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AMMONIA REDUCTION AND MAINTENANCE COSTS FOR OLD AIR CLEANING SYSTEMS AND SLURRY ACIDIFICATION SYSTEMS

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ABSTRACT The objective of the present study was to demonstrate environmental performance and the cost of maintaining, servicing and repairing air cleaners and slurry acidification systems after several years of operation. Previous studies and tests have primarily been carried out on relatively new systems. Since 2002, air cleaning systems have been installed in Denmark on 100 pig farms, and acidification systems have been installed on 80 farms. During the summer of 2009, 17 finisher units with air cleaning or slurry acidification systems were inspected. The units were randomly chosen from among addresses where environmental technologies had been installed. It was necessary to contact 27 owners by telephone in order to arrange the 17 farm visits. Of the 27 owners, 7 responded that their systems were not running. All the systems inspected in this trial were running on the two days of inspections. Ammonia reductions were documented in 9 out of 10 units with air cleaning systems. At maximum ventilation rate, the ammonia concentration was 4.6 ppm in front of the filters, and the average reduction was 65 per cent ($p=0.0018$). In the units with slurry acidification systems, the set point for pH regulation was 5.5. During the inspections the ammonia concentration was 2.6 ppm in units with pH 5.3-5.8 and 5.5 ppm in units with pH 5.8-6.3. However, the difference was not statistical significant. The farm owners received a number of service visits without charge. Pointing forward the service and maintenance costs is estimated to be about EUR 0.60/finisher for a farm with 500 Danish animal units, corresponding to 17.500 produced finisher per year .

Keywords: ammonia, odour, air cleaners, slurry treatment, environment

INTRODUCTION Over the past several years, a number of development projects and tests of different methods for reducing ammonia and odour emissions from pig production units have been conducted all over the world. These have included trials and tests on different feed mixes, design of housing units, slurry pits, slurry cooling, systems for treating slurry with acid and/or ozone, and biological and chemical air purification.

In the individual countries and regions, there are different rules governing when environmental technologies are sufficiently developed and documented for them to be used as a method for reducing ammonia and odour when a farmer needs to build a new

housing unit or renovate existing units. Denmark, the Netherlands and Germany are currently drawing up common test protocols for testing air cleaners and housing unit technologies for reducing ammonia, odour and particle emissions. However, the individual countries are responsible for approving the products for commercial use.

In Denmark, environmental technologies can be used for reducing ammonia and/or odour emissions if they are included in the so-called Technology List from the Danish Ministry of the Environment. The tests that have been performed in order to include new environmental technologies in the Technology List have been performed on relatively new installations. However, it is necessary to assess the extent to which the installations in question are still operational after a number of years. The reason for doing this is that the sale of environmental technologies is expected to increase substantially in the coming years and that the authorities will probably increase the number of inspections and documentation requirements. The pig producers are responsible for documenting that they have complied with the conditions specified in the environmental approval which they received from the authorities before building the housing unit. If it is already possible to specify which areas could be a problem after a few years, the companies can carry out improvements, so that in the future Denmark will not have a large number of environmental technologies that are not working properly.

Besides ammonia and odour reduction, consumption costs such as electricity, water and acid and storage capacity for discharge water are recorded in connection with tests of the environmental technologies. However, when testing newly installed technologies, it has not been possible to investigate the operating life of the installation and the service and repair costs. Furthermore, it has not been possible to find out how much time the individual producer uses on maintaining the installation.

The purpose of the present investigation is to conduct a random sample evaluation of the extent to which earlier well-documented air purification and slurry acidification systems in pig housing units function after a number of years. The evaluation will be conducted on the basis of ammonia and odour concentration measurements, operational reliability and service and repair costs.

METHOD AND MATERIALS The investigation was conducted in 10 finisher herds with air purification systems and 7 finisher herds with slurry acidification systems.

The herds were randomly selected from lists of farm addresses where the companies ScanAirclean A/S, SKOV A/S, Hans Højer Farmtech A/S had installed air purification systems or Infarm A/S had installed slurry acidification systems during 2002-2009. The reason for including these companies in the investigation was that they were on the so-called Technology List of the Danish Ministry of the Environment. In other words, they sold products which the farmers could choose when they needed to reduce ammonia and/or odour emissions in order to obtain environmental approval in connection with extending or rebuilding their pig housing units.

