AIR MONITORING AROUND MSW SANITARY LANDFILLS IN WALLONIA: FEEDBACK OF 10 YEARS FIELD SURVEYS

C. Collart[1], V. Lebrun[1], S. Fays[1], V. Salpéteur[1], J. Nicolas[2], A.-C. Romain[2]

[1] ISSeP - Institut Scientifique du Service Public, Waste department, Liège (Belgium)
[2] University of Liège, Research Group "Environmental Monitoring", Arlon (Belgium).

Contact: Ir. Catherine Collart
ISSeP, Rue du Chéra, 200, 4000 Liège (BELGIUM) – 00(32)4 229 83 53 – C.Collart@issep.be

EXECUTIVE SUMMARY

Background

Monitoring of landfill surface gas-emissions is performed by a simple low-cost method. For more than 8 years, an interdisciplinary air survey was achieved by ISSeP around 10 municipal solid waste (MSW) landfills in Wallonia (Belgium). Surveying campaigns include 4 axes of investigations: landfill gas (LFG) surface emissions detection, ambient air quality control, odours annoyance assessment and measurements on exhaust fumes from LFG valorisation units. This paper focuses only on the 3 first domains.

Methodology

Monitoring of landfill gas (LFG) surface emissions is performed by a simple low-cost method (Awono et al, 2005). Portable FID measurements are taken on landfill surface along regular and dense grids. Krigging measured CH_4 concentrations furnish continuous maps which localize higher and lower emission zones, assuming that, at a medium observation scale, high fluxes zones create high methane concentrations in the upper part of landfill capping.

Assessing odour nuisances created by a wide, heterogeneous, diffuse and multiple sources such as MSW landfills is a difficult challenge. An original assessment approach, developed by Nicolas et al. (2006), was applied to the wallonian landfills. Field human observers first delineate the regions in which odour impact is experienced. Emission rates are then manipulated in a dispersion model until the predicted size of the impact zone matches the one observed in the field, taking into account of measured meteorological conditions.

Ambient air quality surveys are achieved following British methodology (UK-EA, 2000). During several weeks, 8 tracers parameters are analysed continuously by mobile labs. They are placed near exploitation, downwind or in direction of the nearest neighbours. Measured values are compared to health threshold values. Local wind directions are simultaneously recorded in order to draw “pollution roses”. This dual approach allows controlling that air quality remains safe for human health and checking if possible anomalies are produced by the landfill or not.

Results

In situ odour surveys may help to optimize mobile lab positioning. Inversely, analysing odorous compounds near a neighbour helps to corroborate its annoyance by analytical evidences. Knowing intensity and localisation of LFG emissions often contributes to better understanding LFG odours in the neighbourhood, and motivates the placement of H_2S sensor at the right place. Finally, by combining results from three domains of investigation, one can obtain a really efficient and complete environmental impact study of a landfill on its surrounding ambient air. A case study of Cour-au-Bois landfill (CAB) is developed in this paper and illustrates the interest of such a multidisciplinary monitoring. At the scale of the whole monitoring network, 10 years monitoring statistical values are presented like total and mean size of odour annoyance perimeters, total and mean odour emission rates or maximal and average concentrations of pollutant in ambient air. These statistics constitute strategic information for guiding environmental policies and establishing standards and legislations.

Conclusions

The Wallonian monitoring network of sanitary landfills is a unique public multidisciplinary tool for environment quality assessment. It is first preventive control-oriented. Furthermore, it gives a solid technical basis for guiding legislative works. Finally, as it is managed by scientific institutions, it generates a substantial scientific contribution to a better knowledge of sanitary landfills and their impact on the environment.

1 INTRODUCTION

1.1 Background

In 1998, DGRNE (the environmental authorities of Wallonia - French speaking part of Belgium) decided to set up an ambitious monitoring network of sanitary landfills (Dengis & Godfroid, 1999). From 6 sites at the beginning, it includes now 12 MSW landfills located all around the Wallonian territory. This environmental management tools take place in the EU Landfill Directive (EEC/1999/31/EC) philosophy, which aims at improving standards of landfilling, in general, and of monitoring, in particular. DGRNE gives ISSeP (Public Scientific Institute) total freedom to manage technical and scientific tasks linked to the network, from survey strategy to data interpretation. In practice, ISSeP achieves most of the monitoring works, delegating only the odour investigation to a specialised academic research team. Other academic experts often co-operate with ISSeP for specific research and development projects in relation with the network. It makes DGRNE able to acquire its own environmental database, in total independence from landfill owners and to control the impact of each landfill on its close environment. Furthermore, since the beginning, DGRNE is publishing the results of every survey on its free-access website (DGRNE, 2008). These two aspects - independence from owner and transparent communication with the population - make this network original and, probably, unique in EU.

1.2 Research objectives

From interpretation of various field measurements and samplings on and around the site, the monitoring network aims at verifying that landfills environmental impacts remain acceptable during exploitation and aftercare periods. The sampling and field measurement surveys cover two main investigation domains:

- monitoring liquid emissions and controlling their impact on ground/fresh waters ;
- monitoring gaseous emissions and assessing their influence on ambient air quality.

