VALIDATION OF IMPACT MAPS OBTAINED WITH DISPERSIONS MODELS THROUGH NEIGHBOR ANNOTATIONS OF ANNOYANCE, AND CHEMICAL ANALYSIS.

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Keywords: ODOUR, MAP IMPACT, COV.

ABSTRACT.

Results of the odor impact of several agro alimentary production plants are presented in three different ways in order to validate them:

- Map impact obtained with a Gaussian dispersion model, which operates with meteorological data from a local surface station in the zone of study, to calculate the relative concentrations of odor compounds emitted diffusely from the processing plants.
- Annotations of smell perception of odor by neighbors in a scale range from 1 to 5. This is done systematically at least three times at day, in the periods 0-8 hours, 8-16 hours, and 16-24 hours. And also annotations are done during the strong odor episodes, indicating the duration and scale of annoyance.
- Chemical analysis of air during several periods of 24 hours. The system is composed of a chemical compound adsorption multisorbent tube with a forced air flow, that is later analyzed by combining thermal desorption with high-resolution gas chromatography and mass spectrometry detection (TD-GC-MS) method.

This methodology shows that validated odor impact maps obtained could be a very useful tool to improve the air quality.

INTRODUCTION

This is a work about odor nuisance characterization in an urban area, Banyoles, near Girona, in the northeast of Spain (figure 1).

There have been problems with odor in the city due to several agro alimentary industries which nowadays are surrounded by residential area (figure 2). This kind of industry has been one of the bases of the local economy of the area from long time ago. In this city these industrial plants are operating from several decades, and the population growth has approached the houses to them.

The objective of the study of odor was to characterize the initial situation of air in the city, and follow the evolution along the period of time studied, that comprises from June 2004 to January 2005.

A new methodology is used to develop this study, with subjective elements (the smell sense of the citizens), and objective analysis, with mathematical dispersion modeling, and chemical analysis of air. This implies that the study takes into account the social participation as uses them as a scientific tool.

Of course the determination of health risk compounds by chemical analysis was considered the first thing to do, and the results showed that only in one punctual case, there was surpassed the concentration of a dangerous sulfur compound, S_2C, for a short period of time. All the other compounds found are in a level below risk, when the most stringent international norms are applied.

There are a lot of variables affecting the odor, other than odor threshold, which can be grouped in emission, transport or dispersion, and reception by the neighbors. In the emission affects the operations that are done in the industry, if the source is temporal or continuous, punctual or diffuse, the height, temperature, flow, concentration, and others. In the transport from the source to the receptor the atmospheric conditions are important, so a local atmospheric study have been done. The perception of odor by people is subjective, as can be seen in the definition of odor threshold, but when it is treated statistically this perception probes quite well established.

Figure1. Aerial photograph of the zone of Banyoles (Girona, northeast of Spain). The scale of the terrain is showed at top-right.

ODOUR FOCUSES AFFECTING THE CITY.

The possible sources of odor compounds in the city are indicated in figure 2, with their type of activity.

Apparently, the mean focus is the gelatin plant, number 1 in the plan. It has an open reception area, a production process also partially open to the atmosphere, with diffuse emission, and a water treatment plant that consists of a physical and biological phases. It operates in a continuous mode, during 24 hours/day. So it could be considered a source of odor continuous in time and diffuse.

Focus two and three are problematic by its water treatment plants, meanly the 3, because it has only a physical phase. Source 4 is operating with all the installations closed, so the emissions are low. Source 5 produce a non offensive odor, but has been included because some people could consider it bad odor. The 6 is a milk processing plant, and at times it produces some liquid effluents with certain odor. And the 7 source is a poultry meat plantm with no appreciable odor emissions.

