Proceedings of the Third International Symposium on Air Quality Management at Urban, Regional and Global Scales. pp. 976-985, 26-30 September 2005, Istanbul – Turkey

ODOUR DISPERSION MODELLING AROUND A SUGAR BEET FACTORY IN ANKARA

Aysel T. Atimtay*, Wolfgang J. Müller,**
Achim Lohmeyer* and Ulf Janicke******

* Department of Environmental Engineering, Middle East Technical University, Ankara 06531, Turkey, aatimtay@metu.edu.tr
** Industrial Inspectorate, Hildesheim, Germany, wjmueller@web.de
*** Lohmeyer Consulting GmbH & Co. KG, Karlsruhe, Germany, achim.lohmeyer@lohmeyer.de
**** Janicke Consulting, Meersburg, Germany, uj@janicke.de

ABSTRACT

Odour measurements were carried out by executing field inspections in the vicinity of a sugar beet factory in Ankara, Turkey. Emission estimation and dispersion modelling was done in this study to gain some additional insight into the odour problem. This paper contains an overview over the field inspections, the model used – the German regulatory model AUSTAL2000 – and some findings: In this case of missing reliable emission and meteorological data, the model can nevertheless provide some support for the results of the inspections.

Key Words*:* Odour Immission, Field Measurements, Odour Dispersion Modelling, Odour from a Sugar Beet Factory, AUSTAL2000

1. INTRODUCTION

The neighbourhood of a sugar beet factory was selected for the immission measurements in Ankara for a project (carried out between 2002 and 2005) related with "Odour Emission and Immissions Management Policy in Turkey" supported by the LIFE program of the EC. The sugar beet factory under consideration is located within a residential area. Although the location of the factory during establishment was selected at the outside of the city, due to the tremendous expansion of the city, the sugar factory today is surrounded by residential areas. Therefore, the people living around the factory are the direct receptors of odour and many complaints arise from the public.

In this factory approximately 4000 tons of sugar beets are processed per day. 12% of this amount is converted to sugar. In the sugar manufacturing process sugar beets are washed in a pond near the factory and the waste water is sent to the waste water treatment plant. The plant lies within the factory boundaries and consists of equalization basin, sedimentation pond and aeration chambers. All these processes create a special kind of odour peculiar to the sugar factory, like a sweaty, aromatic odour. The treatment plant does not work properly.

The factory works in shifts and emits odour 24 hours per day during the campaign period which lasts for 3-4 months. The intensity of odorous emissions increases during this period and odour in the surroundings becomes more and more annoying. Although some of the residents are used to the situation, odour complaints still arise from that area. Field measurements were conducted to learn more about these complaints and dispersion modelling studies were carried out to gain additional information about the odour problem in this area.

2. FIELD MEASUREMENTS

The location of odour emitters in the plant is shown in Fig.1. An area of 1.7 km^2 was chosen as the assessment area. For measurement purposes, the assessment area was gridded according to the principles stated in VDI 3940. The distance between measurement points is defined according to the desired resolution. In this case, it was taken as 250 m. The grid system is shown on a 1/25 000 topographic map in Figure 2. Grids were located especially in the NE – WSW direction according to the wind rose. The cells were numbered and each corner was visited according to a time plan for 12 months covering the four seasons of spring, summer, fall and winter.

