Air flow and chlorpropham (CIPC) emissions from a potato storage

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Table of Contents

Page

Summary

After having been harvested, potatoes are often stored at the farm. Chlorpropham (CIPC) is used in the potato storage to ensure potato sprout inhibition. This substance has a fairly low vapour pressure and easily attaches itself to material in the potato storage such as: potatoes, soil and construction materials.
The structure of the potato storage often holds a large amount of CIPC. The extent to which CIPC is emitted through ventilation air is unknown.
This study answers the question regarding the extent in which CIPC is emitted from the building to the outside environment via ventilation air and air leaks. Known amounts of CIPC were applied when the potatoes were stored at the beginning of October and in February. After application, the air in the potato storage was continually sampled during defined periods. Samples were taken when there was external ventilation, internal ventilation and no ventilation. For this purpose the sampling pumps were connected to the ventilation computer. The correct air flow rates were determined by using a tracer gas at various ventilation positions.
The largest CIPC emission took place just after the potatoes had been stored and during the second treatment. During the remainder of the storage period, the emission was on average 2.8 g CIPC/day.
Keywords: CIPC, chlorpropham, emission.

1 Introduction

After having been harvested, potatoes are sometimes stored for up to ten months. During the first months following the harvest there usually is no sprouting. The potatoes are in dormancy. The duration of this dormancy period depends on the variety, growing conditions and storage temperature. Potatoes can only be kept sprout-free during a long storage period by ensuring a low storage temperature (approx. 3°C) or by applying sprout inhibitors. Since the low storage temperature also has an effect on other quality properties (reducing sugars), many have to rely on sprout inhibitors.
Sprout inhibitors based on chlorpropham (CIPC) are used the most in the Netherlands.
The total amount applied in the Netherlands for this purpose is 30,000 - 40,000 kg of active ingredients a year. The permitted dosage is 100 ml or 30 g of active ingredients per ton of potatoes per season. The inhibitor attaches itself to the potatoes, adhering soil and construction materials of the building. It is then slowly released again from the wood and concrete used for floors and walls. Once CIPC has been administered in a potato storage, this storage will be unsuitable for storing seeds, etc., for many years.
Chlorpropham is also used as a herbicide for onions, leeks, scorzoneras and a number of other vegetables. In total, approximately 10,000 – 15,000 litres (4,000 – 6,000 kg of active ingredient) is used.
Besides CIPC, a sprouting inhibitor can be used that is based on a vegetable oil. This inhibitor contains S-carvone and is mainly extracted from caraway. A major disadvantage of this product is that it is much more expensive then CIPC.
In a number of situations, it is not possible to treat potatoes with a sprouting inhibitor that contains chlorpropham. Carvone is a good alternative for these situations.
Besides inhibiting sprouting, carvone also has a positive side effect on storage diseases such as silver scurf, fusarium and phoma and it prevents slugs eating into the potatoes during the storage period. Carvone is also used in organic cultivation and for storage of potatoes in countries where the use of chlorpropham is not permitted.
The routes taken by CIPC after having been administered cannot be quantitatively established. CIPC concentrations in the air above treated potatoes in a potato storage and CIPC amounts that have accumulated in construction materials in a potato storage have been studied. Report 54085 (Schans, D.A. van der & M. van Zeeland, 2000. Puntemissies na de oogst, Routes en risico's (Point emissions after harvesting; routes and risks), PAV project report 54085) contains a summary of a study into the routes of CIPC after administration. This report shows that data on direct CIPC emissions via ventilation air is not available.
In order to fill this knowledge gap, the air flow rate and CIPC concentrations in ventilation air were studied in a potato storage between October 2001 and June 2002 (Schans, D.A. van der & J. Mosquera, 2002. Studie naar de CIPC uit een aardappel bewaarplaats (Study of CIPC emissions from a potato storage)), PPO project report 1254685).
This study was repeated during the 2003 - 2004 storage season. The location of sampling in 2001/2002 was probably the reason for unreliable measurement results during part of the sampling periods. During the last series of measurements, the sampling pumps were suspended in the middle of the potato storage over the potatoes.
The study was set up through cooperation between Applied Plant Research (business unit AGV), Agrotechnology & Food Innovations B.V. (is called from 2010: Wageningen UR Food & Biobased Research) and TNO-voeding (Netherlands Organisation for Applied Scientific Research, Food and Nutrition). The Dutch Ministry of Agriculture, Nature Management and Fisheries financed the study.
This report includes the results of the various components of the study.

2 Material and method

The study has been conducted in the potato storage of: A.P. van Tilburg, Lindeweg 14, 8315 RC Luttelgeest, the Netherlands. The potato storage consists of two identical but completely separate compartments in one barn. Each compartment has a concrete slatted floor with an area of 12.25 m x 23 m. The lift is 3.75 m. The storage capacity is 1050 m^3 per compartment (approx. 600 ton). In Annex 1 the floor plan is presented of the compartment in which the measurements were done. Each compartment had four fans, situated above a pressure chamber with four inlet valves. The valve construction and regulation was such that when the inlet valves for external ventilation were closing the inlet side for internal ventilation opened. For internal ventilation the suction inlet was in open connection with the head space of the potato storage. In the pressure chamber below the fans, the pressure of incoming air is stabilised before it spreads below the floor.
The air intake of the potato storage is on the north eastern side. The outlet openings are at the south eastern side of the potato storage. There are five outlet openings measuring 50 cm x 350 cm and one measuring 50 cm x 250 cm (10 m^2 in total).
Air is blown into the pressure chamber through the inlet valve. The pressure chamber has an open connection with the area below the grid floor (approx. 75 cm high) of the potato storage. The space under the floor was divided in four air channels with a width of 4 meters and a length of 23 meters. From these channels the air is blown upwards through the potatoes and exits through the six outlet openings in the head space at the side of the potato storage.
The ventilation capacity of one compartment is 105,000 m^3 air/hour and is provided by four fans. The capacity per fan is 26,500 m^3 air/hour, with a counter pressure of 150 Pascal. This means that one full air circulation cycle with closed external valves and opened inner valves takes 1,020/105,000 * 3,600 = 35 seconds.
Internal, external or mixed air is used for ventilation depending on the temperature and humidity. Immediately after storage, the potato storage was nearly continually ventilated for the first three days to dry the product. Approximately three weeks after storing the potatoes, the temperature was slowly lowered to 7°C by ventilating using low outside temperatures.
Opening and closing of ventilation valves, the burner valve, etc. was computer controlled and mechanically driven.

Photo 1. **Aerial of the test location. Square with black lines indicates the potato storage (source: Google Earth).**

The air volume in the potato storage is calculated as follows:
Potatoes have a specific weight of approx. 1.08 kg/litre. The above parameters indicate that a compartment of 1050 m³ contains 555 m³ of potatoes. This means the compartment has 495 m³ of air. There is also an open space between the roof and the potatoes in the compartment, in the pressure chamber and in the ventilation ducts. In an average potato storage, this volume is approximately 1.5 times what is used for the storage of potatoes. This means this potato storage contained approximately 1050 * 1.5 – 555 = 1020 m³ of free air.

2.1 Initial situation

The potatoes (of the Sante variety) were harvested on 2 and 3 October and deposited in the potato storage. This was done under dry conditions. The potato storage was not fully filled. Approximately 600 tons of potatoes were stored. When the potatoes were being stored, a liquid formulation of CIPC was sprayed over the potatoes at the compartment filler (GRO-STOP BASIS, corresponds to GRO-STOP 300 EC, contains 300 g of CIPC per litre of product, Annex 2). The administered dosage was approximately 42 ml GRO-STOP BASIS per 1000 kg of potatoes (theoretically, 12.6 g CIPC per ton of potatoes was administered).
During storage, 25 litres of product was administered (7.5 kg of active ingredient). The compartment was closed on Saturday morning, 4 October. The ventilation had already started. The ventilation air was not heated.
CIPC was again administered through fogging on 18 February. In total, 7.5 litres of GRO-STOP SC (Annex 3) were administered (2.25 kg of the active ingredient). This is approximately 12.5 ml per ton of potatoes (3.75 g of CIPC per ton of potatoes).
The CIPC concentration was registered during fogging. After fogging the compartment was internally ventilated until the fog had settled after which the compartment was kept closed for 24 hours.
In total, 9.75 kg of active ingredient was administered (16.35 g of CIPC per ton).

