EFFECTIVENESS OF FIELD OLFACTOMETRY AND NEIGHBOR CONTROL TO REDUCE ODOR ANNOYANCE FROM BIOSOLIDS AND MUNICIPAL SOLID WASTE COMPOSTING

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ABSTRACT

An odor monitoring study was carried out with fifteen voluntary residents living in the vicinity of an source-separated municipal solid waste (MSW) composting plant (10^4 T/y) and an aerated channel biosolids composting facility (10^4 T/y). In the period June 2005-October 2007 residents recorded odor annoyance of up to fourteen different odors three times a day (on a 1 to 5 scale). All residents were nose-calibrated three times with the Odor Sensitivity Test (St. Croix Sensory, Inc.).Additionally, five residents were trained to use a field olfactometer (Nasal Ranger™) to measure ambient odor dilutions to threshold (D/T) at home. They participated in several field intercomparisons at the two odor sources obtaining excellent coefficients of variation (< 40%) against a certified odor inspector.

Unannounced field D/T inspections and resident measurements with the Nasal Ranger™ showed very good agreement in both ambient odor strength and time of day. For biosolids odor the highest value recorded at the site was 30 D/T (475 m from the source) while for source-separated MSW odor was 7 D/T (700 m from the source). Good correlations were found between the monthly-averaged Odor Annoyance Index (OAI) and the monthly-averaged global D/T measured around each odor source by a certified odor inspector. Random field D/T inspections at the site agreed also quite well with the daily OAI for each odor source. By the end of 2006 new management practices were implemented in both facilities and major structural changes were undertaken in 2007. The effectiveness of field olfactometry and neighbour control in providing meaningful and objective indicators of odor annoyance reduction following those corrective actions has kept neighbours patient and supportive of the communication program established in June 2005. Odor annoyance in the neighbourhood is expected to reach acceptable levels in the first semester of 2008.

KEYWORDS

Odors, Odor Annoyance Index, Odor diaries, Field Olfactometry, Nasal Ranger™, Composting, Neighbor control, Dilution to threshold (D/T) measurements

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INTRODUCTION

Odor diaries provide a method for quantifying the zone of influence from a specific odor source and the associated characteristics of the odor exposure pattern. Relevant information such as the frequency of odor impacts at various locations, over a defined period of time, allow data to be used to calculate the percentage of time (hours per year) that people are exposed to odors from a specific source, as well as the typical strength and character of the impacts (Aitken and Okun, 1992). Field olfactometry is not a new methodology (McGinley and McGinley, 2002) but since the Nasal Ranger™ came into the market ambient odor measurements are easier to perform and most of the measurement uncertainty has been reduced to statistically acceptable levels (mainly repeatability and intercomparability).

The MSW composting facility dealt with in this study is managed by the Consorci del Bages per a la Gestió de Residus (CBGR) a public body participated by the municipality of Manresa (Barcelona, Spain). The public company Aigües de Manresa, S.A. is also participated by the municipality and runs the biosolids composting plant. An historical record of odor complaints prompted both facility managers to shift from one-way to two-way public relationship building initiatives.

One of the main objectives of this study was to verify whether neighbors in a highly affected community could provide objective data for a socioenvironmental strategy of reducing odor annoyance. The possibility of replacing odor diaries (in the long-run) with random Nasal Ranger™ D/T measurements at the odor sources and/or at the receptors was also within the scope of this study. The project which is still active aims to help managers operate their facilities with the lowest odor annoyance on the surrounding community.

METHODOLOGY

Site description and composting facilities

The site is surrounded by two small rivers, has a medium population density and its topography is especially complex (Figure 1). The site has a long historical record of odor annoyance complaints which have been traditionally ascribed to the source-separated MSW and the biosolids composting facilities although other potential odor sources exist nearby (iron foundry, MSW landfill and a waste water treatment plant).

The biosolids composting facility treats anaerobically digested sludge coming from several WWTPs of the Bages district by mixing them with crushed pine bark as a bulking agent and coffee grounds or pellet of dehydrated sewage-sludge to improve the energetic balance of the process. Aeration of the compost channels and mechanical turning allow the whole process to be ready in 14 days.

The source-separated MSW composting facility initially treats solid waste coming from the Bages district by directly mixing it with green material at variable ratios (1:2 to 1:4). One year ago windrows were turned once a week but presently decomposition takes place inside aerated bunkers and maturation onto aerated static bays for a total processing time of 10-12 weeks.