Both domains need different kinds of investigations, sometimes combined all together, sometimes focused on some particular problems, but always following the same global strategy.

This paper focuses on the second domain. It describes first the field measurements strategy, which is common to every survey. It makes then a review of measurement apparatus and interpretative tools used for each investigated topic. It illustrates them by a specific case study. Finally, the paper presents the most outstanding results within the databases build up from among 24 complete field surveys achieved during 10 years monitoring.

2 METHODOLOGY

2.1 Field measurements global strategy for gaseous emissions

The challenge consists in monitoring gaseous emissions from sanitary landfills, controlling their influence on air quality and assessing the potential risk and/or level of annoyance caused to the neighbourhood via contaminant dispersion. ISSeP developed a monitoring protocol, widely inspired from UK Environmental Agency guidance documents (UK-EA, 2004a-c) including four axes of investigation.

The first one concerns the control of some pollutants in the fumes of landfill gas (LFG) engines - motors and flares - as well as the quality control of landfill gas when entering the engines. This topic is not developed in this paper.

The second problem tackled by the network is the LFG fugitive emission flow through top liners or above working zones of landfills. Methane concentrations are measured on landfills surface by means of portable FID and/or IR devices following regular and dense spatial sampling grids. Drawing CH_4 isograde maps allows delineating the weakest zones and preferred emission pathways along the cover and checking LFG extraction efficiency.

The third field of investigation concerns odour emissions and resulting nuisances for residents in the vicinity. Various techniques are applied, case by case, to assess odour emission rate, to delineate the most probable annoyance perimeters (see fig. 2) created by landfills and to confront them with real disturbance undergone by the nearest residents.

Ambient air quality monitoring is the last field of investigation included in the monitoring strategy. Mobile laboratories designed for continuous analysis of some air pollution tracers are placed on site. Measured values are compared to normal background concentrations, to health standards and/or human olfactory threshold values. This strategy aims at quantifying landfill influence on surrounding ambient air and at assessing risk level incurred by close residents.

Trying to obtain adequate responses to complex questions and optimising knowledge level acquired about multiple and interactive phenomenons are the aims of such a multidisciplinary strategy. Combining results and observations made during the same period by different approaches gives a better image of the environmental situation in the air above and along landfills.

2.2 Detecting and mapping fugitive LFG emission through landfill liners

Monitoring LFG emissions surface on landfills is performed by a simple low-cost method (Bogner et al, 1997). The method is similar to the "primary survey stage" described in UK-EA guidance document (UK-EA, 2004b). Until now (Awono et al, 2005), regular methane emission surveys have been held with a portable flame ionisation detector (FID). A new device (ECOPROBE5), based on IR technology coupled with secondary sensors has been acquired recently and will be coupled to PortaFID M3K for the future campaigns (Lebrun et al., 2007). It will furnish complementary parameter (CO2, O2, T°) and increase the upper limit of CH4 measurement range. First surveys were achieved without the accuracy of current GPS tools. Measurements were performed following regular square grids referenced on some visual benchmarks. Since 2004, the use of a precise and reliable GPS system (Trimble 5700) opened new prospects in the setting up with a lot of options for positioning sampling points and optimizing their spatial distribution.

Simple krigging method using linear variograms models is used for spatial 2D interpolation of measured CH_4 concentrations. This geostatistical data processing is performed with Geological Data Management® (GDM®) software. Isograde maps, created by this geostatistical processing, is then embedded in GIS with site maps for visualisation (Figure 1). Static flux chamber surveys combined with an improvement of geostatistics processing are now in hand with the aim of moving towards quantification of surface emissions.

2.3 Evaluation of odour annoyance

The main odour assessment method that is systematically applied on each landfill monitoring survey has been developed by Nicolas et al. (2006). It is an adaptation of the sniffing team campaigns method (STC), described in German guidelines (VDI, 2003), to the particular case of landfill site odours.

The originality of the method is the way to assess odour emission rate from the source (in ou/s). Whereas classical methods try to measure this emission by on site flux measurements and sampling, the STC deduces it by on field delineating perimeters in which odour is perceptible. Teams of observers build these perimeters by odour detection surveys downwind around the plume axis. As the size of odour perception area also depends on meteorological conditions during measurement, wind direction, wind speed and solar radiation are simultaneously recorded. Then, an atmospheric dispersion model is used with average values of these meteorological data. For simple cases, Tropos Impact from Odotech (bi-Gaussian model) is sufficient. This software implements a special meandering algorithm to cope with odour dispersion. For more complex relief, 3D models are also applied. The emission rate entered into the model is adjusted until the simulated average isopleth for 1 ou/m³ at about 1.5 m height (the height of the human nose) fits the observed maximum perception distance. The same process - field survey + emission rate computation - is repeated for various climatic conditions and the mean emission rate is calculated from every observed occurrences.