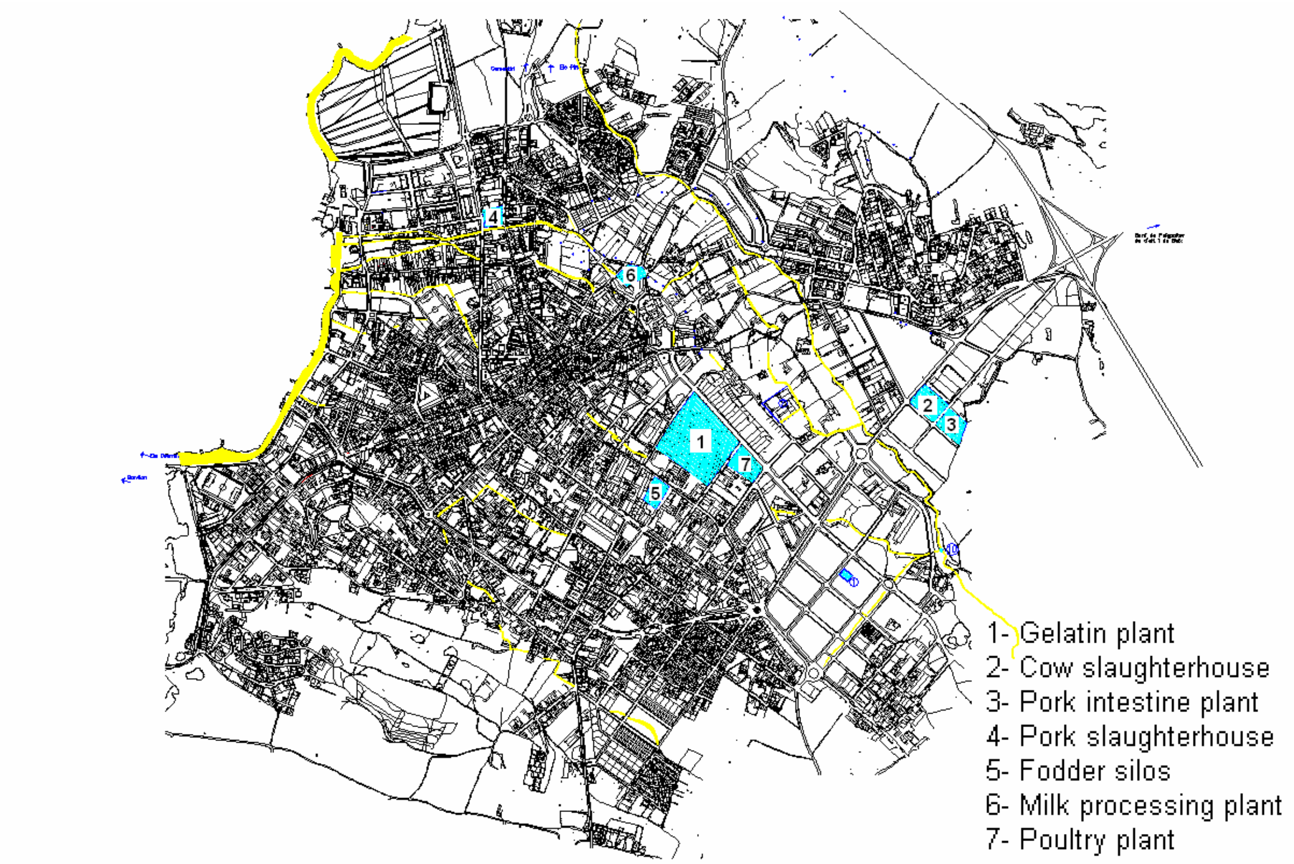


Figure2. Map of the city of Banyoles showing the main odour focuses.

METEOROLOGY

There is a surface meteorological station in the city. Data are acquired each half hour. With the values of wind velocity, wind direction and solar radiation data, for several years, a zonal meteorological study has been done.

In figure 3, there is the monthly wind profile from January 2000 to Mars 2004. The predominant winds are from north and south, with a similar trend for all the months. There seems to be a regular wind regime in all this period, so the results of this study of odor dispersion made from June 2004 to January 2005 could be generalized to other years.