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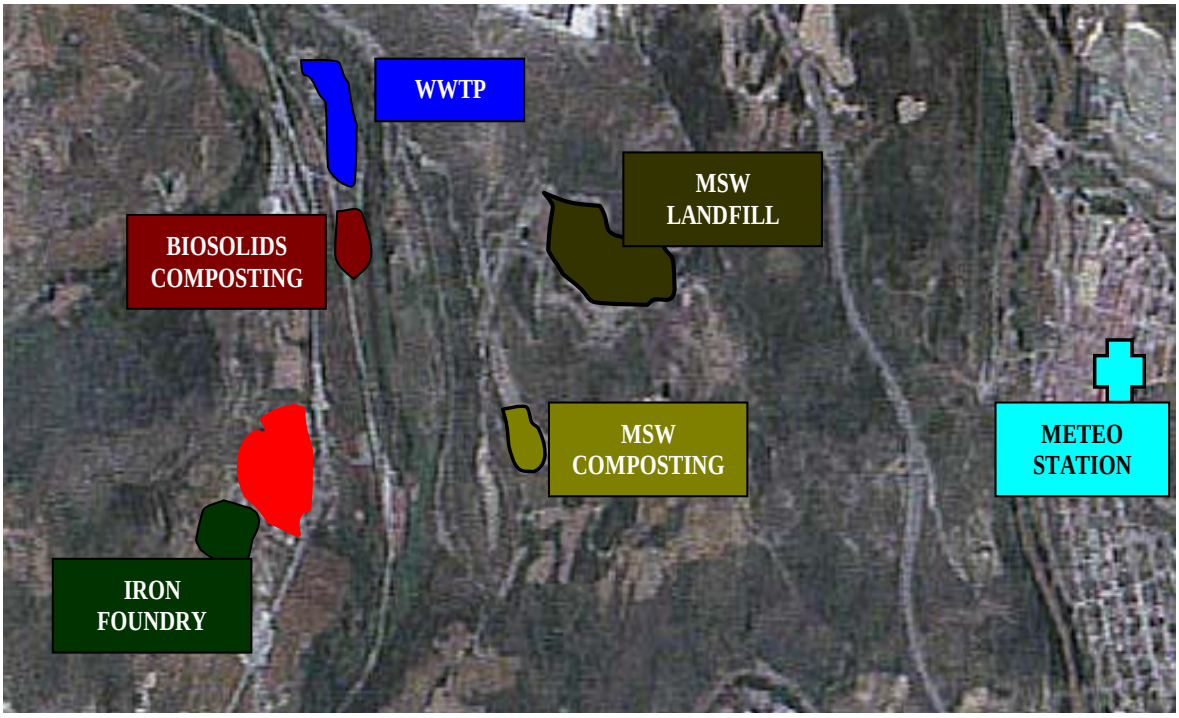

Figure 1. Location of the odor sources, the meteorological station and the affected neighborhood (full red) in the study site (Manresa, Spain).

Odor Diaries

We have adapted the odor forms of Aitken and Okun (1992) and have divided each day into three time periods: 0:00 a.m. to 8:00 a.m. ("a.m. data"), 8:00 a.m. to 4:00 p.m. ("day data"), and 4:00 p.m. to 12:00 p.m. ("p.m. data") (Figure 2). For each time period, a number from 1 (no odor) to 5 (very strong odor) has to be circled to indicate an average perception of odor strength over that eight hour period. In this way, we avoided breaking up periods over which many residents indicated they most often smelled the odors. If the resident was not home during a particular time period, none of the numbers was circled. Residents participating in the study recorded also the type of odors perceived out of fourteen available in a separate sheet. Data considered in this study were collected from June 18, 2005 through October 31, 2007 (28 months). All residents were nose-calibrated three times between June 2005 and December 2006 with the Odor Sensitivity Test (St. Croix Sensory, Inc.).

Community Participation

The affected residents played a key role in this project. Two meetings were held at the start of the project with highly motivated residents from the area indicated in Figure 1. These meetings helped in designing the data collection effort by indicating that the problem was intermittent, varying not only from day to day but over the course of a day as well. Four additional meetings (one every six months approximately) were held to inform residents on the project's development and the main results. Facility workers at the MSW composting plant were also informed through short-seminars once every year. Facility tours were arranged with smaller subgroups (3-4 residents) to recognize the different odors emitted by each of the facilities. Odor diaries we handed over to each participant at the end of the previous month.

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ODOR DIARY
MAY 2007

STREET:... CODE:... .

ODOR INTENSITY

1: NONE 2: SLIGHT 3: MODERATE 4: STRONG 5: VERY STRONG

Date	Day	00:00-08:00						08:00-16:00						16:00-24:00					
1	Tuesday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
2	Wednesday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
3	Thursday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
4	Friday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
5	Saturday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
6	Sunday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
7	Monday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
8	Tuesday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
9	Wednesday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
10	Thursday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
11	Friday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
12	Saturday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
13	Sunday	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	

ODOR TYPE / DURATION OF EPISODE

1: CABBAGE 2: ROTTEN EGGS 3: FISH 4: GARLIC/ONION
5: PUNGENT/IRRITATING 6: BURNT 7: FECAL 8: SWEET 9: WASTE
10: SEWAGE 11: COMPOST 12: EARTHY 13: FOUNDRY 14: OTHER

Date	Day	00:00-08:00		08:00-16:00		16:00-24:00	
		type	duration	type	duration	type	duration
1	Tuesday						
2	Wednesday						
3	Thursday						
4	Friday						
5	Saturday						
6	Sunday						
7	Monday						
8	Tuesday						
9	Wednesday						
10	Thursday						
11	Friday						
12	Saturday						
13	Sunday						

Figure 2. Odor forms used in this project

Field olfactometry with the Nasal Ranger™

Five residents showing acceptable scores with the Odor Sensitivity Test were trained with the Nasal Ranger™ to measure odor D/T levels at home (Figure 3). Several field intercomparisons with a certified odor inspector were performed at the two main odor sources. No restrictions were imposed upon neighbors regarding the use of the field olfactometer, i.e. they were encouraged to use it any time an odor episode of more than five minutes occurred. The average time each neighbour hold a Nasal Ranger™ has been one year.

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Figure 3. Training (above) and field intercomparison (below) with the Nasal Ranger™ at the source-separated MSW composting facility

Meteorological records

Meteorological data from the Pont de Vilomara station (Figure 1; 3 km from the odor sources approximately) was obtained online from the web of the Catalan Meteorological Service (SMC) in the form of half-hourly wind direction, wind speed, temperature, humidity and atmospheric pressure records. Summarized wind speed and direction data represent half-hourly vector averages.