This average flow is then reintroduced in the same (or a more powerful) dispersion model. Global exposition in the surroundings is deduced from percentiles calculated for average climatic conditions by an atmospheric dispersion model (Figure 2). When global annoyance zone is expected as final outcome of the study, there is no need for to much accurate measurement and modelling, especially when aiming at relative comparisons of different sites or working methods.

According to local properties of each landfill, complementary methods are used to refine or complete the main method results. 3D dispersion models allow taking into account relief effects. Gas sampling through dynamic flux chamber for Dynamic Olfactometry analysis gives on site calibration of emission rate assessment. Questionnaire surveys and “resident-watchmen” monitoring contributes to confront modelled percentiles zones with real perceived annoyances.

2.4 Quality monitoring of ambient air

Mobile laboratories including various analysers and meteorological measurements tools perform continuous analyses of some tracers in ambient air around studied landfills. For each survey, several weeks of such monitoring are necessary to obtain representative results under various wind conditions. During this period, typically 2000 to 3000 analyses of each parameter are performed and can be associated with simultaneous wind direction and speed.
The labs are positioned simultaneously upstream and downstream from the site regarding dominant winds direction. Sometimes other emplacements are chosen, like in direction of the nearest neighbours. In normal dominant wind conditions, the first station measures the background ambient air pollution. The second one assesses the maximal pollution caused by the site to its very close environment. If the wind blows in the opposite direction compared to dominant wind, the rolls of the two labs are inverted. Local specificities often induce modifications in labs relative positions. They influence the monitoring duration and justify sometimes the use of a more than two labs.

Measured meteorological parameters are wind direction and speed, ambient temperature and atmospheric moisture. Table 1 gives the list of usually monitored chemical compounds, their significance as landfill pollution tracers, and indicates analysis methods used within the framework of ISSeP's surveys.

TABLE 1 **Ambient air quality monitoring: monitored parameters ands analytical methods**

Tracers	**Significances / motivations**	**Chemical analysis methods**
Methane (CH_4)	LFG principal compound	Flame ionisation detection
Hydrogen sulphide (H_2S)	LFG odour	UV-ray fluorescence
Nitrogen oxides (NO, NO_2)	Toxic compounds frequently emitted by LFG gas engine (motors, flares)	Chemiluminescence with O_3
Sulphur dioxide (SO_2)		UV-ray fluorescence
BTEX	LFG toxic compounds	Gas chromatography after pre-concentration with FID or PID
Limonene and Pinene ($C_{10}H_{16}$)	Fresh waste odour	
Particulate matter	Waste handling activities	Beta attenuation[(1)]

(1) or optical method or tapered element oscillating microbalance

For each parameters, results are interpreted in two steps. The measured concentrations are first compared with standards (limit values and guidelines for human health, olfactory thresholds, regional background concentrations,…). Reports furnished by ISSeP air labs highlight exceedances of these standards and analyse them in terms of occurrence, intensity, duration and frequency. The second interpretative step is a directional analysis of the results. Radial plots of mean pollutant concentrations against the wind direction for wind speed above 1 m/s are built as shown in figure 3. In these rose-plots, the length of each petal is drawn in proportion to the average pollutant concentration for a given wind direction.

3 CASE STUDY OF COUR-AU-BOIS (CAB) LANDFILL

3.1 Site description

CAB is one of the biggest sanitary landfills exploited in Wallonia. It is located into a former sand quarry. Domestic wastes, low rate polluted soils, incinerator ashes and building wastes have been discharged on this site since 1984 in seven exploitation cells. Two of them are definitively rehabilitated; four others are temporarily unused and covered by low-permeability materials. CAB is one of the first landfill that has been included in the monitoring network. Four air monitoring surveys have already been carried out on the site: in 2000, 2002, 2004 and 2007.

One of the particularities of CAB layout is the presence of close residential areas, which constitute sensible targets for any nuisance or potential health problems.

3.2 Monitoring strategy adopted for 2007 surveys

The last monitoring event (2007) includes **LFG surface emissions survey,** using the method described above, which covers all the CAB landfill (past and currently exploited cells).

The **odour survey** has been achieved by the STC method completed with 2 other surveys.

- A couple of residents living near CAB landfill were charged, for more than 3 years, to describe every detected odour event. Furthermore, twice a day at regular hours, they have been checking if odour is perceptible or not.
- A questionnaire about odour and noise nuisance has been mailed to residents of four districts located around the landfill (see figure 2).

The **ambient air quality monitoring** implements 4 lab locations (B01, B02, B03 and B04 in figure 3), where mobile labs have been installed, sometimes simultaneously, sometimes consecutively. 3 locations (B01, B02 and B03) have been chosen on CAB landfill or just near its limits. The fourth (B04) is situated further in the north-east direction, at about 1.5 km off site.

4 Results and discussion

Tables 2-3, and figure 2-3, present the results of odour and ambient air surveys achieved in 2007 on CAB landfill. The tables also give some statistics on data acquired during 10 years on every monitored landfill. Statistics on odour P98 areas and emission flows only include the last survey on each site. This allow computing total additive values like annoyance perimeters and flow ; which give a rough evaluation of global odour emission and disturbance caused by all the landfills together.