Each of the 17 herds with air purification or slurry acidification systems was visited once during the period July-September 2009. The visits were carried out during the summer months in order to ensure that the ventilation system was running at full capacity during the visiting days.

The farm addresses were not selected at the same time. Instead, they were randomly selected 3-7 days prior to the planed visits during the summer months. The owner was contacted by telephone, and, if the farmer said that the installation was running, a visit was arranged. If it was not possible to visit the farm, the reason was written down and a new address was selected.

On days when a herd with a slurry acidification system was visited, a herd with air cleaners was also visited.

Figure 1. Photos from visited farms with slurry acidification systems or air cleaning systems.

Date recordings The data recordings performed on the visiting days are described below.

- The odour concentrations in the housing unit´s ventilation outlets and after the air cleaner were measured twice at approx. 11 am and 1.30 pm, respectively. The air samples were collected in 30 litre nalophane bags over a period of 30 minutes. The samples were collected and analysed in accordance with European CEN standard 13725. Both the collection and the analytical procedures were DANAK-accredited. The samples were analysed by the Danish Meat Research Institute, who use the German ECOMA olfactometer.

- After odour sampling the ammonia concentration, carbon dioxide concentration, hydrogen, temperature and relative humidity were recorded in the housing unit´s ventilation exhausts and after the air cleaner. The ammonia and carbon dioxide concentrations were measured using Kitagawa detection tubes. The temperature and relative humidity were measured using TSI VelociCalc 8386.

- The ventilation flow displayed on the control panel was recorded in connection with odour sampling, and subsequently the pressure drop across the housing unit, the ventilation duct and the air cleaner was measured using TSI VelociCalc 8386.

- The number of animals was counted, and their average weight was estimated. It was planed to take measurements when the animals weighed approx. 65 kg.

- In herds with slurry acidification systems, slurry samples were taken and the pH was measured.

- The pig producers were interviewed about their experience with the air clening systems and slurry acidification operational reliability and about how much time they find necessary in order to maintaining the installation.

Data processing Mean and standard deviation were calculated for all the measured parameters. The efficiency of the air cleaners was evaluated based on the two measurements taken before and after the air cleaner in the 10 herds. Furthermore, the results were compared with results from previous tests. It was more difficult to evaluate the efficiency of the slurry acidification system, because there was no control group to compare with in the herd. Instead, the measurements were compared with measurements taken before the air cleaner in the other housing units included in this investigation and with measurements taken in earlier investigations. The pH measurements in the slurry system were used to evaluate whether the slurry acidification system were running optimally.

The measured pressure drops and the air flows were compared with standard dimensioning practices.

When all the measurements and interviews had been completed, the results were shown to the suppliers of the air cleaners and slurry acidification systems. Meetings were then held to draw up maintenance schedules and service contracts, which were used to calculate the cost of maintaining the installations.

RESULTS AND DATA ANALYSIS The four companies that were chosen to participate in the investigation were asked to deliver lists of farm addresses where they

had installed air cleaners or slurry acidification systems. Table 1 show the number of farm addresses where each company had installed environmental technologies.

Three addresses with chemical air acid cleaners from Scan AirClean A/S were randomly chosen, 7 addresses with biotrickling filters from SKOV A/S were randomly chosen and 7 addresses with slurry acidification systems from Infarm A/S were randomly chosen. The companies have been badly affected by the financial crisis. In January 2009, Scan AirClean A/S went bankrupt. However, their sales activities are now carried out by MHJ Agroteknik A/S. At the beginning of 2009, Hans Højer Farm Tech A/S, who sold BOVEMA chemical acid air cleaners, closed down, and BOVEMA in the Netherlands went bankrupt in the summer of 2009. Two finisher units in Denmark have installed BOVEMA air cleaners, though the herd owners said, when they were contacted, that their installations were not running optimally. Therefore, BOVEMA air cleaners were not included in the investigation.

Table 1. Numbers of addresses with air cleaners or slurry acidification systems installed, in Denmark in January 2009 and numbers of addresses selected for this investigation.