Data treatment

Individual responses to odor diaries were checked before using them for the calculation of global odor annoyance parameters. First, those who responded with less than 10% frequency (less than 10% of all possible data entries of the odor diaries were circled) were eliminated from the database. In addition, frequencies above 50% for the highest scores (4-5) or below 10% for the lowest score (1) were also excluded from the calculations. The Odor Annoyance Index (OAI) for the different averaging periods was calculated following the usual approach (Quére *et al*., 1994), i.e. giving an arbitrary statistical weight to each point of the intensity scale: 1 (0%), 2 (25%), 3(50%), 4(75%) and 5 (100%), summing up all products for all intensities and dividing by the total number of answers. Field D/T measurements represent the worst-case scenario, i.e. highest D/T values have been considered for all the calculations.

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RESULTS AND DISCUSSION

Screening of neighbor's n-butanol sensitivity

Twenty-three people initially volunteered to fill out the odor diaries but few of them were rejected at the beginning of the project for odor sensitivity reasons (Figure 4). Few more declined to participate as the study progressed.

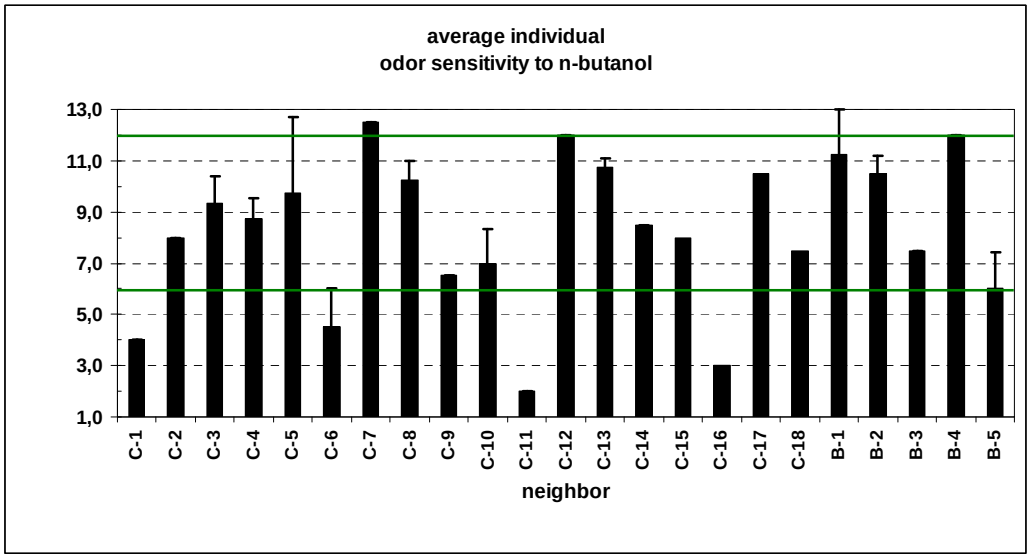

Figure 4. Individual odor sensitivity to n-butanol (average and standard deviation) for participating neighbors (green solid lines represent thresholds of acceptability)

Quality assurance of the Nasal Ranger™ use by neighbors

To help improve the performance of neighbor odor measurements with the Nasal Ranger™ individual short-seminars were given at their homes and a quality assurance strategy was adopted. Table 1 presents the coefficients of variation (CV) for several field D/T intercomparisons carried out along the study against a certified odor inspector (I-1). Average neighbor odor sensitivity is indicated in brackets below the code.

Table 1. Field intercomparisons with the Nasal Ranger™ at the two main odor sources

Date	Source	C-3 (9.3)	B-5 (5)	CTR-1 (7.5)	CTR-2 (7)	C-8 (10)	C-10 (7)	PTF-1 (8.5)	C-15 (8)	I-1 (9)	CV (%)
01-16-06	MSW		X	X		X				X	32
02-15-06	MSW			X	X					X	8
02-27-06	MSW		X							X	19
04-05-06	BIOS					X				X	8,5
06-15-06	BIOS						X			X	17
06-15-06	MSW						X			X	26,5
08-03-06	BIOS							X		X	23
02-13-07	BIOS						X			X	24
02-15-07	BIOS	X								X	11,9
02-15-07	BIOS								X	X	6,5

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The average CV for the solid waste odor (MSW) was 21.4% and for the biosolids odor (BIOS) 15.2%. On the other hand, an excellent agreement was found between Nasal Ranger™ measurements of unannounced field inspections and residents within a time frame of less than one hour (Table 2).

Table 2. Field D/T measurements of biosolids odor by neighbors and inspector (I-1)

Date	Hour	C-3 (9.3)	C-10 (7)	C-15 (8)	I-1 (9)
02-13-07	21:30-22:00	**7**		**4**	**7**
02-15-07	20:30-21:30		**7**		**7**
02-16-07	19:00-19:30			**15**	
02-16-07	21:00-21:30				**4**

Odor annoyance index (OAI)

Clear differences regarding the global odor annoyance reduction can be seen for each source in Figure 5. While the source-separated MSW composting odor begun to reach acceptable levels in March 2007 the biosolids odor annoyance remains still unacceptable although the average frequency of odor episodes is lower in 2007 than in previous years.

By the end of 2006 good management practices were implemented at the MSW composting facility including a change from “first-in last-out” to “first-in first-out” processing of windrows which clearly reduced the formation of carboxylic acids at the end of the decomposition step and an optimization of the vapour-phase GE Prosweet 2533 deodorization system, e.g. working hours according to prevailing meteorological conditions and responses of residents to odor diaries.