TABLE 2 **Odour monitoring - statistics on every landfill (last surveys) and 2007 case study (CAB)**

		network statistics	CAB Case study		
			2002	2004	2007
	nb surveys	15*	1	1	1
	nb field days	87*	11	10	8
Odour emission rate (ou/sec)	Min	8000	20000	18000	60000
	Mean	66400	137500	16000	105300
	Max	405810	62500	84300	78435
	Total flow	**904565**	-	-	-
P98 for 1ou/m³	max dist. (km)	3.4	1.5	2.0	1.8
	mean area (Km²)	9	4.64	5.45	4.79
	Total area (km²)	**78.5**	-	-	-

* Including past surveys

TABLE 3 **Ambient air quality monitoring - 10 years statistics on every landfill and 2007 case study (CAB)**

	CH_4 (mg/m³)				H_2S (µg/m³)			Benzene (µg/m³)				Limonene (µg/m³)			
	SV(1)=1.35				SV(2)=7			SV(3)=5 (annual average)				SV(1)=10			
Network	up	down		far	up	up	down	far	up		up	down	far		up
nb surveys	25	29	-	26	28	-	17	28	-	9	17	-	25	29	-
nb analyses	46464	63953	-	52211	59083	-	38013	57346	-	17387	32757	-	46464	63953	-
Mean	2.8	3.6	-	1.5	1.7	-	0.8	0.7	-	0.9	1.5	-	2.8	3.6	-
Value>VS (%t)	50.1	68.4	-	2.2	3.7	-	-	-	-	-	-	-	50.1	68.4	-
CAB	**B01**	**B02**	**B03**	**B04**	**B01**	**B03**	**B04**	**B01**	**B02**	**B03**	**B04**	**B01**	**B02**	**B03**	**B04**
nb analyses	2006	2753	5024	2945	2009	5454	2970	-	1754	5288	2613	-	1979	3757	1545
Max	66.6	95.2	96.2	5.1	14	30	43	-	7.5	22.3	6.5	-	42.9	32.7	2.2
Mean	3.87	8.01	4.67	1.31	1	2	1	-	0.4	0.3	0.2	-	0.1	0.1	0.1
Value>SV (%t)	55	81	82	23	0.2	1.1	0.2	-	-	-	-	-	0.05	0.13	-

(1) Standard value for CH_4 = background concentration in Wallonia (2) Standard value for H_2S = WHO recommended value in order to avoid substantial complaints odour annoyance (3) Standard value for Benzene = Limit value EU Directive 200/69/CE (Value to be reached after 2010) (4) Standard value for limonene = olfactory threshold from AIHA (American Industrial Hygiene Association)

Statistic or global values are less useful for illustrating the utility of LFG surface emissions surveys achieved during 10 years of monitoring. The results obtained at CAB landfill in 2007 are presented in figure1. A more qualitative evaluation of this contribution is given in chapter 4.2.

4.1 Results of the CAB landfill case study

4.1.1 LFG surface emission survey

Figure 1 presents methane iso-grade map, in which red areas materialise high CH_4 emissions (concentration in superficial air higher than 1.000 ppm). From extension and localisation of these zones, the following interpretation can be deduced.

- The definitive capping placed on cells 1 and 2 appear to be efficient, the survey did not detect any weak point on these areas.
- The border line between this rehabilitated zone and the adjacent cells seems to constitute some preferred pathway for LFG towards atmosphere.
- On the temporarily covered cells 3, 4 and 5, some local hot spots are detected. They seems to be due to the presence of some recent installations or works that needed to reengineer cells top surface (retention basins, technical premise, maintenance area)
- Cell 6, currently in exploitation, and its abrupt south slope logically emit high quantities of methane. They are not equipped with impermeable liners and installing gas extraction wells in these areas is almost impossible due to the movements of compactors and trucks and to relief sharpness.