Company	Technology type	Number of addresses in Denmark with technology	Numbers of addresses randomly selected for this investigation. Year of installation written in brackets.
Scan Airclean A/S	Chemical air cleaner	29 pig units	3 (2005-2008)
SKOV A/S	Biotrickling filter	29 finisher units	7 (2006-2009)
BOVEMA A/S	Chemical air cleaner	8 pig units	0
Infarm A/S	Slurry acidification system	46 pig units	7 (2002-2008)

It was decided not to use time on taking measurements in the herds where the installations were not running properly. If a herd owner said his system was not running, then, a new herd owner on the list was contacted. In order to arrange measurement days in 10 herds with air cleaners, it was necessary to phone 15 herd owners. Four of these herd owners said that their installations were not running optimally and that we could visit them at a later date. Furthermore, one other herd owner said that he was too busy to receive a visit. Table 2 shows the results of the calls to the randomly selected pig herds with air cleaners.

In order to arrange measurement days in 7 herds with slurry acidification systems, it was necessary to phone 12 herd owners. Three of these herd owners said that their installations were not running optimally. One herd owner was too busy to receive a visit and one herd owner had to short experience with the system. Table 2 shows the results of the calls to the randomly selected pig herds with slurry acidification system. Of the 7 planned visits that were arranged 4-7 days in advance, two herd owners had asked Infarm A/S to carry out service before we arrived.

Table 2. Selection of farms with air cleaning systems.

Number of telephone call	Comments on the telephone calls and number of arranged farm visits
1	System is running and visit accepted. (Farm visit 1)
2	Visit initially accepted. On the way to the farm, the farmer called to say there was no acid in the system and that the pH sensor was broken. (Farm visit 2 delayed)
3	System is running and visit accepted. (Farm visit 3)
4	System is running and visit accepted. (Farm visit 4)
5	Farmer was busy harvesting and was not interested in receiving a visit.
6	No pigs on the farm due to depopulation/repopulation procedure.
7	System is running and visit accepted. (Farm visit 5)
8	System is running and visit accepted. (Farm visit 6)
9	System is running and visit accepted. (Farm visit 7)
10	The farmer wanted to wait until the harvest was over. (Farm visit 8 delayed)
11	The air cleaner was not running due to frost damage.
12	The installation was not running properly. However, the installation had been installed voluntarily.
13	Damaged filters. The filters would be replaced in October. No visit, since measurements were planned to be carried out in the summer period.
14	System is running and visit accepted (Farm visit 9)
15	System is running and visit accepted (Farm visit 10)

Table 3. Selection of farms with slurry acidification system.

Number of telephone call	Comments on the telephone calls and number of arranged farm visits
1	System is running and visit accepted. (Farm visit 1)
2	System not running at the selected address. However, the herd owner had another farm where the system was running (Farm visit 2)
3	System is running and visit accepted. (Farm visit 3)
4	System is running and visit accepted. (Farm visit 4)
5	The farmer had got his hand into his combine harvester.
6	The farmer had stopped the system because the sulphuric acid was too expensive. Furthermore, the system was not operational due to a blocked slurry pipe in the ground and an expensive mixer in the tank needed changing.
7	The system has only been running for 2 months and was to new to evaluate the maintenance.
8	The system was installed 9 months ago. However, it was still not operating properly.
9	The farmer was very busy harvesting. He had fewer employees than normal.
10	Visit accepted. Infarm A/S had visited the farm the day before due to an alarm. (Farm visit 5)
11	Visit accepted. Infarm A/S had replaced the computer 3 days before our visit. (Farm visit 6)
12	System is running and visit accepted. (Far visit 7)

Equal conditions The 17 selected farms were visited in the period July – September 2009. Regarding animal's weights, outdoor temperatures and temperatures and carbon dioxide concentrations in the exhausts there were no statistical difference between registrations taken in units with air cleaners and units with slurry acidification. The animal weights were in average 70 kg (std=3). The temperatures outdoor and in the exhausts from the housing units were in average 19.7°C (std=0.6) and 23°C (std=0.9), respectively. The average of the carbon dioxide concentrations were 850 ppm (std=45). According to the ventilation control panel, the average of the ventilation flows through the air cleaners was 95% and through the finishing units 95%.

Ammonia Among the 10 visited herds with air cleaning systems, the ammonia concentration was lower after the air cleaner than before the air cleaner in 9 herds; see Figure 2.