Major structural changes were undertaken in February 2007 such as construction of static aerated channels for decomposition, aeration of maturing windrows and enclosing the reception hall and directing the air through an open bed biofilter (reused wood bark).

Optimization of the vapour-phase GE Prosweet 2533 deodorization system was also implemented at the biosolids composting facility by June 2006. Major structural changes have been initiated in the last quarter of 2007 including sucking air through the channel beds and directing air to a chemical scrubber (40% H_2SO_4) and an open bed biofilter (reused wood bark). Lower odor annoyance seems to have a relationship with the use of coffee grounds instead of pellet of dehydrated sewage-sludge.

Relationship between odor annoyance and field D/T measurements at the receptors

An average of two-to-three random odor inspections were carried out each month for the whole period (146 control days). Figures 6 and 7 show the good correspondence between odor annoyance and random field D/T measurements for each control day.

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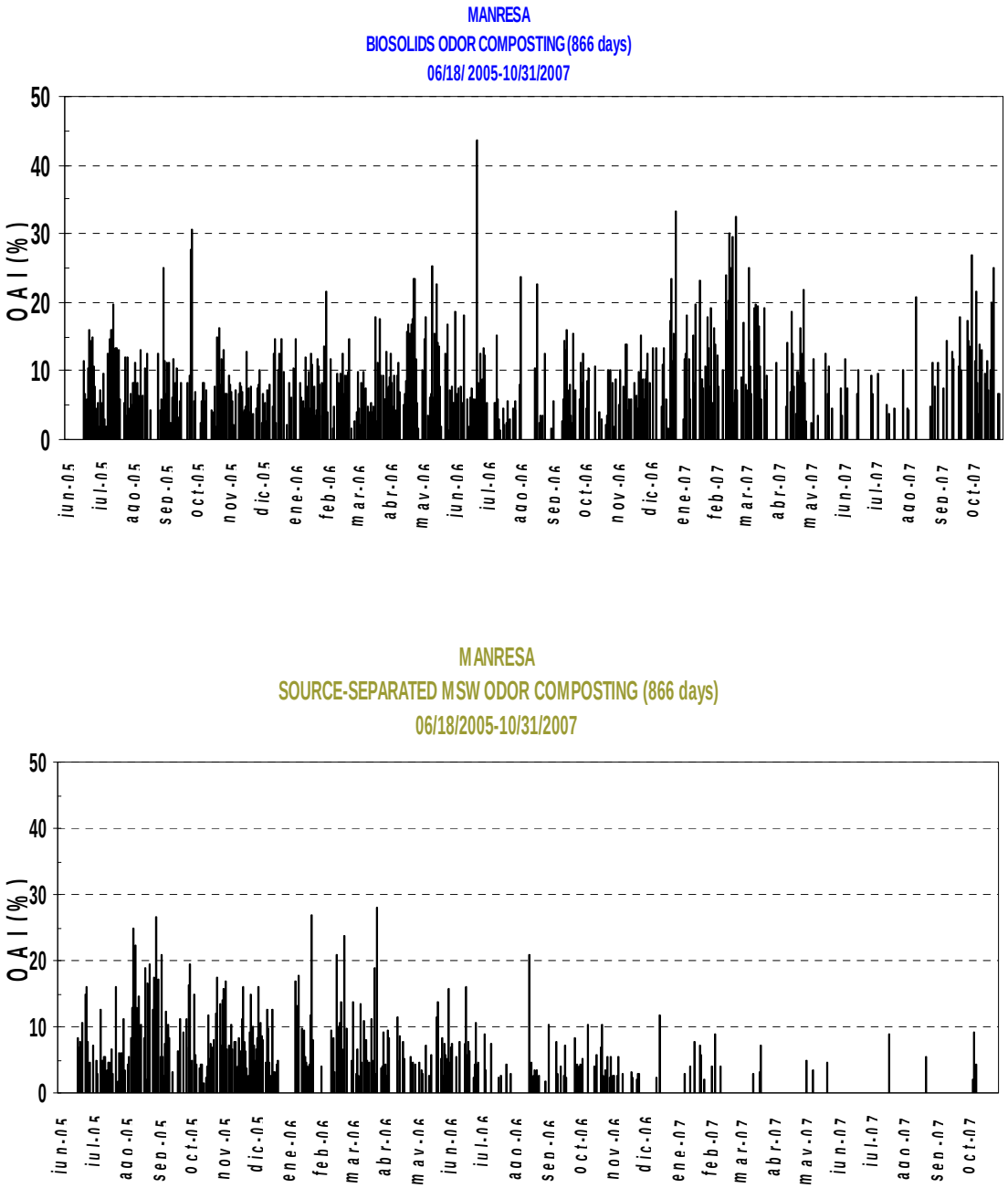

Figure 5. Daily global odor annoyance index (OAI) from the biosolids (above) and source-separated MSW (below) composting facilities for the period June 05-October 07.