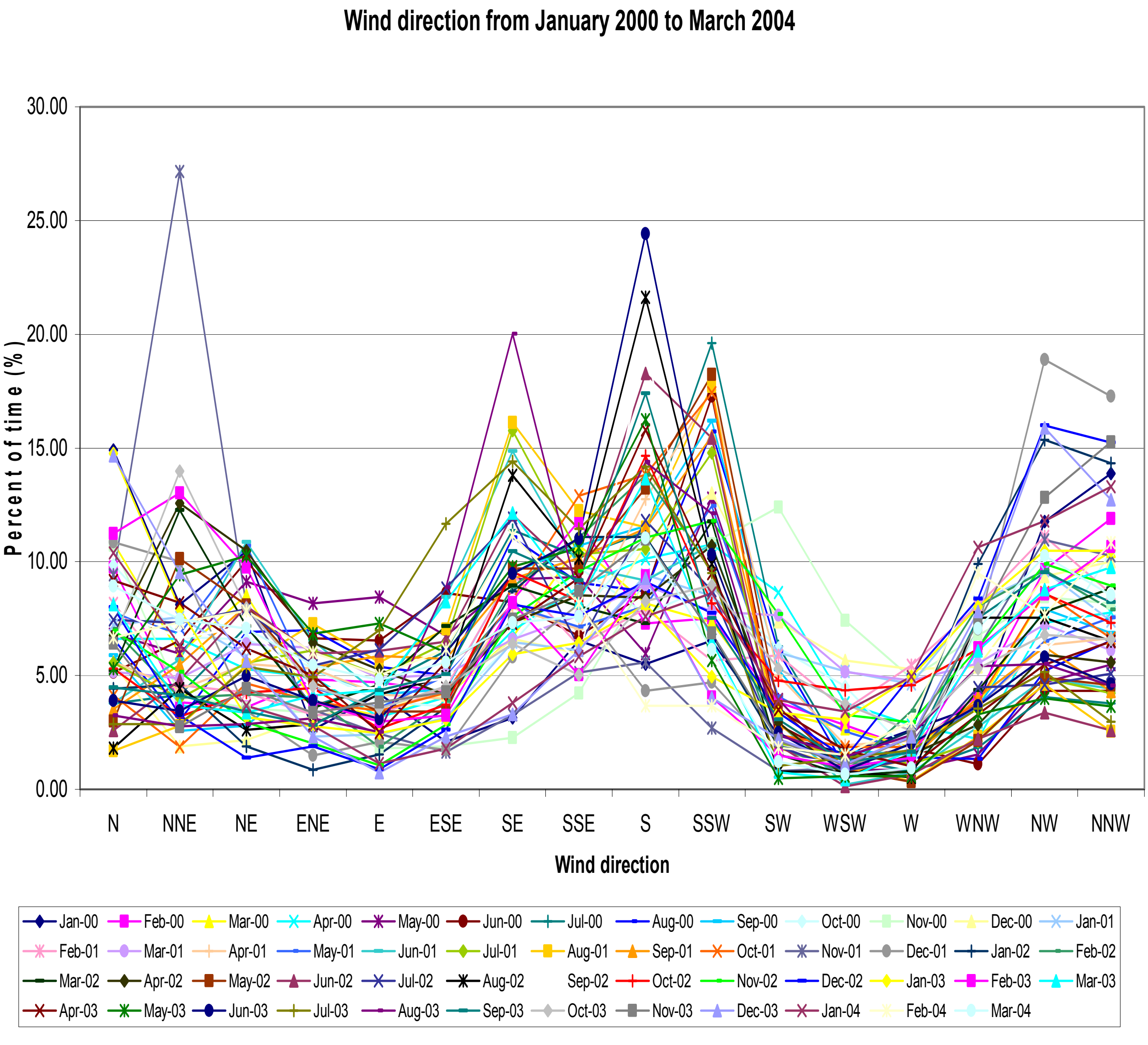


Figure3. Monthly wind profiles form the surface meteorological station of Banyoles.