2.2 Measuring methods

Different factors must be known to establish the CIPC emissions from the potato storage: the amount of air leaving the potato storage through leaks or ventilation at various valve openings and the CIPC concentration of the air exiting the potato storage.

2.2.1 Ventilation periods

It was assumed that the CIPC concentrations in the ventilation air immediately after administration were high and decreased as the storage season moved forward to determine the measuring method. The total storage period was divided into measuring periods of variable duration. The first measuring cycle started immediately after storage on 13 October 2003. This cycle lasted until the second administration on 18 February 2004. The second measuring cycle started immediately after the second administration and lasted until the potato storage was cleared on 11 April 2004. The CIPC concentration of the air in the potato storage was also measured during the second administration. After administration samples were obtained in short intervals (of several days). The more time elapsed since the administration, the larger the sampling intervals became (up to one month by the end of the storage period). Table 1 contains the start and end dates of the periods. The sampling test tubes were replaced two times every two days and then three times a week, two times every two weeks and, ultimately, three times every month.

Table 1. **CIPC measuring periods at the potato storage of Van Tilburg during the October 2003 – April 2004 storage period on behalf of the study into CIPC emissions.**

1st administration: Spraying potatoes at the time of storage 03-10-03

No.	Start date and time		End date and time	
1	03-10-2003	22:30	04-10-2003	23:00
2	04-10-2003	23:00	06-10-2003	07:30
3	06-10-2003	07:45	13-10-2003	08:15
4	13-10-2003	08:15	20-10-2003	08:30
5	20-10-2003	08:30	27-10-2003	08:15
6	27-10-2003	08:30	10-11-2003	08:00
7	10-11-2003	08:15	24-11-2003	07:30
8	24-11-2003	08:10	22-12-2003	12:50
9	22-12-2003	12:50	19-01-2004	08:45
10	19-01-2004	09:00	18-02-2004	08:35

2st administration: Fogging 18-02-04 (9:15 – 10:20)

No.	Start date and time		End date and time	
1	18-02-2004	09:15	18-02-2004	10:20
2	18-02-2004	11:05	25-02-2004	14:00
3	25-02-2004	14:15	03-03-2004	09:30
4	03-03-2004	09:40	17-03-2004	13:35
5	17-03-2004	13:50	31-03-2004	11:25
6	31-03-2004	11:50	11-04-2004	17:00

After fogging, the sample test tubes were replaced: first two times every week and then three times every two weeks after which the potatoes were removed from the potato storage. Table 1 contains the exact measuring periods.

2.2.2 CIPC concentration

Sampling pumps were used to extract both the internal and external ventilation air and guide these through a test tube with XAD-2 (an inhibitor that absorbs CIPC) to measure the CIPC concentration of the potato storage. The connection developed earlier by Netagco-Tolsma was modified to ensure three air sampling pumps were activated when the ventilation valves were open and three other air sampling pumps started pumping when the ventilation valves were closed in order to accomplish this. Two pumps were suspended at three locations (1 pump when the valves were open and 1 pump when the valves were closed; see Annex 1). Contrary to the 2001-2002 season, the pumps for extracting air were not located near the outlet valves but were evenly distributed and suspended in a straight line two meters above the potatoes and six meters from the outlet valves (in the centre of the potato storage). The air that was sampled in the storage at that time, was also the air that exits to the outside environment. The risk of mixing outside air near the openings was zero with this new set-up.
In addition to controlling the pumps, an additional processor also registered every change in ventilation on/off) and valve position (0 – 100% opened).
The pumps were set to specific flow rates and this amount of air was led through an inhibitor that absorbs CIPC.
The test tubes were replaced at the end of each measuring period and analysed in the laboratory of TNO Food and Nutrition in Zeist. There the total amount of CIPC (μg) in the test tube was determined. During the measuring period, the climate computer of the potato storage registered how long internal air and how long external air was used for ventilation.
The total amount of air extracted was calculated by multiplying the time the pump had been operational with the pump flow rate during this period. The average CIPC concentration in the ventilation air was calculated by dividing the amount of CIPC in the XAD test tube by the amount of extracted air.

2.2.3 Air flow rates

Agrotechnology & Food Innovations B.V. created a measuring set-up to determine the air flow rate from the potato storage. To ensure a reliable estimate of the ventilation flow rate, tracer gas SF_6 was constantly injected into the potato storage and the SF_6 concentration in the inlets and outlets of the storage were measured. The ventilation and air leak flow rates were calculated from the measured concentration of SF_6 and the amount of SF_6 added.

2.2.3.1 Measuring method

To determine the ventilation flow rate, the method of continuous tracer gas injection was used. This method is based on the law of conservation of mass. A constant amount of tracer gas (SF_6) is injected into the place to be measured when this method is used. The tracer gas concentration in the space to be measured depends on the tracer gas injection and the ventilation flow rate (Riffat and Cheong, 1995):

$$V\frac{dc}{dt} = (G + Q\cdot c_e - Q\cdot c)\cdot dt = \big(G + Q\cdot(c_e - c)\big)\cdot dt$$

Where: V = Volume of the ventilated area [m^3]
Q = Ventilation flow rate [$m^3.hr^{-1}$]
c = Tracer gas (SF_6) concentration in the space to be measured [ppb]
c_e = Tracer gas (SF_6) concentration in the outside air [ppb]
G = Tracer gas production (injection) [$m^3.hr^{-1}$]
t = Time

Assuming the air in the area is ideally mixed, the following applies:

$$c = \left(\frac{Q\cdot c_e + G}{Q+G}\right)\cdot\left(1 - e^{-\frac{Q+G}{V}\cdot t}\right) + c_o\cdot e^{-\frac{Q+G}{V}\cdot t}$$

c_o = Start tracer gas concentration (t=0) [ppb]

The equilibrium concentration ($C_t \rightarrow \infty$) can be calculated by using:

$$c_\infty = \frac{Q\cdot c_e + G}{Q+G}$$

2.2.3.2 Measuring system

To ensure good tracer gas (SF_6) dispersion throughout the whole space to be measured, the tracer gas is injected near the four ducts below the grid floor. Three sampling pipes (1. inside the space to be measured, in the centre of the storage, 2. in the outgoing air, 3. outside the space to be measured) are used to transport the air from these three locations in the space to be measured to the measuring instruments. All pipes were heated and insulated to prevent condensation problems.
During the study conducted in 2001-2002, syringes were used for sampling the air from the sampling pipes. The syringes were then transported to the Agrotechnology & Food Innovations B.V. environmental laboratory where the tracer gas concentration was determined using a gas chromatograph. This method (syringes) was replaced in 2004 by (semi) continuous measuring of the tracer gas concentration using a gas chromatograph with a built-in ECD (Electron Capture Detector) that was placed inside the potato storage.

3 Results

The first section of this chapter describes the air flow rates. An extensive record of these measurements has been included in the IMAG report 2002-08 by J. Mosquera et al. This report only specifies the connection between the opening of valves during external ventilation and the measured air flow rates. These have been converted into air flow rates per sampling period based on the actual ventilation data collected in the potato storage.
The CIPC levels are presented and described in the second section of this section. The levels are displayed per sampling period. The air flow rates from the previous section were used to calculate the CIPC emissions.