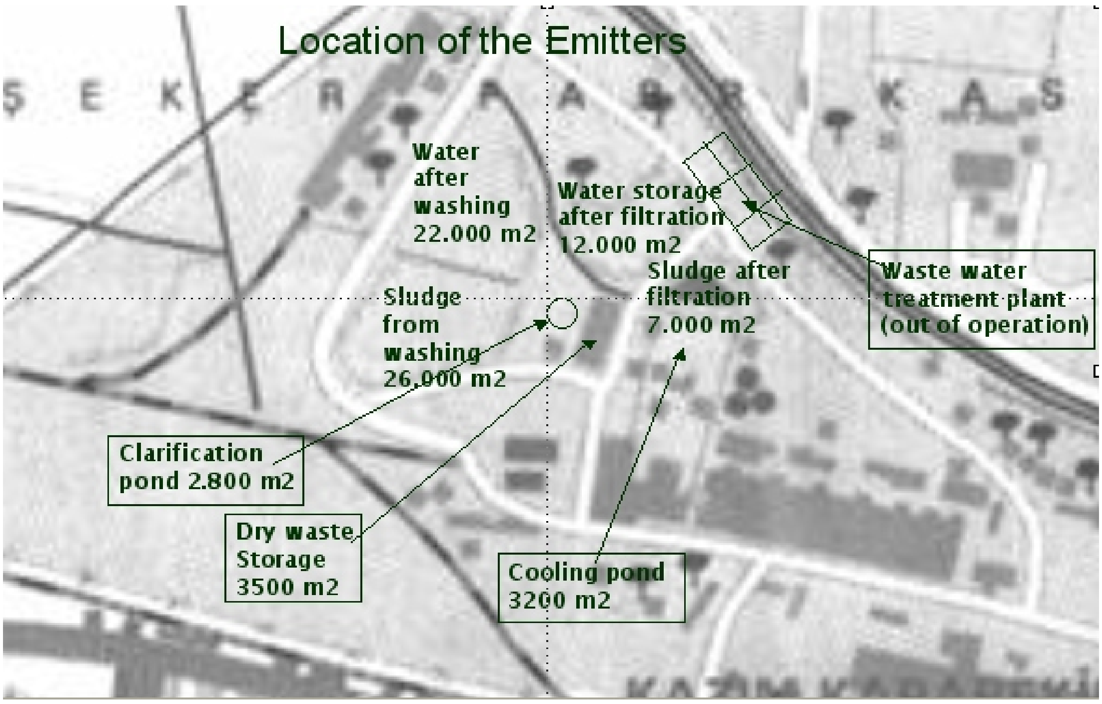

Figure 1. Location of the odour emitters in the sugar plant

The time plan involved visits to the same site for at least 52 times during the year. These visits took place at different days of the week and at different hours of the day. During the visits a protocol on odour perception (according to the German guideline VDI 3940) was filled in. For 60 times within a time period of 10 minutes (i.e. every 10 seconds) the perception of odour was recorded in the form of a yes/no decision.

Figure 2 (left) shows the percentages of hours with odour perceptions as a result of the field inspections and thus the great influence of the odour emissions of the factory. Within the time period of the sugar beet processing campaign (September – December), the perceptions are even more frequent as can be seen in Figure 2 (right), showing the frequencies outside the campaign period. The odour emissions of a sugar beet factory during the campaign are usually dominated by the stack emissions. The other main source usually is the waste water: The sugar beet washing ponds, the sedimentation ponds for the soil washed away from the beets, the waste water treatment plant and the final sludge and water maturation ponds with their residence time up to 1 to 2 years before the water can be released into the discharge system. The waste water emissions, therefore, usually exist for the whole year and odour emission depends on the season (lower in winter, higher in summer). For the detailed description of the immission measurements and odour percentage determination around the sugar beet factory, see Güvener et al., 2004.

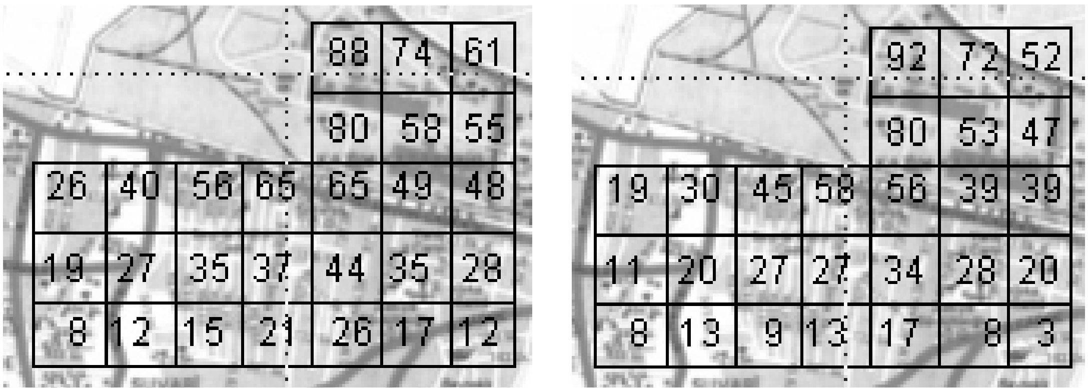

Figure 2. Percentage of odour hours in the neighbourhood of the sugar factory. Result from field inspections. Left side: annual. Right side: outside the campaign period.