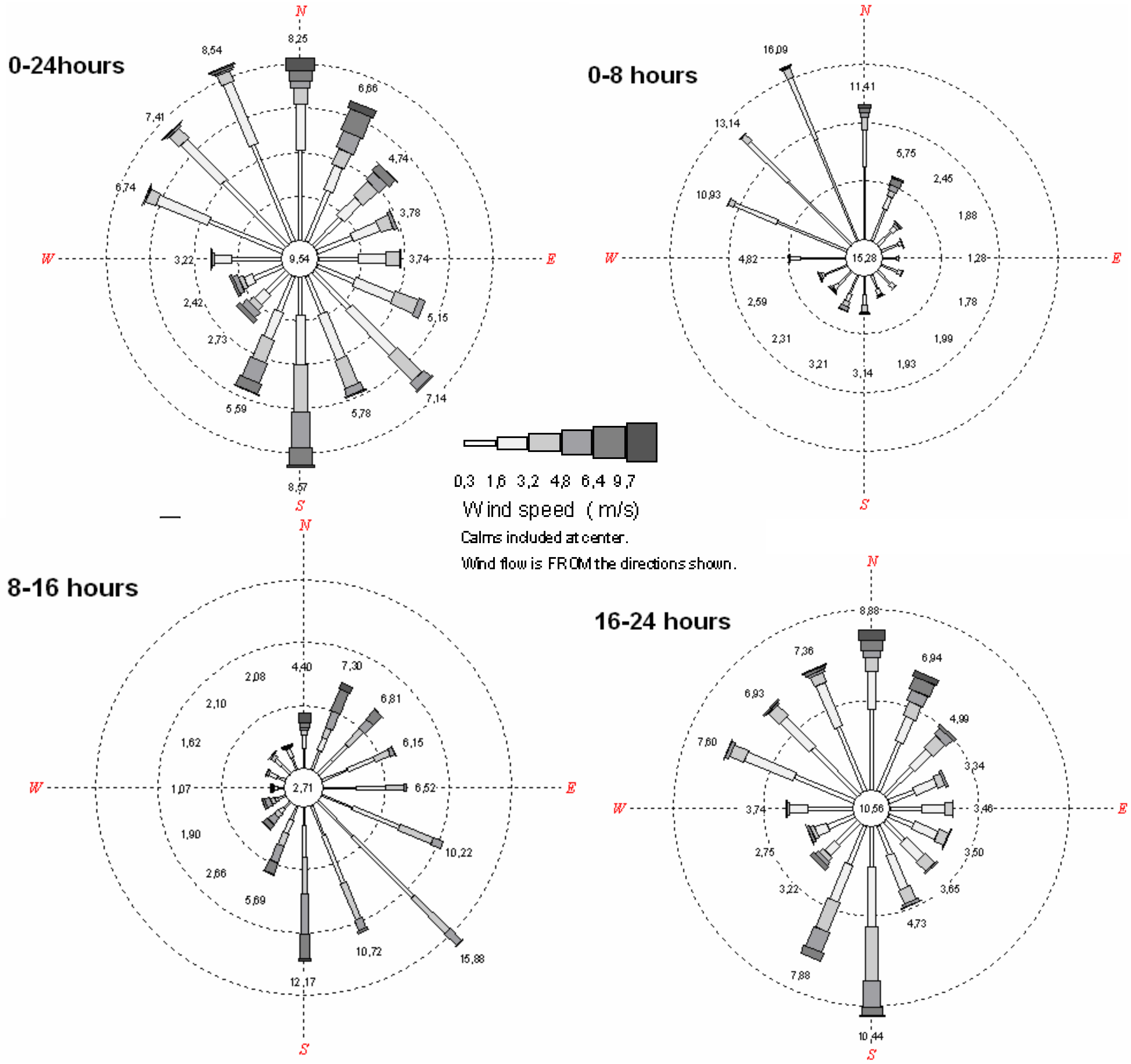


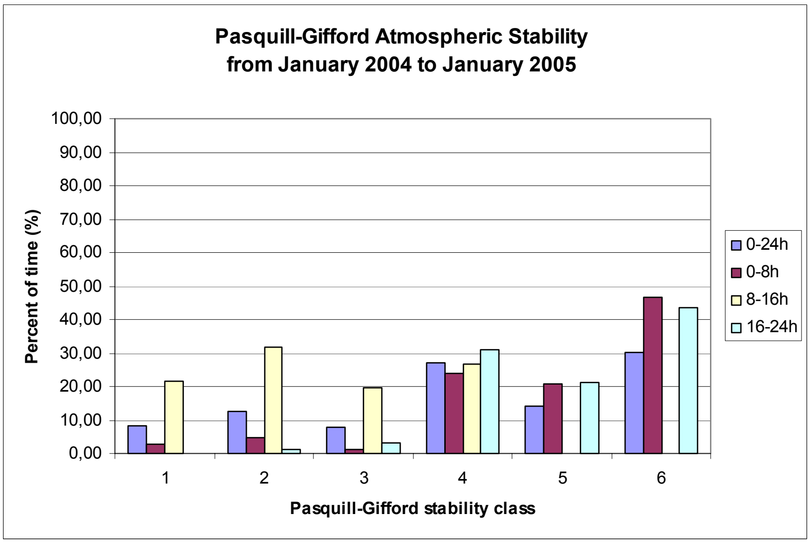
Figure 4. Wind roses at the year 2004 for the city of Banyoles (time showed is local time).

At figure 4, there are included the wind velocity and direction at the wind roses for the entire year 2004. The first wind rose is for the full period of the day, 0-24 hours. The other three wind roses of figure 4 are for three hourly ranges: 0 to 8 hours, 8 to 16 hours, and 16 to 24 hours (legal time).

At night, period 0 to 8 hours, winds are of very low velocity, with a 15% of calms (velocity less than 1 km/h), and predominantly from northwest. At this time the atmospheric dispersion is very poor.

During diurnal period, 8 to 16 hours, wind came from the southeast meanly, and, according to the relative position of the industries at the city, the emitted substances will go directly to the center of the village. Calms are rare, less than 3%.

In the period from 16 to 24 hours, the situation is similar to the 0 to 24 hours, with calms about 10%.