3.1 Air flow rates

3.1.1 Results

Indicative measurements were taken of the ventilation flow rate in the potato storage during two measuring periods between 2001 and 2002 (PPO project report 1254685) and one measuring period in 2004. Four different situations were investigated:

1. Ventilation with outside air (external ventilation). Indoor valves closed and inlet and outlet fully opened. Fans on (maximum capacity).
2. Mix of indoor air and outside air. Indoor valves and inlet and outlet partially opened (different percentages). Fans on (maximum capacity).
3. Ventilation with indoor air (recirculation). Inner valves fully opened and inlet and outlet closed. Fans on (maximum capacity).
4. No ventilation. Fans off. Inlet and outlet partially opened.

The results of both studies are included in figure 1 (and Annex 6).

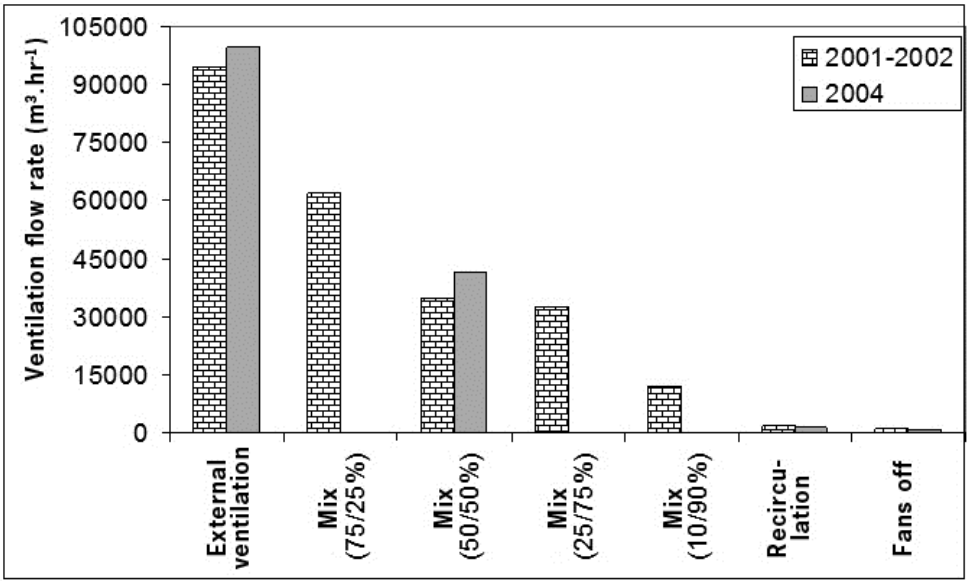


Figure 1. **Ventilation flow rate (measured using the internal tracer gas ratio method) during different ventilation situations**.

The differences between the measurements in 2001-2002 and 2004 were small. However, the results of the (semi) continuous flow rate measurements (2004) are, in general, slightly higher than those of the 2001-2002 measurements.
The nature of the potato batch in the potato storage was different between the two years. In 2001, the potatoes were harvested under wet conditions and this resulting in much adhering soil entering the compartment. In 2003, harvesting took place under dry conditions and the potatoes were clean when they were stored. Much soil results in a higher air resistance, which could explain the differences between the two measuring periods. The difference in measuring method may also play a part. Figure 1 also shows how large the leak of the potato storage is. With recirculation (internal ventilation), a flow rate of 1406 $m^3.hr^{-1}$ (i.e. 1.3% of the total fans' capacity) was measured. When no ventilation took place, the measured flow rate was 688 $m^3.hr^{-1}$ (i.e. 0.7% of the total fans' capacity).
Figure 2 shows the ratio between the opening percentage of the inlet and outlet valves and the measured ventilation flow rate (as percentage of the total fans' capacity), averaged over both seasons. This ratio between the two seasons is only fractionally different.

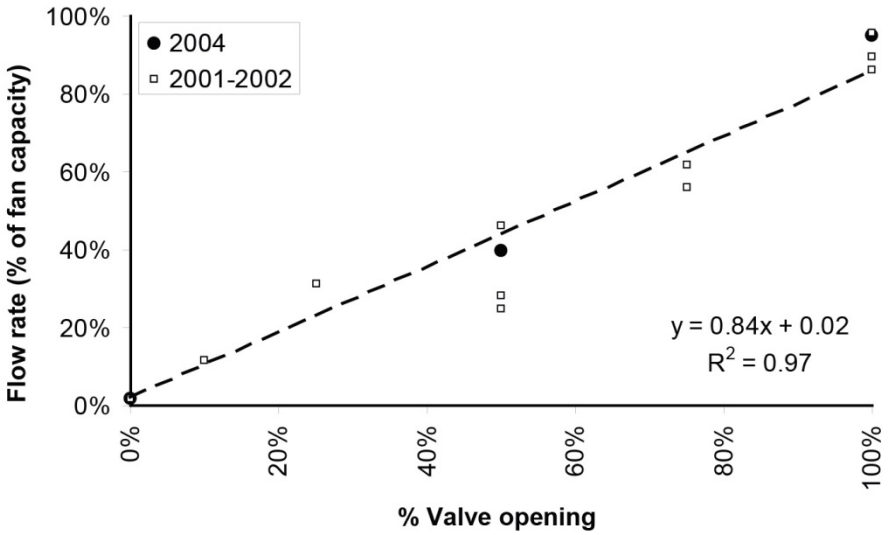


Figure 2. **Ratio between the opening percentage of the inlet and outlet valves and the measured ventilation flow rate for all measuring days (individual dots). The average ratio for both seasons is also shown (line pattern).**

3.1.2 Air flow rate conclusions

The results of the flow rate calculations based on the tracer gas method data lead to the following conclusions:

- When the fans in the potato storage are not operating and the inlet and outlet openings are fully closed, there is an air leak of 0.7% (688 m^3 / hour) of the total ventilation capacity with activated fans. In relation to the assumed air volume in this potato storage (1020 m^3), this amounts to 67% per hour. This is a high leakage level since storage places are constructed in such a way that a constant temperature is maintained. A certain amount of natural convection will always take place as the potatoes produce heat and, therefore, a slow air circulation will be generated as a result of differences in temperature. A leak can be further increased by the wind speed along the building and, therefore, pressure differences can cause more air to escape the potato storage.

- When the fans are operating and the valves of the inlet and outlet openings are closed (internal ventilation), the air leak is 1.3% (1406 m^3 / hour) of the total fan capacity. In relation with the assumed net air volume in this potato storage, it can be concluded that when the fans are operating at full capacity and the outer valves are closed, this area shows so much leakage that,

as a result of pressure differences, the air in the potato storage is refreshed with outside air every 43 minutes.

- The relation between the percentage of ventilation with outside air at maximum fan capacity and the actual air transport (AER) to the outside as a fraction of the total theoretical fan capacity (A_{air}) is as follows:

$$AER = 0.84 \cdot A_{air} + 2100 \quad (m^3 / h)$$

3.2 CIPC concentrations

3.2.1 Period following the first administration

The total air displacement during the period following the first administration has been calculated based on the data (Annex 4 and 5). Table 2 includes the total duration and the time period when external and internal ventilation took place.