The measurements were taken while the ventilation panel showed 100% ventilation except from herd number 9. When the ventilation system is running at maximum capacity, the filter is subjected to the greatest stress, and the retention time of the extracted air through the filter is lowest. In housing units where the ventilation air is extracted through ducts in the ceiling, the average ammonia concentration was 4.6 ppm before the filters, and the average reduction was 65 per cent (p=0.0018).

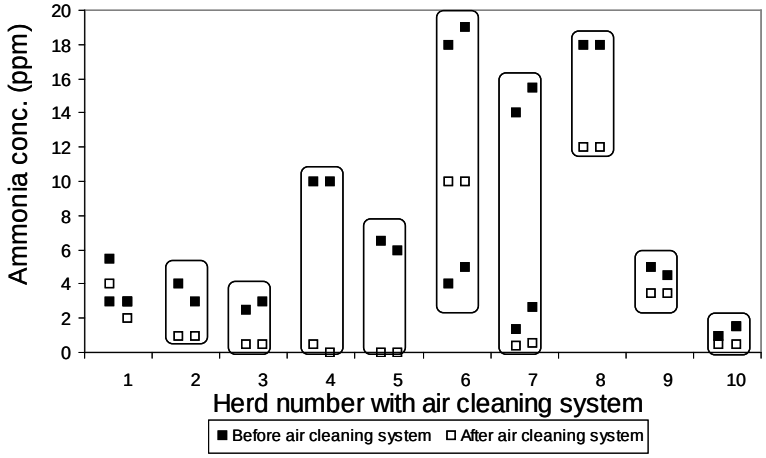

Figure 2. Ammonia concentrations measured before and after the air cleaners. Ammonia measurements were taken about 12 am and 2 pm for each herd. Herd number 3, 4 and 5 had chemical acid air cleaners from Scan Airclean A/S. The others were bio-trickling filters from SKOV A/S. In herd 6, 7 and 8 a part of the ventilation air was extracted from the manure channels, while the rest of the air was extracted through a duct in the ceiling.

Figure 3 illustrates the measured ammonia concentrations in the housing units with slurry acidification system. In the herds with slurry acidification systems, the slurry is flushed out to a treatment tank every 1-1.5 days. The slurry is treated with sulphuric acid until the pH level in the slurry is 5.5. The slurry is then re circulated to the housing unit.

In all 7 herds with slurry acidification systems, the control panel showed that, at the last recirculation, the pH level in the reticulated slurry was 5.5.

On the measurement days, samples of the slurry from the housing unit were pumped into 1 litre plastic containers. Among the 7 herds with slurry acidification systems, the logarithm average of the 14 pH measurements was 5.8 and the 95% confidence interval was 5.6-6.0. When the pH level was 5.3-5.8 the ammonia concentration was 2.6 ppm, and when the pH level was 5.8-6.3 the ammonia concentration was 5.5. However, the difference was not statistical significant (p=0.1).

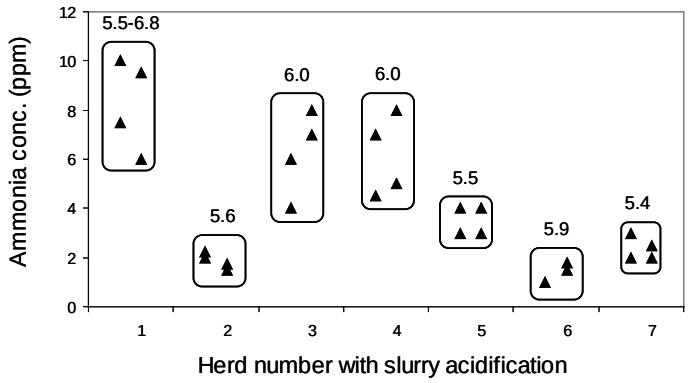

Figure 3. Illustration of ammonia concentration measured in housing units with slurry acidification systems. The numerical values close to the rectangles show the logarithm average of the pH in the slurry in the pits.

Odour The measured odour concentrations in herds with air cleaning systems are illustrated in Figure 4. Because of the high variation of odour analysis the percentage difference in odour concentration before and after the filter will not be calculated. However, it can be noticed that in 5 herds the odour concentrations were lower after the air cleaner (herd 2, 4, 5, 6 and 10), and in 2 farms were measured the same very low level of odour before and after the air cleaner (herd 3 and 9). In herd 7 the trickling water had a conductivity at 17 mS/cm which should secure odour reduction, even though the affectivity could be better.