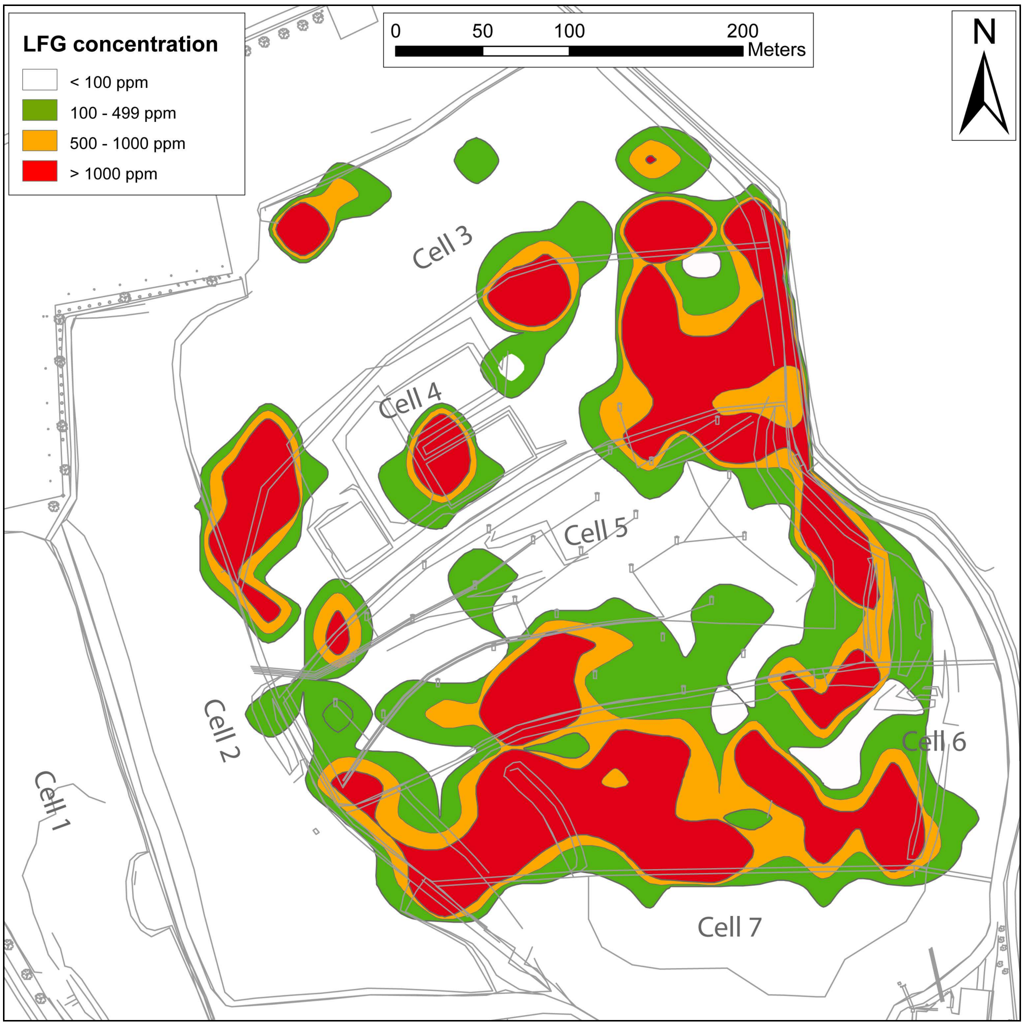

FIGURE 1 **Methane Iso-grade map from FID survey on landfill surface (CAB landfill - 2007)**

4.1.2 Odour surveys

The figure 2 shows the extension of the P98 zone for 1 ou/m³, computed by the STC method. It is an elliptical zone of about 5 km² modelling the most probable perimeter outside of which odour is perceptible during less than 2 % of time. The longest distance of odour perception from the landfill reaches about 1800 meters. Such an extension corresponds to the mean distance computed on other landfills (see table 2). 533 houses are located inside the perimeter, which probably corresponds to more than 1500 residents. In the same figure, blue flags and the associated values indicate the P98 level of exposure for a resident living on this point.

Globally, the questionnaire survey allows validating P98 perimeter.

- Residents of district 1 and 2, the closest to the odour emission source, perceive annoyances more frequently and more intensively.
- In districts 3 and 4, residents perceive odours seldom and with low intensity. They are not always able to identify the nature of odour as landfill odour. In both areas, noise (coming from other sources) is judged more inconveniencing than odour.

The residents-watchmen survey gives the following interesting results.

- Odour detection events occur most often outside working periods (in the evening and early in the morning).
- Odour detections frequency seems to follow a global downward trend from 2004 to 2007. April and September appear to be more favourable to odour events.
- As shown in figure 2, residents-watchmen are living on P98 perimeter related to 4 uo/m³. Their observations tend to show that they are disturbed by odour around 1 % of time. The value to which is related the P99 perimeter passing on their house is 4.8 ou/m³. This seems to indicate that, to be not only detectable but clearly annoying, the odour should reach 5 ou/m³, which corresponds effectively to the value announced in literature.