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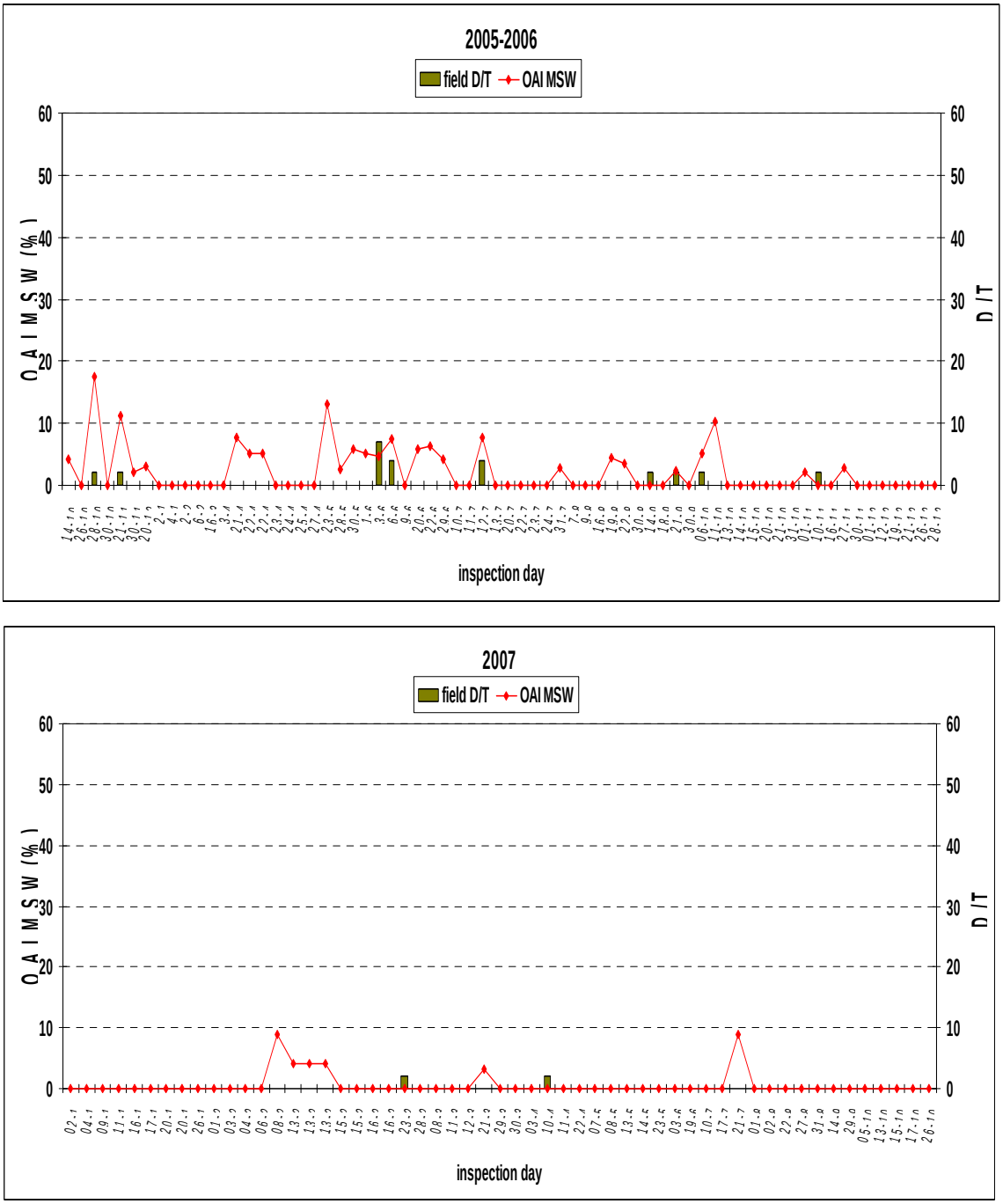

Figure 6. Odor annoyance index (OAI) for the MSW odor and random field D/T measurements by an odor inspector at the neighborhood

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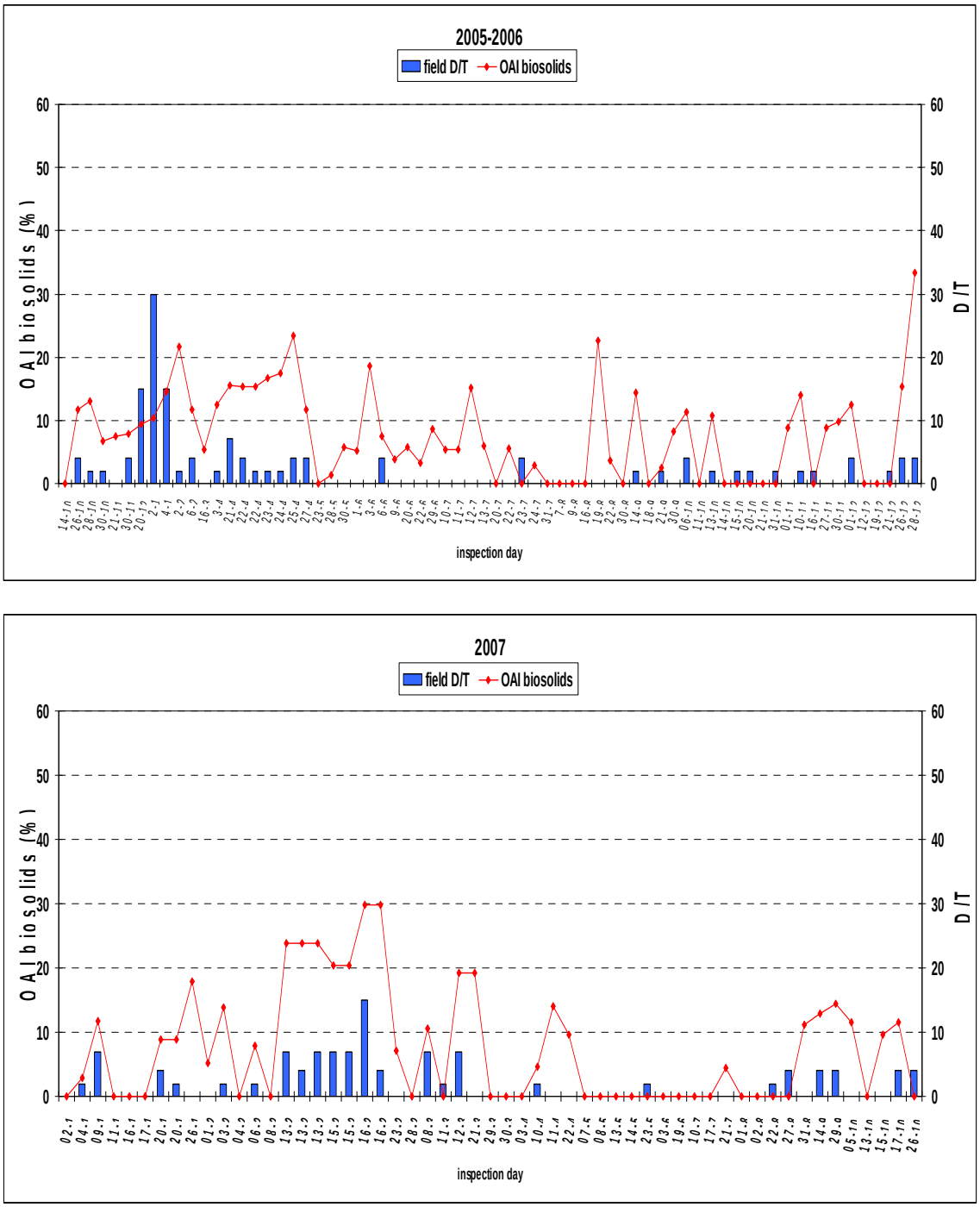