Regarding odour concentrations measured on the same day in front of the filter in herds with air cleaning system and in the exhaust in herds with slurry acidification, there was no significant difference. In the herds with slurry acidification the odour concentration was 810 OU_E/m^3 with 95% confidence interval 410-1600. In the herds with air cleaners the odour concentration was 830 OU_E/m^3 in front of the filter with 95% confidence interval 420-1650. A previous test had also demonstrated that in housing units with slurry acidification systems the odour concentration is not affected (Pedersen, 2006).

Temperatures Across the filters the average air temperatures were reduced from 23°C (std=0.9) to 19.4°C (std.0.8) and the relative humidity increased from 67% (std=4) to 93 % (std=2).

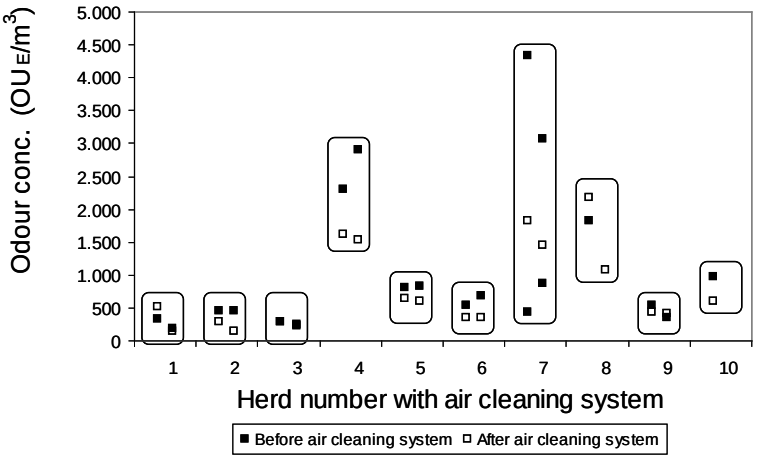

Figure 4. Odour concentrations measured before and after the air cleaners.

Pressure drops For the finishing units with air cleaning systems the average pressure drop across the total system including the air intake was 136 Pa (std=10). This pressure drop is larger than for traditional ventilation systems. In the units with slurry acidification the ventilation system was traditional with temperature regulated exhausts fans and with air inlet through valves or diffuse air intake through the ceiling, and the average pressure drop was 22 Pa (std=3,5).

There was a tendency for the filters to be partially clogged, which will extend the energy consumption and reduce the ventilation capacity in maximum. The average pressure drop across the filters was 67 Pa (std=9). In previous tests the pressure drops across new filters in a biotrickling filters from SKOV A/S were 16-20 Pa and in a number of tests are seen pressure drops across the whole system at around 100 Pa (Lyngbye 2008; Riis 2007).

Maintenance costs After the environmental data recordings and the interviews on the 17 farms during the summer, the results were presented to farmers and the companies who had previously installed the air cleaners or slurry acidification systems on the visited herds. In cooperation with them, different maintenance contracts (basic, standard and super) were drawn up. The "super" contract, which ensures that the installations run optimally, includes:

- 3 annual service visits and replacement of parts liable to wear
- Free assistance and spare parts
- Free software updates in connection with service visits
- Free hotline
- Free inspection of the compressor system, in accordance to the Danish regulation

Every day, the farmer must check the alarms and take corrective action if necessary. Furthermore, once a month, the farmer must go through a check list and carry out service if necessary.

In accordance with the above conditions, maintenance of a slurry acidification system costs EUR 0.60 per produced pig (30-102 kg) for a farm, which produces 17,500 finisher pigs per year. For other herd sizes table 5 shows the maintenance costs.

Table 5. Maintenance costs of slurry acidification system.

Danish animal units* (DE)	Produced pig annually from 30-102 kg (number/year)	Maintenance costs including farmers work and super service contract (EUR/produced finisher)
125	4,375	2.00
250	8,750	1.10
500	17,500	0.60
750	26,250	0.45

*: 1 Danish animal unit corresponds to 35 produced finishers weighing 30-102 kg.