Table 2. **Ventilation data, CIPC concentrations and CIPC emission calculation through leakage and external ventilation during the 3 October 2003 - 18 February 2004 period for a potato storage with 600 tons of consumption potatoes after administration of 25 litres of GRO-STOP BASIS at the time of storage (12.5 g CIPC per ton of potatoes).**

Period			External ventilation		Average CIPC Concentration		CIPC emissions		
From	Until	Total time (min)	Runtime (min)	Flow rate (m^3)	Internal ($\mu g/m^3$)	External ($\mu g/m^3$)	External (g)	Leakage (g)	Total (g)
3 Oct	4 Oct	1,470	1,348	2,028,740	*	0.044	89.4	0.0	89.4
4 Oct	6 Oct	1,950	1,941	2,773,911	*	0.034	93.2	0.0	93.2
6 Oct	13 Oct	10,110	4,855	4,249,396	0.110	0.042	176.5	8.8	185.4
13 Oct	20 Oct	10,095	772	651,476	0.068	0.033	21.4	10.4	31.7
20 Oct	27 Oct	10,065	684	218,715	0.092	0.053	11.7	13.1	24.7
27 Oct	10 Nov	20,130	1,495	1,991,843	0.170	0.019	38.2	40.6	78.8
10 Nov	24 Nov	20,115	1,100	1,481,893	0.090	0.013	18.8	23.1	41.9
24 Nov	22 Dec	40,600	3,326	4,065,271	0.069	0.010	41.5	33.9	75.4
22 Dec	19 Jan	40,075	2,337	2,650,914	0.060	0.008	22.5	30.0	52.4
19 Jan	18 Feb	43,175	2,358	2,177,060	0.040	0.005	11.9	21.5	33.4
3 Oct	18 Feb	197,785	20,216	22,289,218	N/A	N/A	525.0	181.1	706.2

* The sampling test tubes were not replaced because external ventilation took place 100% of the time.

During the first period immediately after storage, the ventilation need with mainly outside air is the greatest as the potatoes have to be dried and cooled down to a temperature of 7°C. The CIPC concentrations appeared to be highest during this period. Therefore, the most extensive CIPC emissions took place just after the potatoes were placed in storage. The potatoes are then still warm, resulting in the air containing more CIPC than when the air is cold. During the first ten days of storage, more than 52% (368 g of the active ingredient) of the CIPC emissions were emitted (706 g of the active ingredient until 18 February). Nearly all of the CIPC was emitted from the potato storage through the outlet openings during the first ten days. Only 2.4% (8.8 g) was emitted through leakage.
Of the applied 7500 g of CIPC (active ingredient) at the time of storage, only 760 g (active ingredient) or nearly 9% was emitted from the potato storage through the air during the period following the first administration.

3.2.2 Period during and following the second administration

The total air displacement during and after the second administration has also been calculated. Table 3 includes the total duration and the time period when external and internal ventilation took place.

Table 3. **Ventilation data, CIPC concentrations and calculation of the CIPC emissions through leakage and external ventilation during the 18 February 2004 – 11 April 2004 period for a potato storage with 600 tons of consumption potatoes after the administration of 7.5 litres of GRO-STOP Fog HN (300 g CIPC per litre of product) through fogging on 18 February 2003.**

Period			External ventilation		Average CIPC Concentration		CIPC emissions		
From	Until	Total time (min)	Runtime (min)	Flow rate (m^3)	Internal ($\mu g/m^3$)	External ($\mu g/m^3$)	External (g)	Leakage (g)	Total (g)
18 Feb	18 Feb	65	0	0	23.485	*	0	35.8	35.8
18 Feb	25 Feb	10,255	327	159,401	0.218	0.009	1.5	27.6	29.1
25 Feb	3 Mar	9,795	275	216,748	0.096	0.007	1.5	12.2	13.7
3 Mar	17 Mar	20,395	665	504,406	0.100	0.004	2.2	26.3	28.5
17 Mar	31 Mar	20,015	1,620	1,843,779	0.141	0.004	8.1	33.0	41.0
31 Mar	11 Apr	16,150	1,164	1,377,999	0.265	0.003	3.7	48.0	51.7
18 Feb	11 Apr	76,675	4,051	4,102,333	N/A	N/A	16.9	182.8	199.7
3 Oct	11 Apr	274,460	24,267	26,391,551	N/A	N/A	541.9	363.9	905.8

* Pumps were not activated since the valves remain closed during fogging.

During fogging (65 minutes), more than 18% (36 g of active ingredient) of the CIPC emissions were emitted during this second period (200 g of the active ingredient).
Contrary to what happened immediately after putting the potatoes in storage, the valves were opened for a limited number of times during the second administration, which is why the CIPC emissions through leaks is relatively high during this period (92%/183 g of this period's CIPC emissions).
Of the administered 2250 g of CIPC (active ingredient) at the time of loading the storage, only 200 g (active ingredient) or nearly 9% was emitted from the potato storage through the air during the period following the first administration.

3.2.3 Full storage period

The leak that occurs when the valves are closed is considerable (including during internal ventilation). During the full storage period, 3.3 million m^3 of air exits the potato storage with closed valves through leaks (Table 3). With external ventilation, 26,4 million m^3 of air exits the potato storage.
During storage, 40% (364 g of the active ingredient) of the total CIPC emissions was emitted through leaks. Of the total amount (9750 g) of CIPC applied at loading the `potato storage and through fogging during storage, only 906 g, or about 9%, exited the potato storage through the air (Figure 3).

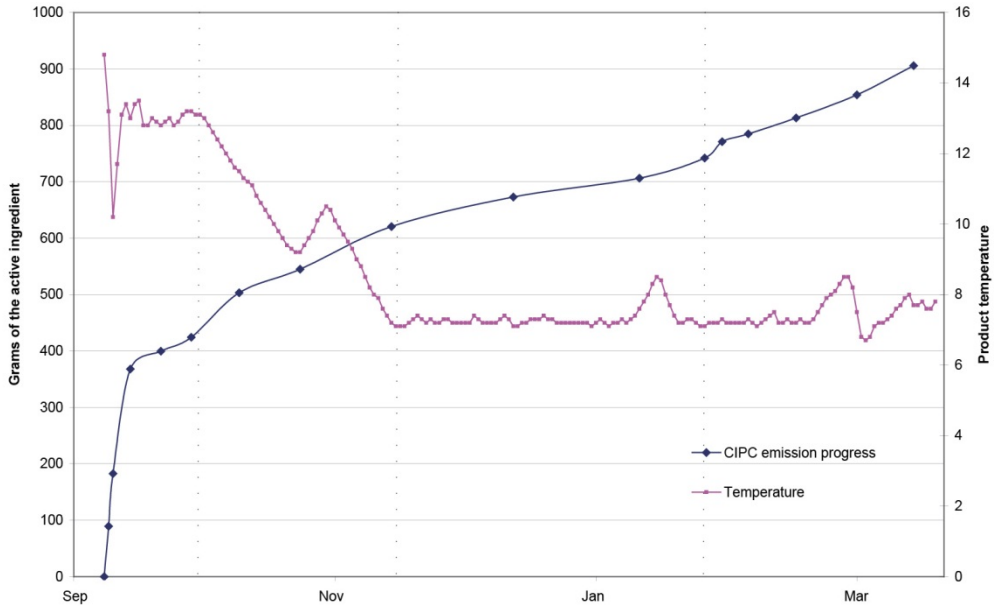


Figure 3. **Emission progress (cumulative) in grams of active ingredient and the registered product temperature measured during the 2002 – 2003 storage season.**

4 Conclusions and discussion

- The total CIPC emissions was approximately 706 grams of CIPC or approximately 9% of the CIPC administered in the total of the 7500 grams during the period spanning loading the storage to fogging. The duration of the first period was 138 days.
- The largest volume (over 50%) was emitted during the first ten days following application. The emission during administration after harvest on the conveyor belt could not be determined because this took place in an area that was not closed off.
- During the second period, 2250 g was administered through fogging. According to the measurements, 200 g (9%) exited the potato storage through ventilation and air leaks. The duration of the second period was 53 days.
- The CIPC emission was determined during the second administration. This turned out to be 36 g of CIPC (18% of the emission following the second administration).
- During the second period, emissions were mainly through leakage (closed ventilation valves). From this we can conclude that the CIPC concentration in the potato storage must have been high in comparison with the first period. After all, relatively the same amount of CIPC was emitted during this second period compared with the first period.