Figure 7. Odor annoyance index (OAI) for the biosolids odor and random field D/T measurements by an odor inspector at the neighborhood

The agreement between odor diaries and Nasal Ranger™ measurements is also shown in Figure 8 where the monthly-averaged contribution of each type of odor perceived by neighbors is confirmed by random field D/T odor inspections.

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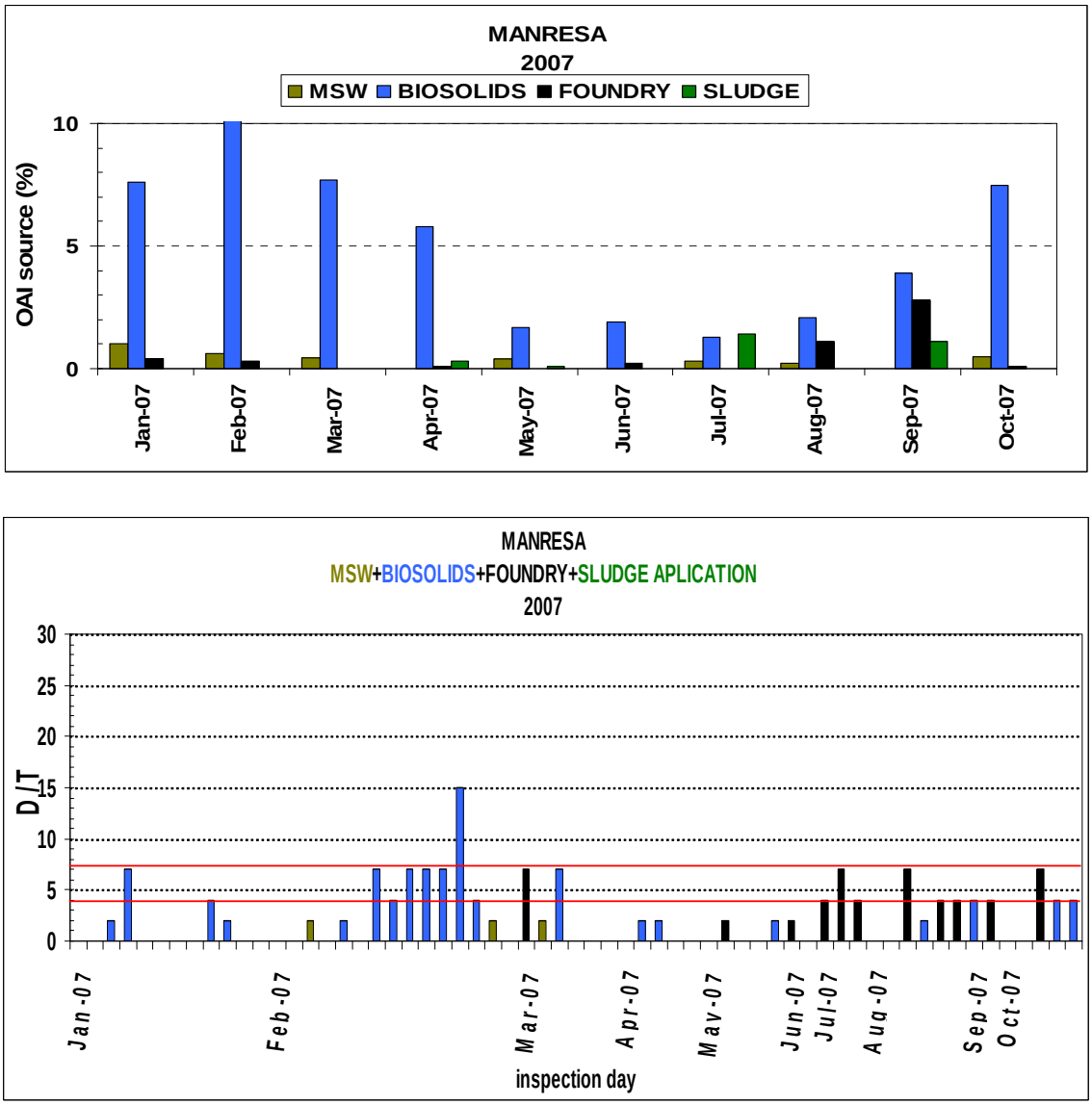

Figure 8. Monthly-averaged odor annoyance index (%) for each odor source (above) and random field D/T inspections at the neighborhood (below).