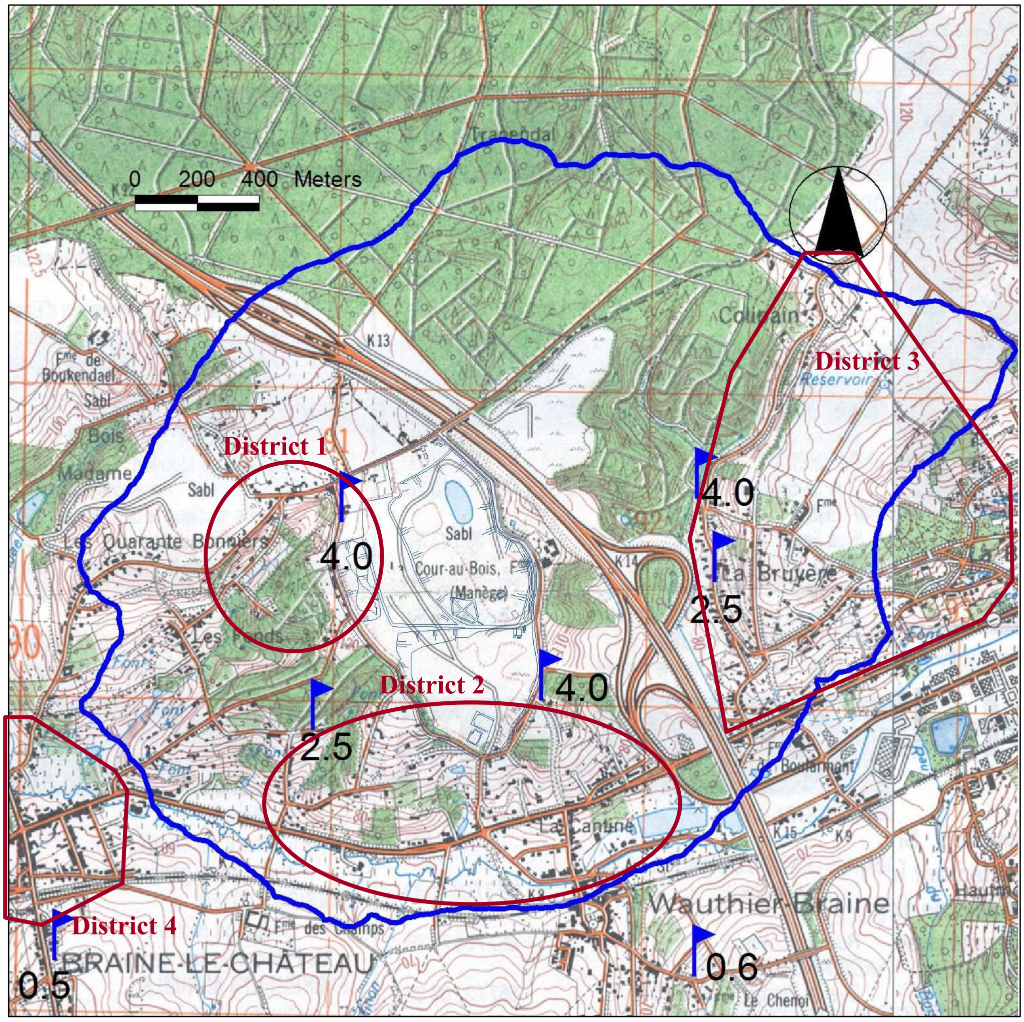

FIGURE 2 **P98 perception odour perimeter for 1 ou/m³ in medium climate (CAB landfill - 2007)**

4.1.3 Ambient air quality survey

The figure 3 shows that methane concentration in ambient air is significantly influenced by landfill activity. Directional analyse for this parameter clearly points out the landfill exploited cells as emission source. Similar conclusion can be made on every other location, even at the far position (B04) where influence is much weaker (background concentration + 25%) but remains detectable. Methane is not selected in WHO guidelines (WHO, 2001) as health problematic substance in ambient air. Then, it do not cause any direct health effect for residents. On the other hand, it confirms that CAB landfill could have a contribution to greenhouse effect, which gives further arguments for developing quantitative investigation and measurement techniques.

Table 3 shows that the olfactory thresholds of H_2S (common tracer for LFG odour) and limonene (chosen tracer for fresh waste odour) are rarely exceeded, even just near the landfilled cells. This could be interpreted as a contradiction with the results of the odour survey. But it rather confirms that odour annoyance is generated by the combination of numerous odorous compounds. Continuous measurement of only few tracers is probably not sufficient to assess the real odour nuisance undergone by residents.

The directional analysis of BTEX is represented by the graphs of toluene in figure 3. They show different behaviours from the other monitored parameters. Even if measured toluene concentrations are sometimes higher than in normal ambient air Wallonia, CAB landfill does not seem to be the principal contributor, even at local scale.