The measurements during the 2001/2002 storage season showed that the total of the CIPC emissions was 635 g, i.e. 7% of the total (9000 g). Approximately 11% of the CIPC administered during the period between storing to fogging was shown to have been emitted during this period while this was only 1% after fogging. The large difference between the two periods and the improbable low level of CIPC concentrations in the air ventilation could probably be ascribed to the locations where sampling took place. Measurements were taken in the inlet and outlet openings.

During the 2003/2004 storage season, sampling took place in the middle of the potato storage, above the potatoes. Samples were taken during external ventilation, internal ventilation and when there was no ventilation taking place at all. The CIPC concentration in the air was, therefore, reliably determined. The emission was calculated by linking these concentrations to flow rate measurements. The emissions during the periods several weeks after administration were fairly constant during the full storage season and amounted to an average of 2.8 g of CIPC per day. Immediately following administration and during fogging, the emission figures were much higher. The emissions during administration of the liquid formulation at the time of storage could not be measured.
The excellent CIPC distribution in the total product is a considerable advantage of this method of administration. As a result, the inhibitor was more effective and lasted longer. It is impossible to state whether the high efficiency of this administration counterbalances the higher emissions during fogging.
The intensive external ventilation following storage determines the CIPC emissions to a large extent. Perhaps a change in procedure during the initial period of storage might further lower the emissions, for example, if it were possible to first dry the potatoes through intensive external ventilation before CIPC is administered. This will have to be discussed by manufacturers, distributors and companies that store potatoes.

To get an impression of the emissions when the potatoes are stored for a longer period, the emission process can be extrapolated with 2.8 g per day.
The average emissions of 11% during the full storage period are low. The emissions of CIPC that is administered as a herbicide in the field are probably higher where load is concerned.

5 Literature

Mosquera, J., A. Scheer, M.J.M. Wagemans & D.A. van der Schans, 2002. Measuring techniques to determine the air exchange rate during the storage of potatoes for consumption. IMAG Report 2002-08.

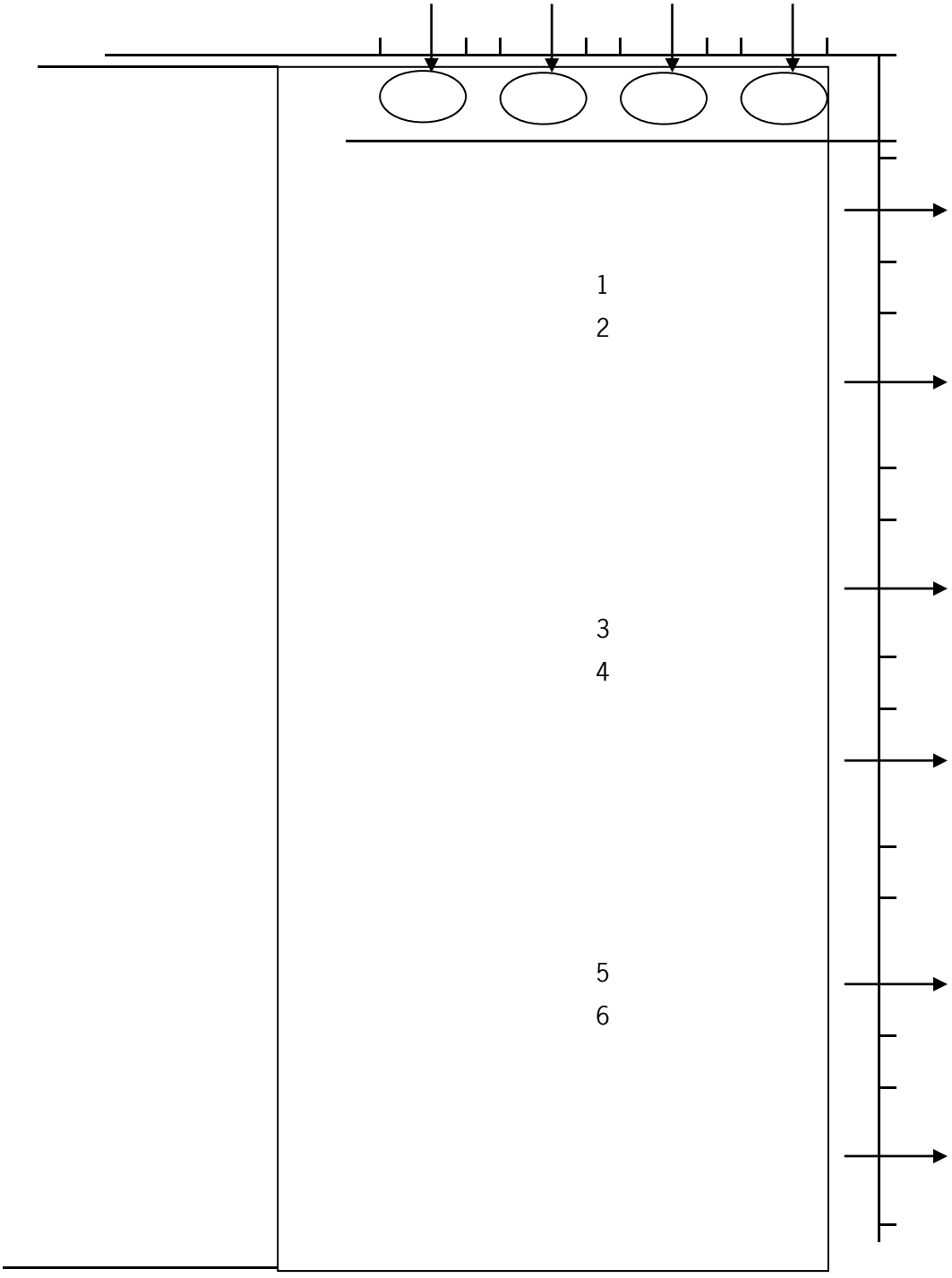
Riffat, S.B. and K.W. Cheong, 1995. Tracer gas techniques for measuring airflow in ducts: a review. International Journal of Energy Research vol. 19, 461-477.

Schans van der, D.A. & M. G. van Zeeland(2000) Puntemissies na de oogst, Routes en Risico's (Point emissions after harvesting, routes and risks); PAV rapport 54685

Schans van der, D.A & J. Mosquera Losada (2002) Studie naar CIPC uit een aardappelbewaarplaats (Study of CIPC emissions from a potato storage). PPO project report 1254685.

Annex 1. Floor plan potato storage

Location: A.P. van Tilburg, Lindeweg 14, 8315 RC Luttelgeest, the Netherlands



Annex 2. Authorization decree GRO-STOP 300 EC

MINISTRY OF AGRICULTURE, NATURE MANAGEMENT AND FISHERIES
Approval number 11631 N
THE MINISTRY OF AGRICULTURE, NATURE MANAGEMENT AND FISHERIES,
in agreement with
THE STATE SECRETARY OF HEALTH, WELFARE AND SPORTS,
THE MINISTRY OF HOUSING, REGIONAL DEVELOPMENT AND THE ENVIRONMENT and
THE STATE SECRETARY FOR SOCIAL AFFAIRS AND EMPLOYMENT,
Deciding on the application submitted on 18 October 1994 (application number 94-276 T) of
LUXAN B.V.
INDUSTRIEWEG 2
6662 PA ELST
To obtain approval as referred to in Article 2, first paragraph of the Pesticides Act 1962 (Bulletin of Acts and Decrees 288) for the inhibitor

GRO-STOP 300 EC,

having due regard to Articles 3, 3a, 4 and 5 of the Pesticides Act 1962,

HEREBY DECREE:

§ I. Approval
1. The pesticide GRO-STOP 300 EC has been approved as defined by Article 2, first paragraph of the Pesticides Act 1962, under the number and date thereof.
2. The approval applies until 1 June 1998.