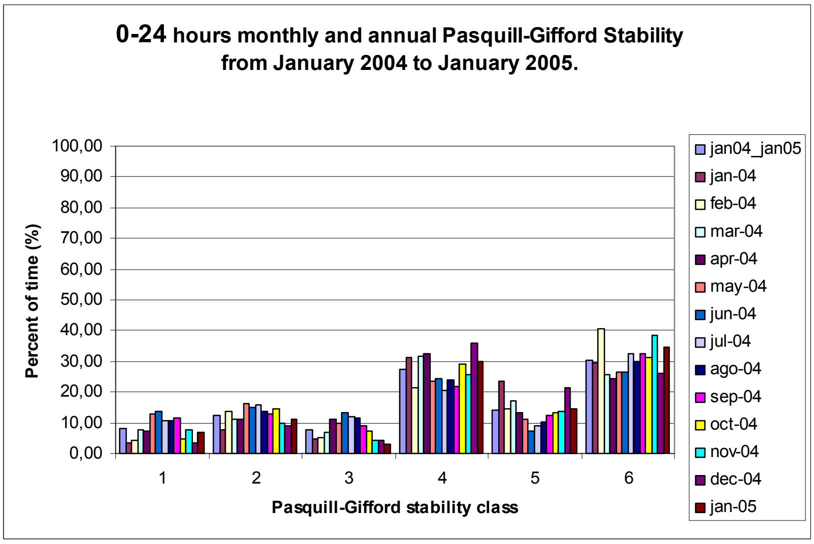


Figure 5. Atmospheric stability at the city of Banyoles.

Atmospheric stability is plotted in figure 5, according to Pasquill-Gifford (P-G) stability criteria. It gives a situation for the vertical movement of air by convection relatively poor, because predominates stability from 4 to 6 (4=D neutral, 5=E slightly stable, 6=F moderately stable in the classification of P-G).

Only at the diurnal range, 8 to 16 hours, as can be seen in the first graphic of figure 5, the dispersions of emitted substances will be good.

So the city of Banyoles has an ambient predominantly stable, especially at night, during the period from 0 to 8 hours, when the situation is classified as moderately stable.

These stability data, from January 2004 to January 2005, compares very well with the general data obtained from year 2000.

MATHEMATICAL MODEL OF DISPERSION OF ODOR

A Gaussian-type model has been developed in the LCMA (Laboratori del Centre de Medi Ambient, DEQ, UPC) to study the dispersion of the odor compounds in the atmosphere surrounding the different focuses.

This model uses the experimental meteorological data collected at the surface station, which is introduced after mathematical treatment in the form of arrays of wind velocity, wind direction, atmospheric stability and time frequency.

The time frequency has been calculated from the surface station meteorological data, for all of the 16 wind directions considered (22.5 º widths), for the six Pasquill-Gifford stability index (A, B, C, D, E, F), and for each of the wind velocity range, whose central values are:

[0 1,6 3,2 4,8 6,4 8 9,7 11,3 12,9 14,5 16,1 17,7 19,3 20,9 22,5 24,1 >24,1] m/sec

The time frequency array resulting has a dimension of 96x17, and includes all the significant information produced from the surface meteorological station for the desired period of time, which can be a day, week, month, year or group of years. For this work the period of time considered is the month.

The results obtained are impact maps of the focuses that emit chemical substances. These impact maps are the tri-dimensional representation of time-averaged cumulative concentrations for the period of time considered, at the surface of land around the emissions sources. The use of a color code allows the bi-dimensional representation, and also a very clear visualization of the average impact of a source in its surroundings during the period of time in study.

There is a lack of experimental data of the different production plants emissions, so the criteria has been to consider them proportional to horizontal surface area of the plant, and in the cases when only the water treatment plants are the emitters, only to the area of these water plants.

In order to obtain the impact maps, and according the characteristics of the sources, emissions are taken continuous in time. This is not quite true, because sometimes there are punctual emissions added to the diffuse emissions, that can originate episodes of strong odor, but when these punctual emissions are considered statistically, averaged impact maps obtained represent very well the annoyance in the neighborhood.

Relative concentration is represented in the impact maps. It serves to compare a point in the map with others, and to establish where the odor annoyance could be greater or smaller. The validation of these modeling results, which also serves as calibration of the odor threshold, comes from the neighbor annoyance maps explained next.

NEIGHBOR ANNOYANCE MAPS

The participation was demanded to the all the citizens for this study. The response was limited to the areas where the odor is present, but people who participate showed a very good response. The odor was quantified from 1 (no perceptible odor) to 5 (very strong), in three periods during the day, 0-8 hour, 8-16 hours, and 16-24 hours.

Percent annoyance index are calculated from these data, assigning 25% to the value of 2, 50 % to 3, 75% to 4, and 100% to the 5 value. With this index, averaged monthly values are obtained from the daily data for each point of the map that corresponds to the neighbor address. And with this monthly data collected, odor maps from June 2004, to January 2005 are drawn. The participation was about 40 persons along the study that take the odor level at their homes, in different localizations.