Relationship between odor annoyance and wind direction

Figure 9 shows the monthly-averaged OAI and the monthly-averaged frequency of highest impact wind direction sectors for each odor source. For the MSW odor an almost constant wind frequency can be observed until October 2006 but management changes and as a result lower annoyance were observed already in July 2006. Wind frequencies continued to decrease until June 2007 but structural changes already implemented demonstrated its efficiency when wind frequency began to increase again by the end of 2007. For the biosolids odor the OAI remained almost constant until June 2006 although wind frequency reached up to 60% of the time. However, after the summer of 2006 OAI and the wind frequency seem to follow a similar pattern.

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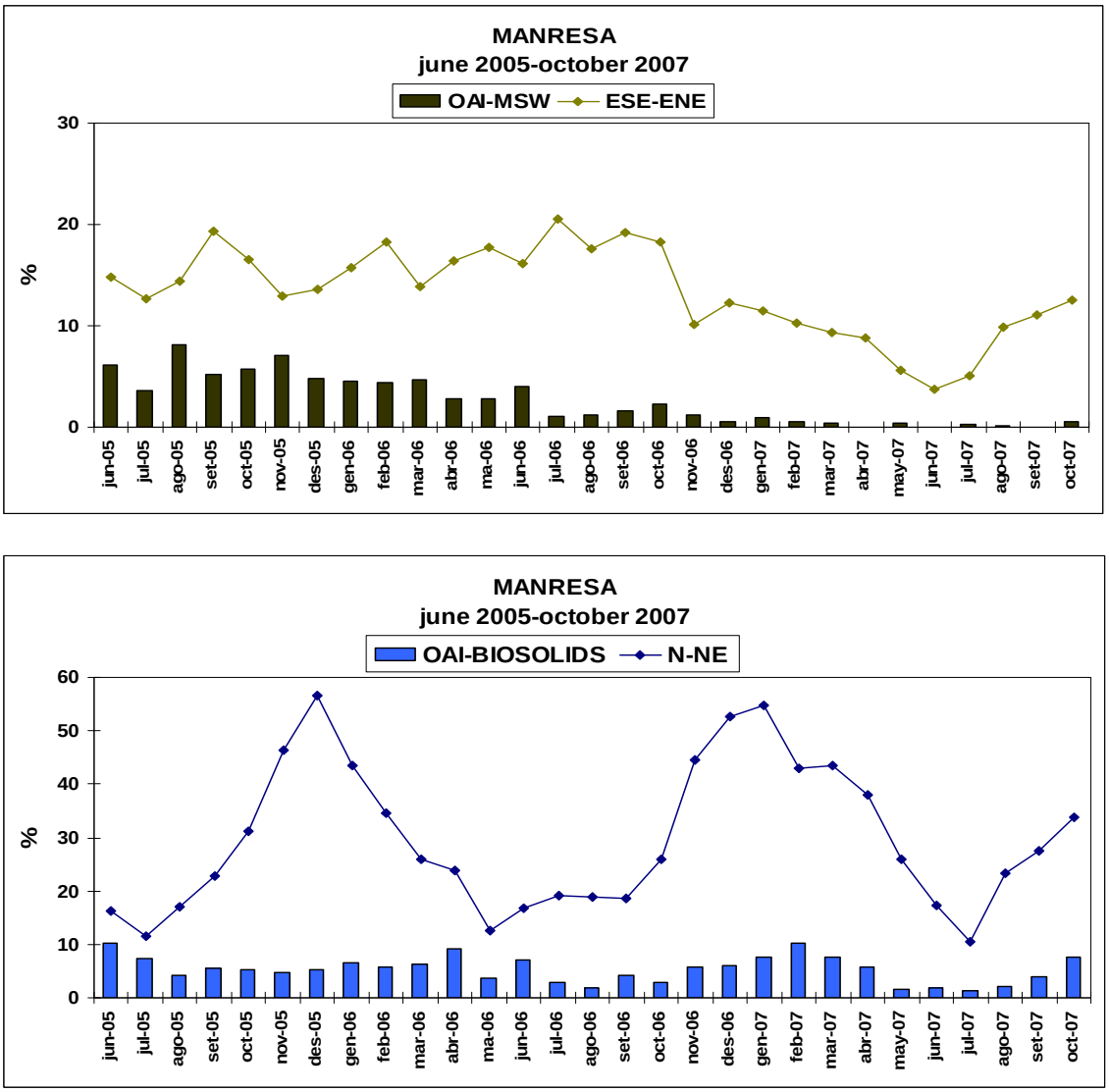

Figure 9. Monthly-averaged OAI (%) and wind direction sectors of highest potential impact (% frequency) for source-separated MSW (above) and biosolids (below) composting facilities.

Relationship between odor annoyance and D/T measurements at the source

Figure 10 shows the monthly-averaged odor annoyance index and the monthly-averaged global D/T for each odor source. An average of two-three random odor inspections were carried out each month for the MSW facility (89 days) and the biosolids facility (66 days). Data are grouped without regard to the operation of GE Prosweet system or the period of the day during measurements (we are currently performing those calculations). Notwithstanding it seems interesting to note that an average of random D/T measurements at the source could become an indicator of odor annoyance at the receptors.