No emission measurements could be done for the plant within the study period of the project and no further details about the emissions could be obtained. This is the classical case where field inspections are particularly helpful. Additionally, the location contains water surfaces whose emissions are difficult to measure. Modelling around the factory was done to gain some additional understanding of the situation.

3. THE FLOW AND DISPERSION MODEL

3.1 Model used

Odour dispersion calculations were carried out with AUSTAL2000, the official reference model for licensing procedures (TA Luft, 2002) and odour assessments (GIRL, 2004) in Germany. It implements the odour dispersion model AUSTAL2000G.

AUSTAL2000 is a Lagrangian particle model that is set up and verified according to the German Guideline VDI 3945 Part 3, 2002. Main advantages of a Lagrangian dispersion model over other model types are:

- The model is applicable to the near field of sources, where the classical equation of diffusion does not apply.
- Time-dependent dispersion situations can be handled.
- The model does not rely on calibration parameters.
- Arbitrary source geometries can be accounted for (e.g. a point source is truly modelled as a point source or area source).
- Source dynamics can be accounted for explicitly.
- Complex meteorological profiles and three-dimensional wind and turbulence fields can be applied.

For complex terrain (terrain profile, buildings), AUSTAL2000 invokes a diagnostic wind field model for the calculation of the three-dimensional wind fields. Alternatively, the fields calculated by more sophisticated wind field models can be applied. Program, source code, and documentation of AUSTAL2000 are available free of charge (AUSTAL2000). The program package is available in German, and the English version is intended for next year.

3.2 Development of AUSTAL2000G

AUSTAL2000G was developed in 2003/2004 by Janicke Consulting on behalf of several federal states in Germany (Janicke, L. and Janicke, U., 2004). Starting point was the model of a meandering plume. From the concentration fluctuations of the odourous substance, the frequency of odour perceptions can be deduced which is the basis for the assessment of odour impact. In German regulations, for example, odour assessment is based on the concept of the so called odour hour. An hour is called "an odour hour" when at least at 10% of the time within this hour odour is perceived (VDI 3788, Part 1, 2000). The frequency of occurrence of "odour hours" within a year is then compared to given limit values. These limit values are 10% for the residential areas and 15% for the industrial areas in Germany. In the draft Turkish Odour Regulation these limits are taken as 15% and 20%, respectively.

Concentration fluctuations in meandering plumes had been studied in detail by means of LIDAR measurements which were reviewed and evaluated recently within the project COFIN (Nielsen et al., 2002 and Janicke, 2004). In other data sets, the dispersion of a passive tracer (SF_6) was investigated concomitant with the odour dispersion (Bächlin et al., 2002). By means of a sensitivity analysis, possible and desirable simplifications of the modelling concept were investigated with the aim to broaden the range of application and to reduce computational expenses. The resulting modelling variants were tested on various experimental data sets. The simplified modelling variant (with the working title AUSTAL2000G), in which the presence of an odour hour is deduced from the hourly mean concentration of the odourant, gives in general a satisfactory agreement with the more sophisticated model variant. Subsequently AUSTAL2000G was implemented into the existing dispersion model AUSTAL2000.

The basic result of a dispersion calculation with AUSTAL2000 is the concentration distribution near ground level for the trace substance of interest in form of a time series of hourly means. From this data base, short-time values according to EU directives, annual means, and the frequency of odour hours are deduced by the program. The capability of calculating the concentration of trace substances simultaneously and consistently with the frequency of odour hours turns out to be of great practical advantage for assessment - licensing procedures for authorities.

The frequencies of odour hours predicted by AUSTAL2000 are valid for receptor points. However, odour assessment often refers to area averages. A post processor exists to perform the required averaging in the model.

3.3 Model calculations

AUSTAL2000 can be used to re-calculate measurement campaigns. Here, the actual time series of meteorological parameters (wind velocity, atmospheric stability) and odourant emissions as well as the actual topographical situation (terrain profile, nearby buildings, surface roughness) can be accounted for.