COMPARISON OF CALCULATED IMPACT MAPS WITH EXPERIMENTAL ANNOYANCE MAPS

Maps for all the period studied, from June 2004, to January 2005, are represented in figures 6 to 13. At the top of each figure there is the calculated map, and at the bottom the experimental map.

Figure 6 is for the first month of the period, June. In this month the social participation was the highest of all the entire study, and can be considered the most representative.

It is important to note that the two figures show the same trend for the variation of calculated relative concentration and for the variation of experimental annoyance with distance, which means that the two variables represented are equivalent.

Also, from the comparison of the two maps of figure 6, the concentration that approximately could be taken as the odor threshold can be obtained using the color code for the map at top, which indicates 1 microgram/m^3

In general there can be observed a difference between the top and bottom maps of figures 6, 7 and 9, especially in 7, July, to the northwest of the source 1, the gelatin plant, that consist of a bigger experimental annoyance compared to the calculated concentration. This is due to the fact that at this position there were a bigger number of odor receptors than at the southeast, where there is and industrial installation with no odor receptors.

In figure 8, August, was the holidays period of the gelatin plant. And, except for the last week of this month, there was no production. Also some receptors were in holidays.

The change in wind direction to the northwest is depicted in figures 9, 10, 11, 12 and 13. The calculated concentration is bigger at the southeast, and it the experimental maps this situation is reflected from September 2004 to January 2005.

During the study, it was observed that annoyance decreased gradually from June 2004 to January 2005, as can be observed when compared the calculated maps with the experimental maps, especially in December 2004 and January 2005. The temperature change can not explain all the differences.