§ II. Composition, shape and finish
Without prejudice to what has been determined regarding composition, shape and finish in the Order on the Composition, Classification, Packaging and Labelling of Pesticides:
a. The composition, shape and physical condition of the inhibitor as well as its chemical and physical properties, must match the data provided with the approval application and the sample provided with the approval application.
b

§ III. Usage
The pesticide may only be used whilst observing the provisions made in the present Annex I under A.

§ IV. Packaging and labelling
1. The indications, which pursuant to Article 15 of the Order on the Composition, Classification, Packaging and Labelling of Pesticides must be specified on the packaging, are hereby determined as follows:
- Nature of the preparation: Emulsifiable concentrate
- Active ingredient(s): Chloropropham
- Level(s): 300 g/l
- Other very toxic, toxic, corrosive or irritating substance(s):
- Toxicological group(s):
- Expiry date:

2. In addition to the indications and statements specified under 1 and others prescribed in the Order on the Composition, Classification, Packaging and Labelling of Pesticides, the packaging must include:

a. Literally and without any supplement:
What has been specified in the present Annex I under A.

b. Either literally or the substance:
The text included in the present Annex, I, on the understanding that not all applications specified here need to be stated and the contents of this text may only be supplemented with technical instructions for optimal control, provided these do not contradict the text.

c. Literally and without any supplement:
- **Special hazards:**
- **Safety recommendations:**
Keep out of the reach of children.
Keep away from food and drink, and animal feed.
Do not eat, drink or smoke during use.
Do not inhale spray mist.
Wear suitable gloves and protective clothing.
Use suitable respiratory protection when there is insufficient ventilation.
d. Pursuant to Article 15 of the Order on the Composition, Classification, Packaging and Labelling of Pesticides, the following hazard symbol must be included on the packaging: with the following caption:
Stakeholders can submit a substantiated notice of objection with the Dutch Ministry of Agriculture, Nature Management and Fisheries. When a notice of objection is submitted, this must be sent to the following address within six weeks following the publication date of this decree: The Ministry of Agriculture, Nature Management and Fisheries, attn. the Bureau bezwaarschriften en geschillen (Notice of Objection and Dispute Office), PO Box 0401, 2500 EK The Hague.
Wageningen, 17 November 1995

THE MINISTRY OF AGRICULTURE,
NATURE MANAGEMENT AND FISHERIES
and on whose behalf:
BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS,

(Chair)

MINISTRY OF AGRICULTURE, NATURE MANAGEMENT AND FISHERIES
ANNEX I to the authorisation decree of the GRO-STOP 300 EC inhibitor,
Authorisation number 11631 N

A.

STATUTORY INSTRUCTIONS FOR USE

Only the use as a sprouting inhibitor for consumption and factory potatoes in air-cooled and/or mechanically cooled storage places is permitted, on the understanding that the period between the last treatment and the release on the market of treated batches must be 2 months as a minimum.

B.

INSTRUCTIONS FOR USE

GRO-STOP 300 EC can be used as a sprouting inhibitor for consumption and factory potatoes. It must never be administered to seed potatoes.

General

The potatoes to be treated must be dry and as soil-free as possible. Diseased and damaged tubers must be removed beforehand. The potatoes must be treated only once at the time of storage.
Potatoes that will be marketed within two months of having been placed in storage must not be treated.

Applications

Consumption and factory potatoes (in air-cooled or mechanically cooled storage places at 4-8°C). The potatoes that are stored in bulk, in boxes or bags must be treated on the conveyor belt at the time of storage and/or when filling the boxes or bags, using special high-pressure/low-volume spraying equipment (e.g. a Mafex machine or another suitable spraying or misting machine).

60 ml of GRO-STOP 300 EC per 1000 kg of potatoes.

Dosage: Depending on the used spraying equipment, at most 140 ml water per 1000 kg of potatoes should be used to dilute GRO-STOP 300 EC before administering.

Remarks
- Do not administer by using 'hot-fog' equipment.
- Seeds or other parts of a plant meant for breeding must never be stored in places where GRO-STOP 300 EC has or will be administered because it may damage the sprout.

Wageningen, 17 November 1995
THE MINISTRY OF AGRICULTURE,
NATURE MANAGEMENT AND FISHERIES
and on whose behalf:
THE BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS,
Approval number 4563 N

Annex 3. Authorization decree GRO-STOP SC

The Board for the Authorisation
of pesticides in the Netherlands,
having due regard to Article 5 of the Pesticides Act 1962 (Bulletin of Acts and Decrees 288),
DECREE

Sole Article

The authorisation decree for the GRO-STOP SC inhibitor under no. 4563
dated 23 September 1988, last amended by the Decree dated 28 July 1995 is, based on the grounds indicated in Annex II of the present Decree, amended as follows as of today:
In the text under § IV.2. e "W.1" now reads "W.2".
Annex 1 of the aforementioned Decree is replaced by Annex 1 of the present Decree.
Packaging that has not been changed in accordance with this decree making amendments may be used, stored for this use or kept in stock during the period randing from
24 June 2002 through to 1 July 2003.
Packaging that has not been changed in accordance with this decree that makes amendments may be sold, offered for sale or exchange, made available, given or distributed during the period ranging from 24 June 2002 through to 1 January 2003.
People who have a direct interest in this decree may submit an objection to the administrative body that is responsible for this decree within six weeks after the Decree has been published, having regard to Article 8 of the Pesticides Act 1962 and Article 7:1, paragraph 1 of the General Administrative Law Act. This objection must be addressed to: The Board for the authorisation of pesticides in the Netherlands, PO Box 217, 6700 AE WAGENINGEN, the Netherlands.
Wageningen, 24 June 2002
THE BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS,

(Chair)
To:
LUXAN B.V.
Industrieweg 2
6662 PA ELST GLD

THE BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS
ANNEX I to the decree making amendments with regard to the GRO-STOP 300 EC inhibitor,
Authorisation number 4563 N
A.
STATUTORY INSTRUCTIONS FOR USE
The substance use authorisation is limited to the use as a sprouting inhibitor for consumption and factory potatoes in air-cooled and/or mechanically cooled storage places.
B.
INSTRUCTIONS FOR USE
Important:
The potatoes to be treated must be dry and as soil-free as possible.
The skin has to be slightly hardened.
Diseased and damaged tubers must be removed.
It may not be used for the treatment of small batches by individuals.
Time and method of administration:
Treating the potatoes as early as possible is recommended, preferably before the formation of sprouts is observed.

The doors and ventilation openings to the storage places must be tightly closed during the treatment. Only internal ventilation must be activated.
The internal ventilation should be operated after the treatment until the sprayed inhibitor has settled. Keep the room closed for another 24 hours or so after which ventilation can take place in the usual manner.
The inhibitor must be administered using a jet motor engine.
Dose:
The maximum dosage is 100 ml inhibitor sprayed per 1000 kg potatoes, spread over multiple treatments. The maximum dose for the first treatment is 25 ml per 1000 kg of potatoes after they have hardened, approximately 2 weeks after placing the potatoes in the storage place. The dose for subsequent treatments is 12.5 ml per 1000 kg of potatoes to be administered every four weeks with a maximum of 7 treatments (1 x 25 ml + 6 x 12.5 ml/1000 kg of potatoes).