It is a "state of the art" in Germany now to make dispersion calculations by using AUSTAL2000. In former times a Gaussian type model was used for the licensing procedures. But the restrictions of the old model often resulted in serious disagreements in the licensing process. This lead to unreasonable situations that for quite some projects "official" concentration predictions by the old official Gaussian type model AUSTAL86 had to be prepared plus additionally a more believable 3-dimensional flow and dispersion calculation had to be made. The disagreement arose from the following deficiencies:

a) Influence of buildings
   Especially in the near field (up to say 200 m) of emissions from low source heights, where the concentrations might still be relatively high, the influence of buildings on the dispersion might be important. The effect might as well increase as decrease the concentrations.
b) Dispersion parameters
   The Gaussian plume dispersion parameters σ_y and σ_y in TA Luft, 1986, were determined from measurements in distances much greater than 100 m downwind the source. Theoretical considerations indicate, that they might not be applied for downwind distances smaller than 100 m. Additionally σ_y and σ_y should depend on the height of the plume above the ground and the aerodynamic roughness of the location. Both parameters were not contained in AUSTAL86.
c) Low source height emissions
   The proper wind velocity in the Gaussian dispersion equation has to be the velocity in the actual height where the plume travels. For large source heights, say 100 m, that is not a problem as the wind velocity does not change significantly in these heights with distance from the source. But for ground level sources, it is difficult to provide the proper wind velocity. On the first meters downwind the source the wind velocity is near zero (as the plume is near the ground level). Further downstream it increases as the plume thickness increases, and only further downstream than say 100 m the wind velocity in a height of 10 m might be appropriate. Using just 10 m reference height for the wind speed for all distances downwind of the source might easily result in an error of a factor of 2 in the concentration calculation near a ground level source.

d) Topography
   The former German regulatory model AUSTAL86 was unable to properly account for influences of topography. This was corrected by the new model.

All these restrictions lead to the development AUSTAL2000 where AUSTAL2000G is contained.

3.4 Input data used

The following input data were used to do first runs with the model AUSTAL2000 for this study. The odour emissions are first rough estimates. Table 1 contains more detailed estimations. But the calculations, displayed in this paper, were executed with the first estimates:

a) Emission data
   Number stacks: 1
   Stack height: 20 m
   Exhaust volume: 10.000 m^3/h
   Exhaust temperature:105 ^oC
   Relative humidity: 100 %
   Odour concentr. in the stack: 10.000 OU/m^3, thus emission of 100 MOU/h
   (MOU/h = Million Odour Units/hour)
   Duration of emission: 1. August 2003 to 30. November 2003 (campaign period)
   Area of waste water lagoons: 20.000 m^2
   Emission factor: 10.000 OU/m^2h in November – March
   30.000 OU/m^2h in April – October
   thus emissions of 200 and 600 MOU/h

b) Meteorological data

Meteorological data for the study has been taken from the Esenboga meteorological station. Instead of Esenboga meteorological data, data from Etimesgut meteorological station would be better. However, this station is a very small one and all the required parameters for the model runs are not measured here or are not available..

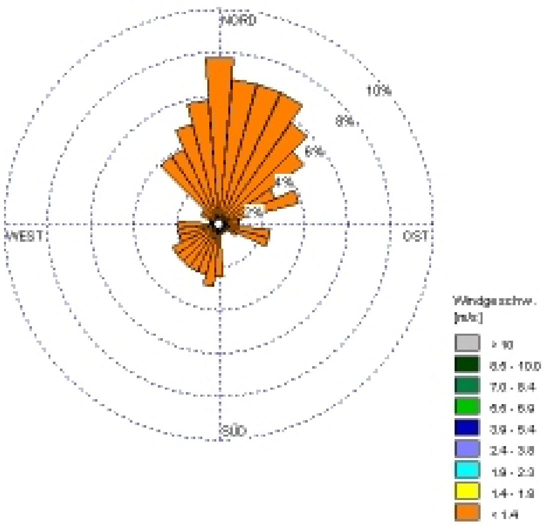

Figure 3. Wind rose of meteorological station Esenboga

c) More detailed emission estimates

Odour sources containing water surfaces have emissions being difficult to measure. The odour emission from these sources may be determined by using emission factors from the literature or gained by comparison between inspection an modelling. The results of the emission factors estimated for the sugar plant on the basis of such emission factors are given in Table 1. As can be seen, emissions depend on the month of the year because of the temperatures. The highest emissions are expected in the summer months.

Table 1. Odour emissions in MOU/h of the Ankara sugar plant, estimated for the water surfaces by application of emission factors [OU/(m^2 h)], observed for plants in Germany. (MOU/h = Million Odour Units/hour).