Maintenance costs for the air cleaning systems will depend on the amount of air that is cleaned. However, it also depends on the proportion of the total amount of air that is cleaned. This is shown in Table 6. When air cleaners are installed in Denmark due to reduced ammonia emission, often partly air cleaning system is chosen instead of cleaning 100% of the ventilation flow. Only in the warm summer month the fans are running in maximum, and if the first 20-40%. of the ventilation flow are cleaned, then all the ventilation air will be cleaned during the winter months with low outdoor temperature. Due to that, cleaning of 20% of the maximum capacity will lead to about 70% reduction of the ammonia emission if the efficiency of the air cleaner is 90%. For a heard which produces 17,500 finisher a year, the maintenance cost will be EUR 0.46-0.72 per produced pig for partly air cleaning system with a capacity of 20-30% of maximum ventilation.

Table 6. Maintenance costs for the air cleaning systems in EUR/finisher pig.

Danish animal units* (DE)	Produced pig annually from 30-102 kg (number/year)	Ventilation capacity (m^3/hour)	Proportion of the total amount of ventilation air that is cleaned				
			100%	80%	60%	40%	20%
125	4,375	135,000	2.00	1.70	1.40	1.15	0.85
250	8,750	225,000	1.85	1.45	1.20	0.90	0.65
500	17,500	450,000	1.65	1.35	1.04	0.72	0.46
750	26,250	675,000	1.60	1.30	1.00	0.70	0.42

Conclusion A total of 27 farmers were contacted, and, of these, 17 said that their air cleaners or slurry acidification systems were running optimally and agreed to receive visits with 4-7 days notice.

The ammonia concentration was lower after the air cleaner than before the air cleaner on 9 out of 10 farms. The filters were partially clogged, which reduced the ventilation rates in the housing units during the summer when the ventilation systems were running at full capacity. In all of the 7 visited farms with slurry acidification systems, the control panels showed the desired pH level of 5.5; however in the housing units could be measured higher levels.

The daily and monthly services can be performed by the farmer. However, it is recommended that the more complicated services that have to be carried out every 3-4 month should be performed by the suppliers of the installations. The maintenance of the slurry acidification system costs EUR 0.60/pig for a farm with 500 Danish animal units, corresponding to 17.500 produced finisher pigs per year. In connection with air cleaners, most of the farmers have installed partial air cleaning instead of full air cleaning. By cleaning 20 per cent of the air with an air cleaner that can reduce emissions by 90 per cent, the annual ammonia emissions can be reduced by 70 per cent under Danish weather conditions. The maintenance of an installation that cleans 20 per cent of the air costs EUR 0.46/pig for a farm witch produce 17.500 finisher pigs per year.

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References

Jensen, T.L. and Hansen M.J., 2006. A Biotrickling Filter for Removing Ammonia and Odour in Ventilation Air from a Unit with Growing-Finishing Pigs. Workshop on Agricultural Air Quality, Washington DC / Potomac, Maryland, USA June 5-8, ISBN 0-9669770-4-1, page 844-846

Kai, P.; Pedersen, P.; Jensen, J.E.; Hansen, M.N. and Sommer S.G., 2008. A whole-farm assessment of the efficacy of slurry acidification in reducing ammonia emissions. Science Direct, European Journal of Agronomy 28 (2008) 148-154

Lyngbye, M., 2008. Test of the filter area and demonstration of Farm Airclean Biomodul from SKOV A/S at maximum ventilation in a unit for weaners, Pig Research Centre, Danish Agriculture & Food Council, Publication no 830. In Danish http://vsp.lf.dk/Publikationer/Kilder/lu_medd/2008/830.aspx?full=1

Pedersen, P., 2006. Treatment of slurry with sulfuric acid in a finishing unit with drained floor, Pig Research Centre, Danish Agriculture & Food Council, Publication no 683. In Danish. http://vsp.lf.dk/Publikationer/Kilder/lu_medd/2004/683.aspx?full=1

Riis, A.L., 2007. Bovema S-Air two-step tested during the summer period in an unit for weaners, Pig Research Centre, Danish Agriculture & Food Council, Publication no 776. In Danish. http://vsp.lf.dk/Publikationer/Kilder/lu_medd/2007/776.aspx