Note: Do NOT use in areas where seed-potatoes are or will be stored.
Wageningen, 24 June 2002
THE BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS,

(Chair)

THE BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS

ANNEX II to the decree making amendments with regard to the GRO-STOP SC inhibitor,
Authorisation number 4563 N
LUXAN B.V., authorisation holder of the
GRO-STOP SC inhibitor, with chloropropham as the active ingredient, has sent a letter dated 30 January 2002 to submit an amendment request for the waiting period and dose.
The amendment request is as follows:
Decreasing the waiting period from 2 months to none.
Increasing the authorised dose from 60 ml/1000 kg to 100 ml/1000 kg of potatoes.
The reports provided with the amendment request have been assessed and it has been determined that the requested decrease in the waiting period and increase in the dose does not pose any unacceptable public health risks.
Conclusion
The Board has assessed the amendment request for the Decree dated 28 July 1995 based on the written request submitted by the authorisation holder consisting of the following:
Decrease of the waiting period from 2 months to none in the Statutory instructions for use,
Increase of the authorised dose from 60 ml/1000 kg to 100 ml/1000 kg of potatoes in the Instructions for use,
and decided to amend the Decree of 28 July 1995 accordingly.

Decree

The Board has decided to amend the Statutory instructions for use and the Instructions for use for the GRO-STOP SC inhibitor, 4563 N, according to the request submitted by the authorisation holder.
Wageningen, 24 June 2002
THE BOARD FOR THE AUTHORISATION OF PESTICIDES IN THE NETHERLANDS,

(Chair)

Annex 4. Specification of sample intervals

Calculation of the CIPC concentration per period. Valves open means sampling pump on.
Sampling at inlet valves

	Start date	Time	End date	Time	Total time	Valves open 1-100%	CIPC IN	Flow pump	Total flow period	CIPC conc
	(dd-mm-yy)	(hh.mm)	(dd-mm-yy)	(hh.mm)	(min)	(min)	(mugr/l)	(ml/min)	(ml)	mug/m3
1	18-03-2002	16,00	200302	14,00	2760	0	0	0	0	0
2	20-03-2002	14,00	220302	18,00	3120	549	0.74	180	98820	7.49
3	22-03-2002	18,00	280302	16,30	8550	490	0.61	174	85260	7.15
4	28-03-2002	16,30	40402	14,30	9960	186	0.12	175	32550	3.69
5	04-04-2002	14,30	110402	14,00	10050	328	0.31	170	55760	5.56
6	11-04-2002	14,00	250402	9,00	19860	1078	0.81	157	169246	4.79
7	25-04-2002	9,00	160502	17,00	30720	1148	0.64	157	180236	3.55
8	16-05-2002	17,00	290502	17,00	18720	871	0.55	160	139360	3.95
9	29-05-2002	17,00	30602	14,00	5760	815	0.55	170	138550	3.96

Sampling at outlet valves

	Start date	Time	End date	Time	Total time	Valves open 1-100%	CIPC IN	Flow pump	Total flow period	CIPC conc
1	18-03-2002	16,00	200302	14,00	2760	0	0	0	0	
2	20-03-2002	14,00	220302	18,00	3120	549	0.16	170	93330	1.71
3	22-03-2002	18,00	280302	16,30	8550	490	0.12	172	84280	1.42
4	28-03-2002	16,30	40402	14,30	9960	186	0.12	175	32550	3.69
5	04-04-2002	14,30	110402	14,00	10050	328	0.12	180	59040	2.03
6	11-04-2002	14,00	250402	9,00	19860	1078	0.12	180	194040	0.62
7	25-04-2002	9,00	160502	17,00	30720	1148	0.12	170	195160	0.61
8	16-05-2002	17,00	290502	17,00	18720	871	0.2	175	152425	1.31
9	29-05-2002	17,00	30602	14,00	5760	815	0.2	170	138550	1.44

Continuous measurements within the concentration to determine the air leakage

	Start date	Time	End date	Time	Total time	Valves open 1-100%	CIPC IN	Flow pump	Total flow period	CIPC conc
1	18-03-2002	16,00	200302	14,00	2760	0	12	170		
2	20-03-2002	14,00	220302	18,00	3120	549	17	170	530400	32.05
3	22-03-2002	18,00	280302	16,30	8550	490	4.8	170	1453500	3.30
4	28-03-2002	16,30	40402	14,30	9960	186	15	175	1743000	8.61
5	04-04-2002	14,30	110402	14,00	10050	328	17	170	1708500	9.95
6	11-04-2002	14,00	250402	9,00	19860	1078	14	175	3475500	4.03
7	25-04-2002	9,00	160502	17,00	30720	1148	38	175	4480000	8.48
8	16-05-2002	17,00	290502	17,00	18720	871	26	170	2652000	9.80
9	29-05-2002	17,00	30602	14,00	5760	815	26	170	816000	31.86
10	14-06-2002	16:00	21-06-2002	16:00	10080		42	173	1743840	24.08

Annex 5. Sample results

Period	Start date	Time	End date	Time	Total time	Fan on	Internal ventilation	Conc off	Conc continuous inside	CIPC from leakage	CIPC from External vent	Total CIPC emissions
	(dd-mm-yy)	(hh.mm)	(dd-mm-yy)	(hh.mm)	(min)	(min)	(min)	(mugr/l)	(mugr/l)	(g)	(g)	(g)
1	18-03-2002	16,00	20-03-2002	14,00	2760	203	203		35	4.50	0	4.50
2	20-03-2002	14,00	22-03-2002	18,00	3120	577	28	7.49	32.05	3.84	7.28	11.11
3	22-03-2002	18,00	28-03-2002	16,30	8550	2843	2353	7.15	3.30	1.24	4.79	6.03
4	28-03-2002	16,30	04-04-2002	14,30	9960	2021	1835	3.69	8.61	3.92	1.12	5.04
5	04-04-2002	14,30	11-04-2002	14,00	10050	3091	2763	5.56	9.95	4.50	2.78	7.28
6	11-04-2002	14,00	25-04-2002	9,00	19860	7001	5924	4.79	4.03	3.52	8.48	12.00
7	25-04-2002	9,00	16-05-2002	17,00	30720	14685	13540	3.55	8.48	11.68	6.97	18.65
8	16-05-2002	17,00	29-05-2002	17,00	18720	3574	2703	3.95	9.80	8.15	5.65	13.80
9	29-05-2002	17,00	03-06-2002	14,00	5760	2717	1902	3.97	31.86	7.33	2.75	10.08
									24.08			
Total	18-03-2002	16,00	03-06-2002	14,00	109500	36712	31251			48,68	39,82	88,49