Name of module	Surface area [m^2]	Emiss. [MOU/h] August	Emiss. [MOU/h] Septem.	Emiss. [MOU/h] Octob.	Emiss. [MOU/h] Novem.	Emiss. [MOU/h] Dec.-Apr.	Emiss. [MOU/h] Mai-July
Clarification pond	2.800	2.8	7	14	28	0	0
Sludge from washing beets	26.000	13	26	78	78	2.6	78
Water after washing beets	22.000	22	55	110	220	0	330
Water storage after filtration	12.000	6	15	30	60	0	90
Sludge after filtration	7.000	3.5	7	21	21	0.7	21
TOTAL	69800	47.4	110	253	407	3.3	519

4. RESULTS AND CONCLUSIONS

The results of the dispersion model calculations are given in Figure 4 and 5 for the percentage of odour hours including the campaign period (annual) and for the percentage of odour hours outside the campaign period, respectively.

As can be seen from Figure 4, the percentage of odour hours including the campaign period (annual) with the area sources and stacks (h=20 m) are quite high. The percentage of odour hours goes as high as 73% just around the factory. A little further away the percentage is about 50%. Along with the dominating wind direction in most of the areas in the southern part of the factory, the percentage of odour hours are approx. 20%. This is the limit for the industrial areas according to the draft Turkish Odour Regulation. Modelling and field inspection leads to the same conclusion in this case.

As far as outside the campaign period (January to August) is concerned (Figure 5), the percentages are at first expected to be lower than in the previous case because the odour emissions during the campaign period are dense. However, it was not surprising to find out that the percentages of odour hours are more or less the same as in the "campaign case" in most of the areas around the plant. This is on one hand attributed to the ponds where water and sludge is stored before they are given to the wastewater treatment plant of the Ankara municipality, thus representing a low level source. On the other hand it is due to the low height of the stack, also representing a low level source, leading to a low level concentration field.

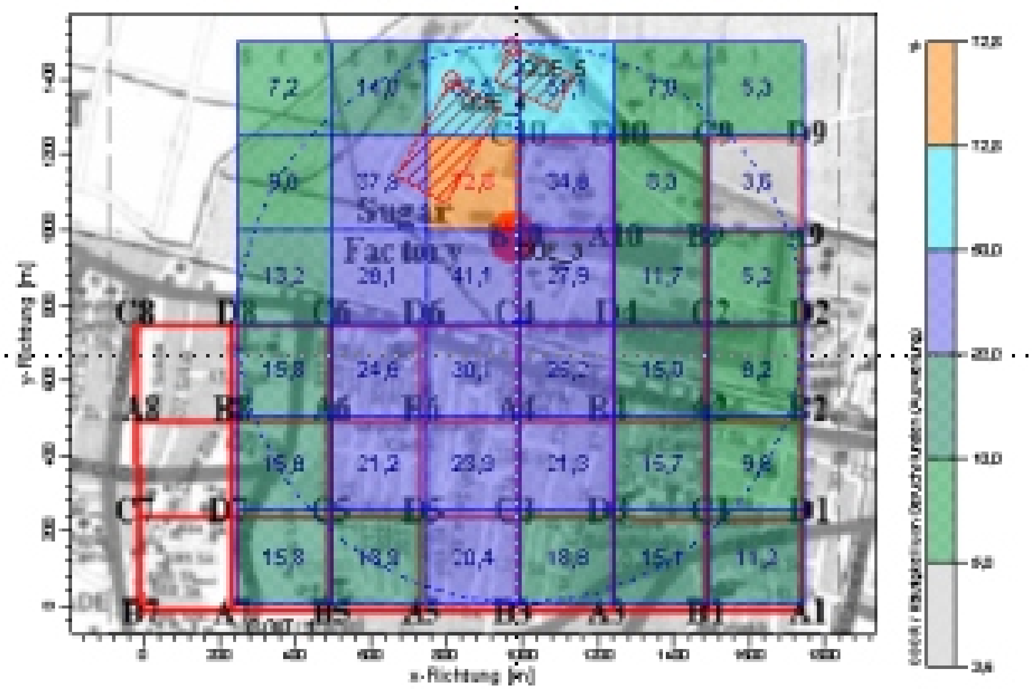

Figure 4. Percentage of odour hours including the campaign period (annual)