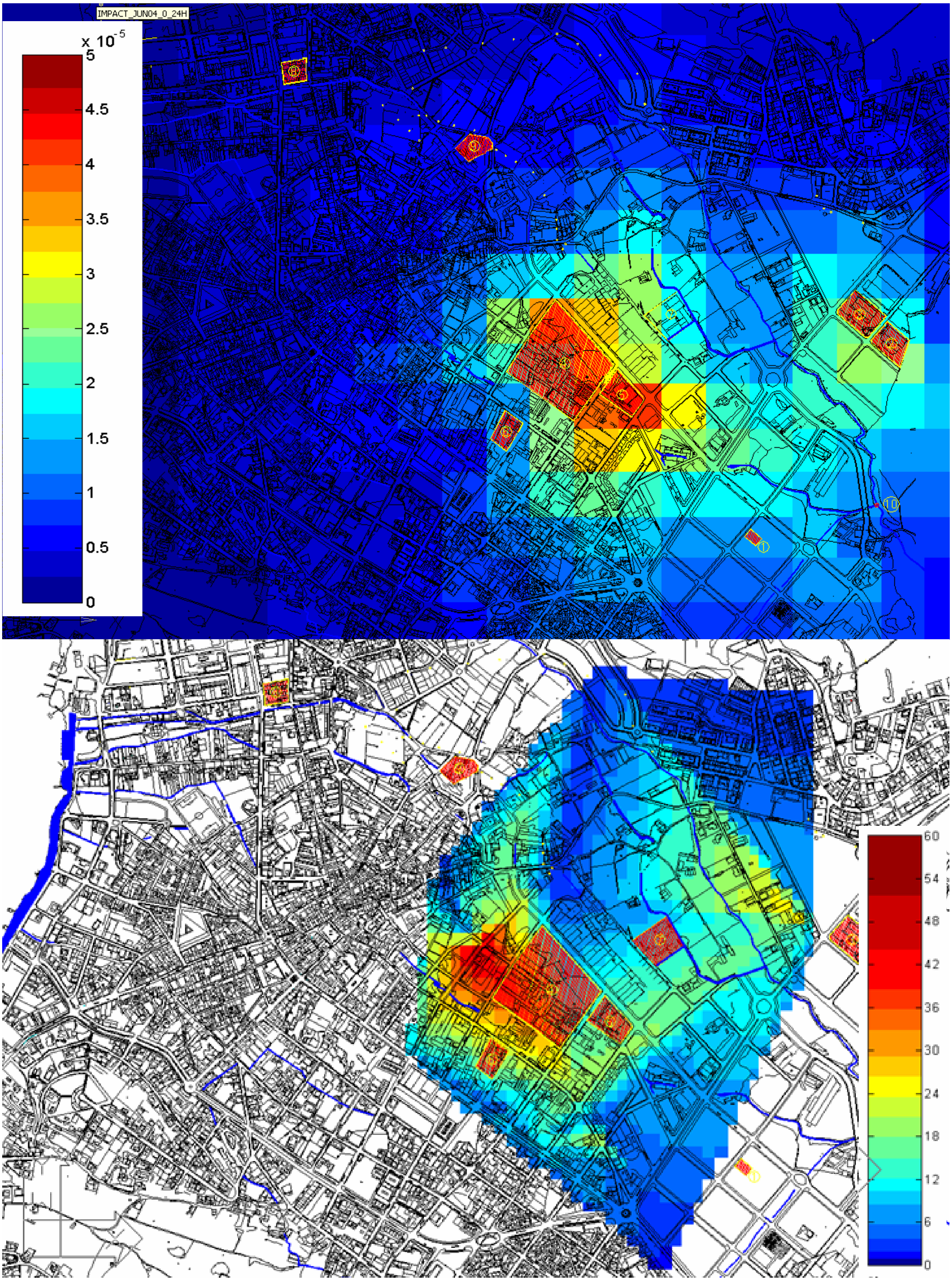


Figure6. Impact map obtained from mathematical model and annoyance index map for June 2004.

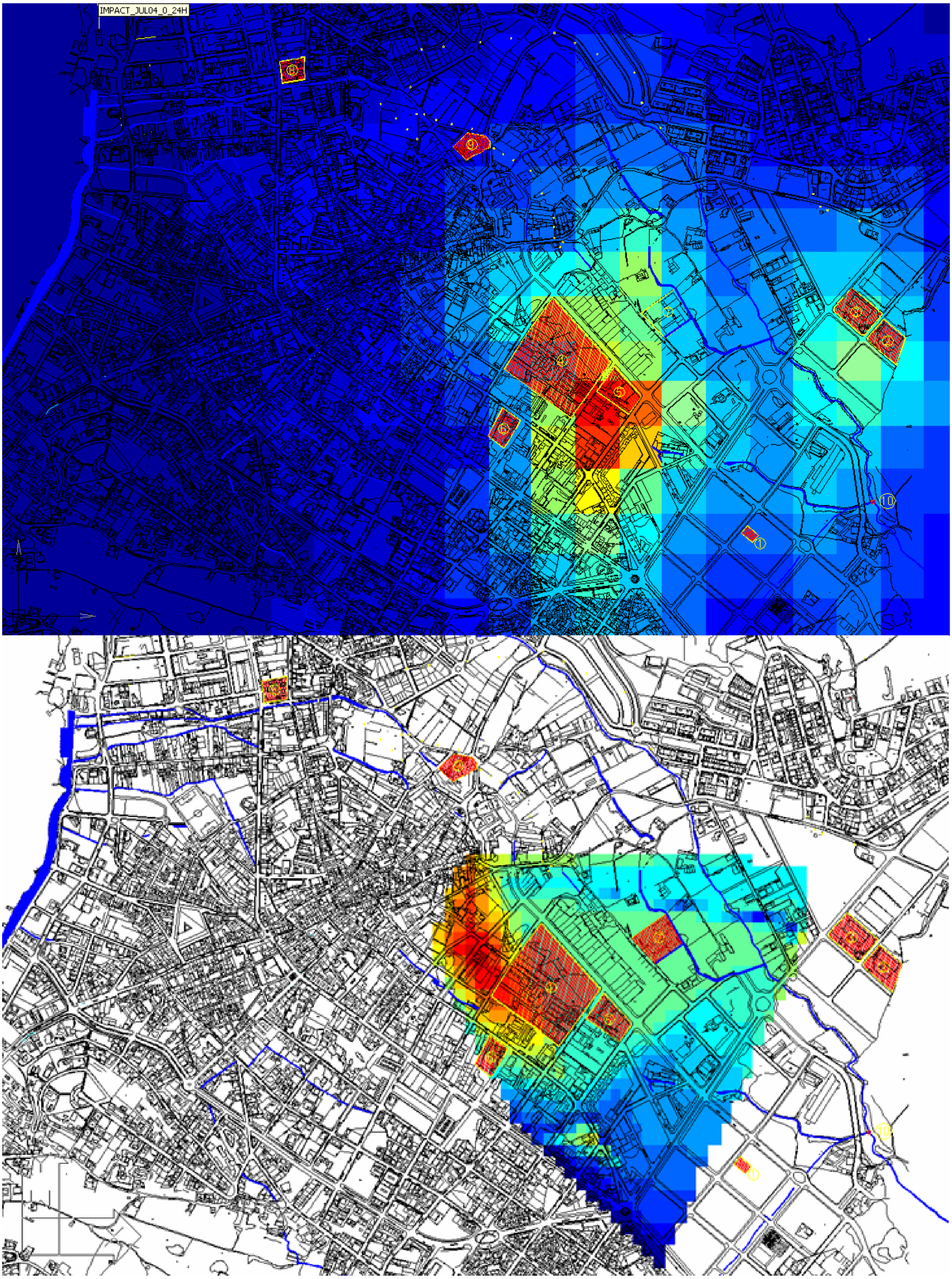


Figure7. Impact map obtained from mathematical model and annoyance index map for July 2004.