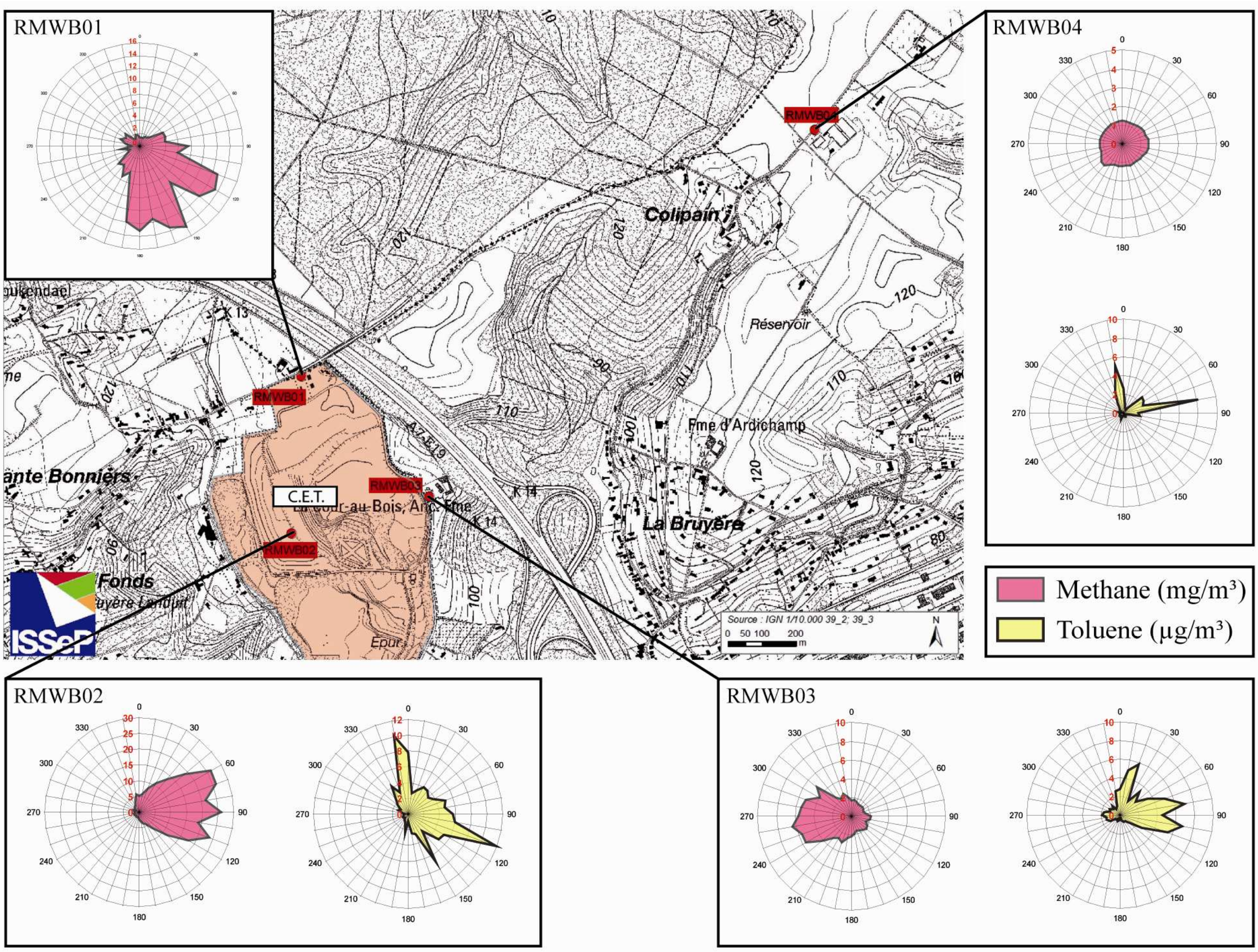

FIGURE 3 **Ambient air quality monitoring around MSW landfill, mean pollution roses of methane and toluene (case study of CAB landfill – 2007)**

4.2 Global results from 10 years of field measurements surveys

27 LFG surface emission surveys have already been achieved. Every landfill has been surveyed at least once and up to four successive campaigns took place at some locations. The number of LFG concentration measurements performed during a single survey varies strongly with landfill size, from 150 up to 800 points. In total, 5000 punctual measurements have already been stored network database. These results allowed detecting numerous capping defects, which have been followed by corrective actions (addition of clay, boring of additional LFG collecting wells). At Malvoisin, intense emissions rates on the entire site, coupled with bad performance of LFG extraction system and intense LFG odour in the surroundings forced the owner to close the landfill and to begin rehabilitation works. In general, abrupt slopes, slope breaks along crests and junctions between cells often present the highest LFG emissions rates. Preferred pathways, where top liner installation is technically more difficult, is probably the explanation of these observations. Some surveys detected systematic LFG vertical flows along extraction wells, but out of them. This observation should motivate owners to take great care with the design and implementation of LFG extraction wells.

Odour emission rate and P98 area may strongly differ from one to an other site. Odour emission flows computed during the last surveys on each site vary from 8000 to 405800 ou/sec with a mean value of 66400 ou/sec. Some explanations of such variability are evident. Rehabilitated landfills do not emit any fresh waste odour and, if LFG extraction is efficient, no odour at all. Landfills including composting plants emit mixed odour of compost and waste. Both odours produce an additive annoying effect, which increases the extension of P98 zones. Sometimes, the observed extension of P98 perimeters is high in comparison with landfill size. Odour experts give only hypothetical explanations to this observation, which demonstrate the need to further development in the field of modelling and measurement tools.

The global odour flow, emitted by all the landfills together, reaches 905000 ou/sec. This global emission produces a total cumulated nuisance area of about 80 km². This is a very low fraction of Wallonian territory (0.5%). Weighted with relative low population density of landfill surroundings, this territorial proportion is still lower regarding potentially annoyed residents. Recents odour surveys (like CAB) tend to confirm the added value of questionnaire and residents-watchmen surveys. It helps to define the optimal value (in odour unit per cubic meter) which corresponds to the real nuisance threshold. Finally, it brings an interesting in situ validation of P98 perimeters computed for this threshold value.