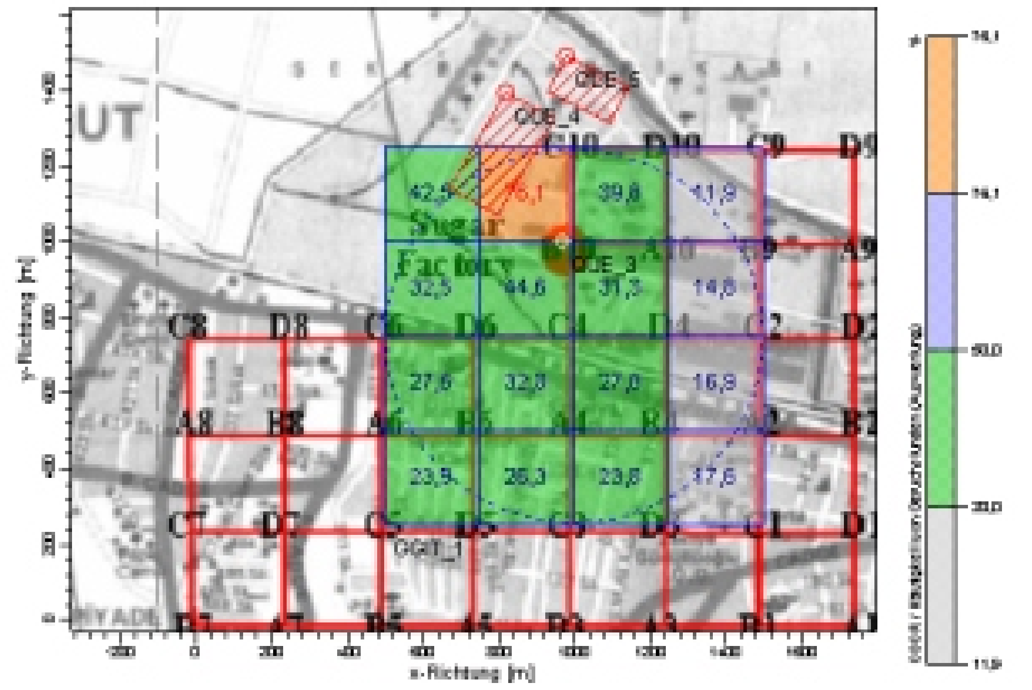

Figure 5. Percentage of odour hours outside the campaign period

Figure 6 shows the distribution of percentage of odour hours found by immission measurements. Again around the immediate vicinity of the plant highest percentages are found. Since the dominating wind direction is from N-NE to S, the percentages get smaller towards the south (about 20-40%).

The model results by AUSTAL2000 were in principle in accordance with the results of the immission measurements. The combination of immission measurements and model calculation is needed to gain additional information about the odour problem and possible solutions in such an area. However, because of some assumptions (meteorological data, emission data etc.) made for the model inputs because of the lacking these data, the results obtained from model runs do not fit exactly with the results obtained from immission measurements.

