007. Surviving escalating feed prices. *National Hog Farmer*, February 2007, pp. 131-135.
- Hanson RP, Hanson MG. 1983. *Animal Disease Control Regional Programs*. The Iowa State University Press, Ames, IA. ISBN 0813801214
- Neumann EJ, Kliebenstein JB, Johnson CD, Mabry JW, Bush E, Seitzinger AH, Green A. 2005. Assessment of the economic impact of porcine reproductive and respiratory syndrome on swine production in the United States. *J Am Vet Med Assoc* 227:385-392
- Zimmerman JJ. 2005. Assessment of the economic impact of porcine reproductive and respiratory syndrome on swine production in the United States. *J Am Vet Med Assoc* 227:385-392.
- Polson D.D., Marsh W.E., Dial G.D. 1990. Financial implications of mystery swine disease (MSD). *Proc the Mystery Swine Disease Committee Meeting*, Livestock Conservation Institute, Denver, Colorado, pp. 8-28.
- Polson D, Spiess D, Philips R, Kjaer J, Holtkam D 2005. PRRS Risk Assessment for Swine Production Sites: Development & Utilization of a Tool for the Measurement of Risk. *George A Young Swine Conference Proc.*, 64-87.
- Polson DD and Holtkamp D 2008. in PADRAP (Production Animal Disease Risk Assessment Program), Risk Assessment Training Session.
- Reicks DL 2006. Alternative filters for boars. *AD Leman Conference*, pp.99-100.
- Reicks DL 2007. Field experiences with air filtration. *AD Leman Conference*, pp.23-26
- Reicks DL 2008. Field experiences with air filtration: Results and costs. *AD Leman Conf.*, pp.42-43.
- Torremorell M, Geiger JO, Thompson B, Christianson WT. 2004. Evaluation of PRRSV outbreaks in negative herds. *Proceedings of the 18th International Pig Veterinary Society Congress* 1:103
- Zimmerman, J 2008. PRRSV - The Disease That Keeps Bugging Us *London Swine Conference* 2008.