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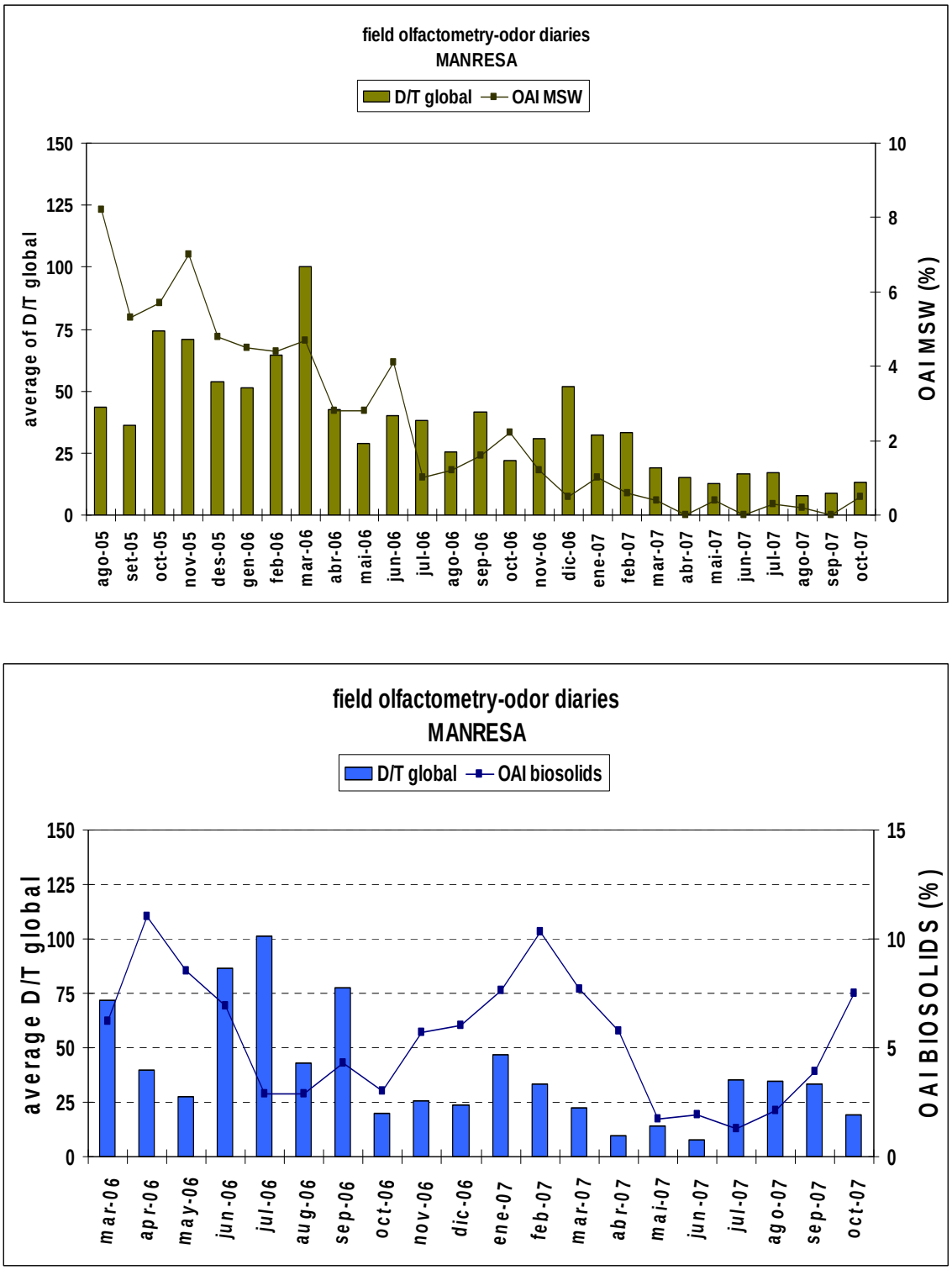

Figure 10. Monthly-averaged OAI (%) and monthly-averaged global D/T at the source-separated MSW (above) and biosolids (below) composting facilities.

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CONCLUSIONS

The results from 866 days of odor diaries confirm this tool as an effective and inexpensive means of quantifying annoying odors in Manresa and elsewhere. There was a very good agreement among neighbors with respect to odor ratings and generally they also exhibited a reasonable ability to distinguish among different degrees of odor. Participation in the project allowed residents to become involved in the solution process and contrary to reported experiences on application of odor diaries the information received back was filled in correctly. Moreover, this project has demonstrated that it is incorrect to assume that people are not good at discerning different sources of environmental odors and that it should not be assumed that information from community residents about the perceived source of a specific odor is not reliable.

Unannounced odor inspections with the Nasal Ranger™ confirmed the biosolids composting plant as the major source of odor annoyance followed by the source-separated MSW composting plant and the iron foundry. Random field D/T inspections at the neighbourhood agreed quite well with the daily OAI for each odor source. Good correlations were found between the monthly-averaged Odor Annoyance Index (OAI) and the monthly-averaged global D/T measured around each odor source.

The effectiveness of field olfactometry and neighbour control in providing meaningful and objective indicators of odor annoyance reduction following those corrective actions has kept neighbours patient and supportive of the communication program established in June 2005. Odor annoyance in the neighbourhood is expected to reach acceptable levels in the first semester of 2008.

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