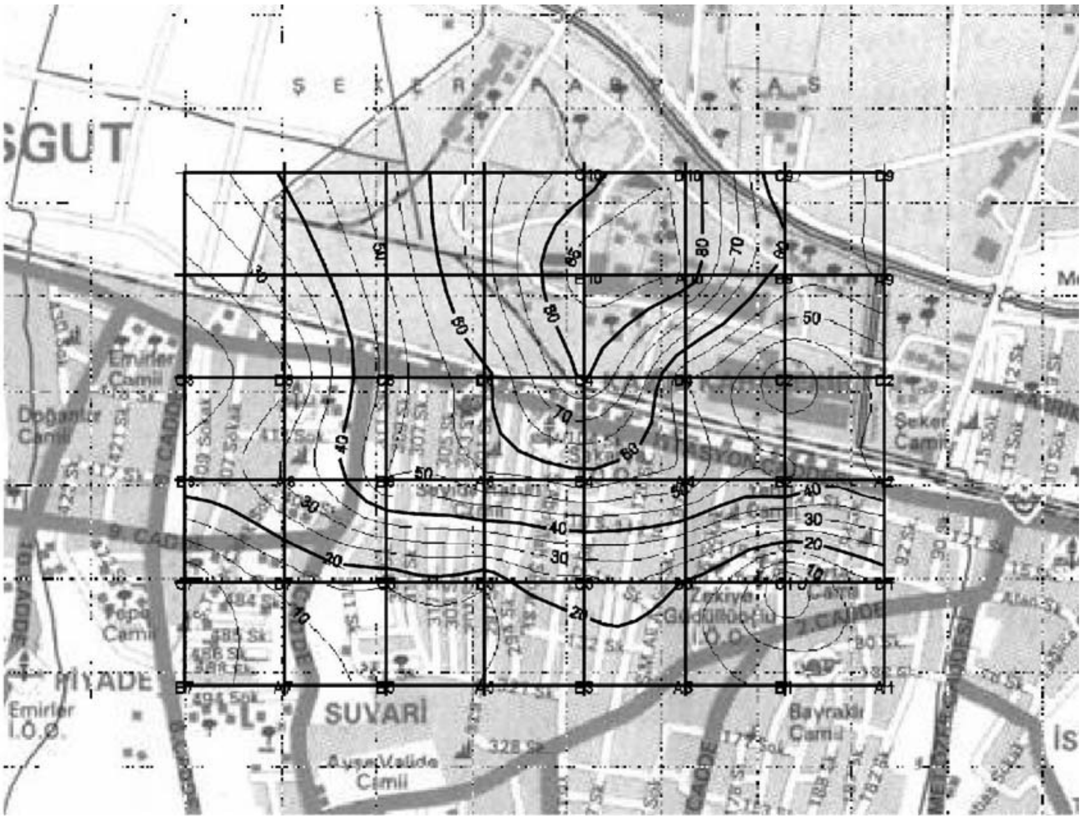

Figure 6. Lines of equal percentages of odour hours determined by immission measurements for the whole period (annual)

5. ACKNOWLEDGEMENTS

We would like to extend our appreciation to LIFE Program of EC for the financial support provided for the part of the project where immission measurements carried out around the sugar factory. Also, we thank to Sabine Barth from Barth & Bitter GmbH, Germany for the provision of the emission factors from the waste water surfaces.

REFERENCES

AUSTAL2000. Internet: http://www.austal2000.de (in German).

Bächlin, W., Rühling, A., Lohmeyer, A., 2002. Provision of validation data for odour dispersion models - outdoor measurements (Bereitstellung von Validierungsdaten für Geruchsausbreitungsmodelle - Naturmessungen). Report FZKABWPLUS, 2002. Lohmeyer Consulting GmbH & Co KG, Karlsruhe, Germany (in German).

GIRL, 2004. Feststellung und Beurteilung von Geruchsimmissionen mit Begründungen und Auslegungshinweisen vom 21.09.2004. Landesumweltamt Nordrhein-Westfalen. See http://www.lua.nrw.de/luft/gerueche/infos.htm. (in German). Guideline on Odour in Ambient Air, 1998, (in English). See http://www.lua.nrw.de/luft/gerueche/GOAA_200303.pdf

Güvener, M., Atimtay, A.T., Dincer, F., Muezzinoglu, A.., 2004. Immission measurements and odour percentage. Determiation around a sugar beet factory in Ankara. VDI-Berichte Nr. 1850, 2004.

Janicke, L., 2004. A note on the distribution function of density fluctuations in the model COFIN. Reports on Environmental Physics 4, 2004. ISSN 1439-8222, also available at www.janicke.de.

Janicke, L., Janicke, U., 2004. The development of the dispersion model AUSTAL2000G (Die Entwicklung des Ausbreitungsmodells AUSTAL2000G). Reports on Environmental Physics, 2004. ISSN 1439-8222, also available at www.janicke.de (in German).

Nielsen, M., Chatwin, P.C., Jørgensen, H.E., Mole, N., Munro, R.J., Ott, S., 2002. Concentration fluctuations in gas releases by industrial accidents. Risø-R-1329(EN), 2002. Risø National Laboratory, Roskilde, Denmark.

VDI 3940, 1993. Bestimmung der Geruchsstoffimmission durch Begehungen. Beuth Verlag, Berlin, Germany. Revision in press (German/English).

TA Luft, 2002. Technical Instruction on Air Quality Control (Technische Anleitung zur Reinhaltung der Luft, TA Luft). Internet: http://www.bmu.de/files/pdfs/allgemein/application/pdf/ taluft.pdf (in German).

VDI 3788 Part 1, 2000. Environmental meteorology; Dispersion of odourants in the atmosphere; Fundamentals, July 2000. Beuth Verlag, Berlin, Germany (German/English).

VDI 3945 Part 3, 2002. Environmental meteorology; Atmospheric dispersion models; particle model, September 2000. Beuth Verlag, Berlin, Germany (German/English).