Probably the most important result given by 10 years ambient air monitoring is the lack of any evidence of health risk caused by sanitary landfill in Wallonia. Of course the set of monitored parameters is not exhaustive. Other compounds could be present in the air in concentrations higher than health standards. One of the main future challenges is to implement additional control, guided by recent literature and with an optimal cost-result ratio. Finally, ambient air surveys often allow detecting external odour emission sources. Sometimes, it is possible to identify the nature of this source, for example BTEX emitted by road traffic or urban centres. Sometimes, it is only possible to conclude that the source is not the landfill, without any other precise details. In most of the surveys, pollution peaks have been observed more frequently in the evening and early morning. This tends to indicate that climatic parameters influence air quality in a more intense way than waste discharging activities.

Concluding, as in CAB case study, that H_2S and terpenes (limonene, pinene) monitoring is not sufficient to assess odour nuisances in the surroundings of landfills has been repeated in several occasions. On the other hand, resident complaints linked to landfill odours have already been verified by placing mobile lab in the garden of the complainants. A quite good correlation between the detection of "odour events" by these residents and the recording of concentration peaks by the lab has been found. The experience acquired with time allows affirming that odour annoyance survey and ambient air quality monitoring are really complementary.

5 CONTINUOUS UPGRADE AND FURTHER DEVELOPMENTS

The monitoring network profits of continuous improvements. Results of every successive survey allow garnering more and more skills, which are used for modifying, upgrading and, in fine, optimizing network surveys and maximizing its benefit for Wallonia's administration.

Adaptations take place most often at local level by focusing surveys on specific weak/significant aspects of each landfill. But global investigation strategy is not immutable either. Some of the controls, like for example airborne particles analyses, was initially considered as primordial but, in the light of first surveys, appear to be most often useless because influence is never detected. Perpetual evolutions of measurement technologies, surveying methods and interpretative tools has to be taken into account. ISSeP, together with international experts and academic research teams, initiated various practical research and development. Some of them already furnished sufficient results to motivate methodological adaptations, others are now in hands and some has not been concretised yet. Among these projects four have to be highlighted.

1. During the surveys achieved in 2006, a new portable LFG analyser device (Ecoprobe 5) has been tested (Lebrun et al, 2007). This test, which has been performed partly on artificial composite gasses of known compositions and partly on LFG samples first conduced to hardware and software modification by the manufacturer in order to enhance the CH4 detection limits. The modified version of the analyser has been acquired by ISSeP and is now used in combination with classical portable FID detector for currents LFG surface emission surveys.
2. Another research and development project began in june 2008 with two partners: Inéris and FSS International. Inéris will help ISSeP to improve the LFG surface emissions assessment, by combining static flux chambers measurements with FID/Ecoprobe surveys. FSS will bring its wide skills in geostatistics to optimize data processing methods, and to try to process both concentration and flux together. Finally, this study aims at roughly quantifying the global emission of LFG into ambient air in order to assess its contribution to greenhouse effect.
3. One of the main limitations of current ambient air monitoring protocol is the lack of flexibility regarding number and position of mobile labs. The cost of each lab is too high to place them in a lot of place simultaneously. The use of cheaper methods, but including much more sampling points is now in hands. Passive diffusive tubes (Radielo and Carbo pack b), able to adsorb different kinds of compounds, are used for air sampling. Adsorbent matters are frequently replaced and analysed in lab. This survey should give a better idea of the spatial distribution of pollutant in the air.
4. Finally, odour experts and ISSeP must take up a big challenge in a near future: the implementation on every sanitary landfill of mailed questionnaire surveys and residents-watchmen in order to complete and to validate more systematically the results of odour annoyance assessment.

6 CONCLUSIONS

The monitoring network of sanitary landfills, created by DGRNE ten years ago and managed by ISSeP, has been developed, before all, as a controlling tool. It allow DGRNE checking that all necessary protective measures are taken by the owners and are enough to preserve human health and environment integrity. As the surveys occur systematically, not only after plaints or establishment of impact, it has a preventive vocation, more than repressive.

Furthermore, data and experience built up by the network are more and more used to endorse modifications of the legal cadre and to improve the legislative framework in Wallonia.

Finally, the monitoring network is managed by a scientific institute with an official mission, which opens the doors of every landfill to research and development projects. Moreover, routine monitoring surveys brings a lot of interesting data sets accessible for developing data processing methods and decision tools. This way, the network is acquiring a new dimension: it generates scientific co-operation and research development projects including authorities and local research team. This paper is an example of this interesting co-operation and furnishes, as we hope, an original contribution to a better knowledge of sanitary landfills and their impact on the environment.

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- The technical team of Research Group "Environmental Monitoring" (University of Liège) for the realisation of odour surveys and measurements.

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