Calculation of the CIPC concentration per period

	Start date	Time	End date	Time	Total min	Valves open 1-100%	CIPC mugr IN	Flow pump -ml/min	Total flow period -ml	CIPC conc mug/m3
1	14-10-01	18:00	16-10-01	9:30	2310	2310	11	162	374220	29.394
2	16-10-01	9:30	18-10-01	10:30	2940	1927	7	162	312174	22.423
3	18-10-01	10:30	19-10-01	10:30	1440	194	5.3	165	32010	165.573
4	19-10-01	10:30	23-10-01	10:45	5775	3440	12	168	577920	20.764
5	23-10-01	10:45	25-10-01	17:45	3300	475	0.31	169	80275	3.8617
6	25-10-01	17:45	1-11-01	11:45	9720	3096	1.41	180	557280	2.5301
7	1-11-01	11:45	8-11-01	9:10	9925	643	1.44	168	108024	13.33
8	8-11-01	9:10	15-11-01	11:20	10210	539	0.85	168	90552	9,387
9	15-11-01	11:20	22-11-01	14:35	10275	876	0.2	162	141912	1.409
10	22-11-01	14:35	29-11-01	13:35	10020	667	0.3	169	112723	2,66139
11	29-11-01	13:35	13-12-01	9:15	19900	2017	0.3	174	350958	0.854803
12	13-12-01	9:15	11-01-02	16:25	42190	1976	0.12	168	331968	0.361481
13	11-01-02	16:25	8-02-02	13:40	40155	3360	0.12	167	561120	0.213858
14	8-02-02	13:40	15-03-02	16:50	50590	4200	0.12	168	705600	0.170068
Sampling at outlet valves										
1	14-10-01	18:00	16-10-01	9:30	2310	2310	14	165	381150	36.73
2	16-10-01	9:30	18-10-01	10:30	2940	1927	12	168	323736	37.067
3	18-10-01	10:30	19-10-01	10:30	1440	194	7.1	169	38024	186.724
4	19-10-01	10:30	23-10-01	10:45	5775	3440	18.5	173	595120	31.086
5	23-10-01	10:45	25-10-01	17:45	3300	475	9.5	182	86450	109.890
6	25-10-01	17:45	1-11-01	11:45	9720	3096	1.85	181	560376	3.30135
7	1-11-01	11:45	8-11-01	9:10	9925	643	1.,5	173	111239	13,4844
8	8-11-01	9:10	15-11-01	11:20	10210	539	0.55	173	93247	5.898
9	15-11-01	11:20	22-11-01	14:35	10275	876	1.2	173	151548	7.9183
10	22-11-01	14:35	29-11-01	13:35	10020	667	0.8	170	113390	7,0553
11	29-11-01	13:35	13-12-01	9:15	19900	2017	0.9	168	338856	2.656
12	13-12-01	9:15	11-01-02	16:25	42190	1976	0.6	168	331968	1.8074
13	11-01-02	16:25	8-02-02	13:40	40155	3360	0.2	173	581280	0.3441
14	8-02-02	13:40	15-03-02	16:50	50590	4200	0.18	170	714000	0.2521

Annex 6. Summary of all flow rate measurements

Table 1. **Tracer gas (SF_6) concentrations.**

	Date	Investigated situations	Inlet	Outlet	Inside
Period 1	25-10-2011	No ventilation	8.70 +/- 0.00	1700.00 +/- 0.00	1800.00 +/- 0.00
	01-11-2011	100% external ventilation	0.23 +/- 0.23	14.10 +/- 0.44	23.27 +/- 0.81
	08-11-2001	50/50% mixed	0.40 +/- 0.52	15.55 +/- 0.21	24.80 +/- 0.85
	15-11-2001	100% recirculation	68.67 +/- 10.69	653.33 +/- 64.29	636.67 +/- 66.58
	23-11-2001	10/90% mixed	4.36 +/- 4.77	99.33 +/- 2.52	100.33 +/- 4.73
	29.11-2001	50/50% mixed	4.33 +/- 1.63	39.00 +/- 2.65	46.00 +/- 4.24
	06-12-2001	100% external ventilation	0.17 +/- 0.11	6.65 +/- 0.67	11.97 +/- 0.68
	13-12-2001	100% recirculation	0.79 +/- 0.51	758.33 +/- 97.08	716.67 +/- 83.58
Period 2	23-03-2002	100% external ventilation	0.14 +/- 0.12	6.61 +/- 0.61	12.77 +/- 0.21
	26-03-2002	50/50% mixed	3.66 +/- 2.98	48.97 +/- 16.84	40.47 +/- 3.99
	28-03-2002	75/25% mixed	0.26 +/- 0.22	12.03 +/- 0.92	20.40 +/- 0.75
	09-04-2002	25/75% mixed	0.20 +/- 0.09	46.07 +/- 13.44	36.47 +/- 2.91
	12-04-2002	75/25% mixed	0.05 +/- 0.03	20.20 +/- 11.99	18.50 +/- 0.78
Period 3	23-04-2004	No ventilation	3.04 +/- 0.50	722.95 +/- 72.92	716.44 +/- 65.17
	24-04-2004	100% external ventilation	1.02 +/- 0.17	6.09 +/- 0.29	10.15 +/- 0.38
	24-04-2004	50/50% mixed	0.61 +/- 0.26	14.60 +/- 0.48	18.37 +/- 0.86
	24-04-2004	100% recirculation	6.63 +/- 0.00	369.46 +/- 0.00	398.72 +/- 0.00
	25-04-2004	No ventilation	10.71 +/- 24.44	907.48 +/- 113.22	924.77 +/- 127.78

** Note: During periods 1 (2001) and 2 (2002), the tracer gas injection was 20 $ml.min^{-1}$ and during period 3 (2004) this was 10 $ml.min^{-1}$. That is why there are lower concentrations in period 3 compared with periods 1 and 2.

Table 2. **Ventilation flow rate (internal tracer gas ratio method).**

	Date	Investigated situations	Ventilation (m^3.$hour^{1}$)	Ventilation (% fan capacity)
Period 1	25.10-2001	No ventilation	1167 +/- 0	1.1 +/- 0.0
	01-11-2001	100% external ventilation	90258 +/- 3159	86.00 +/- 3.0
	08-11-2001	50/50% mixed	48387 +/- 1656	46.1 +/- 1.6
	15-11-2001	100% recirculation	1885 +/- 197	1.8 +/- 0.2
	23-11-2001	10/90% mixed	11960 +/- 563	11.4 +/- 0.5
	29-11-2001	50/50% mixed	26087 +/- 2406	24.8 +/- 2.3
	06-12-2001	100% external ventilation	100279 +/- 5704	95.5 +/- 5.4
	13-12-2001	100% recirculation	1674 +/- 195	1.6 +/- 0.2
Period 2	22-03-2002	100% external ventilation	93995 +/- 1533	89.5 +/- 1.5
	26-03-2002	50/50% mixed	29654 +/- 2926	28.2 +/- 2.8
	28-03-2002	75/25% mixed	58824 +/- 2177	56.0 +/- 2.1
	09-04-2002	25/75% mixed	32907 +/- 2630	31.3 +/- 2.5
	12-04-2002	75/25% mixed	64865 +/- 2738	61.8 +/- 2.6
Period 3	23-04-2004	No ventilation	845 +/- 81	0.81 +/- 0.08
	24-04-2004	100% external ventilation	99726 +/- 4621	94.98 +/- 4.40
	24-04-2004	50/50% mixed	41585 +/- 1314	39.60 +/- 1.25
	24-04-2004	100% recirculation	1667 +/- 233	1.59 +/- 0.22
	25-04-2004	No ventilation	679 +/- 92	0.65 +/- 0.09

Table 3**. Ventilation effectiveness.**

	Date	Investigated situations	Ventilation effectivity
Period 1	25-10-2001	No ventilation	1.06 +/- 0.00
	01-11-2001	100% external ventilation	1.66 +/- 0.06
	08-11-2001	50/50% mixed	1.48 +/- 0.20
	15-11-2001	100% recirculation	0.99 +/- 0.21
	23-11-2001	10/90% mixed	1.01 +/- 0.04
	29-11-2001	50/50% mixed	0.82 +/- 0.63
	06-12-2001	100% external ventilation	1.83 +/- 0.14
	13-12-2001	100% recirculation	0.95 +/- 0.02
Period 2	22-03-2002	100% external ventilation	1.96 +/- 0.22
	26-03-2002	50/50% mixed	0.89 +/- 0.29
	28-03-2002	75/25% mixed	1.72 +/- 0.14
	09-04-2002	25/75% mixed	0.82 +/- 0.17
	12-04-2002	75/25% mixed	1.11 +/- 0.50
Period 3	23-04-2004	No ventilation	1.01 +/- 0.06
	24-04-2004	100% external ventilation	0.57 +/- 0.05
	24-04-2004	50/50% mixed	0.79 +/- 0.04
	24-04-2004	100% recirculation	0.93 +/- 0.00
	25-04-2004	No ventilation	0.98 +/- 0.06