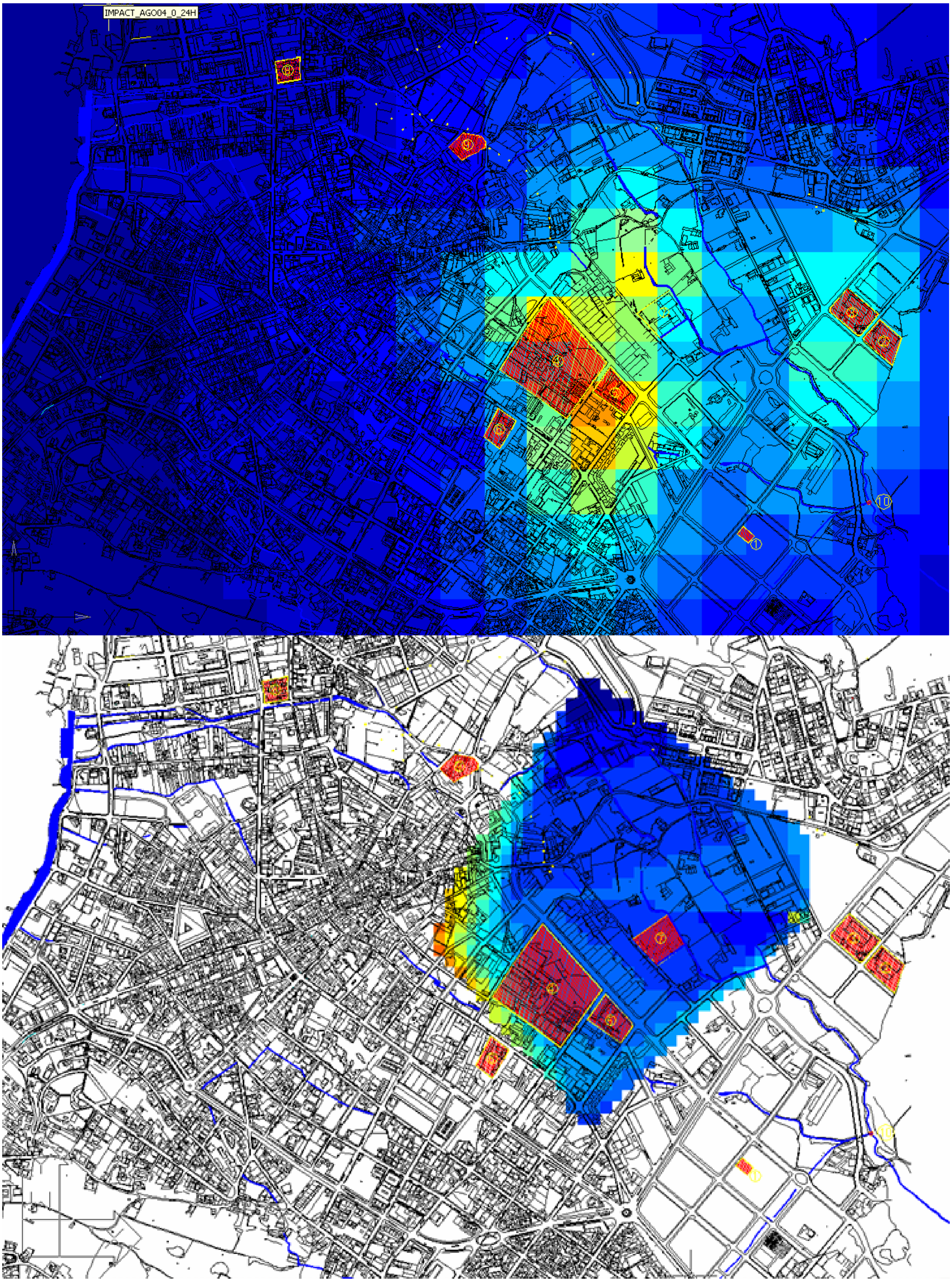


Figure8. Impact map obtained from mathematical model and annoyance index map for August 2004.

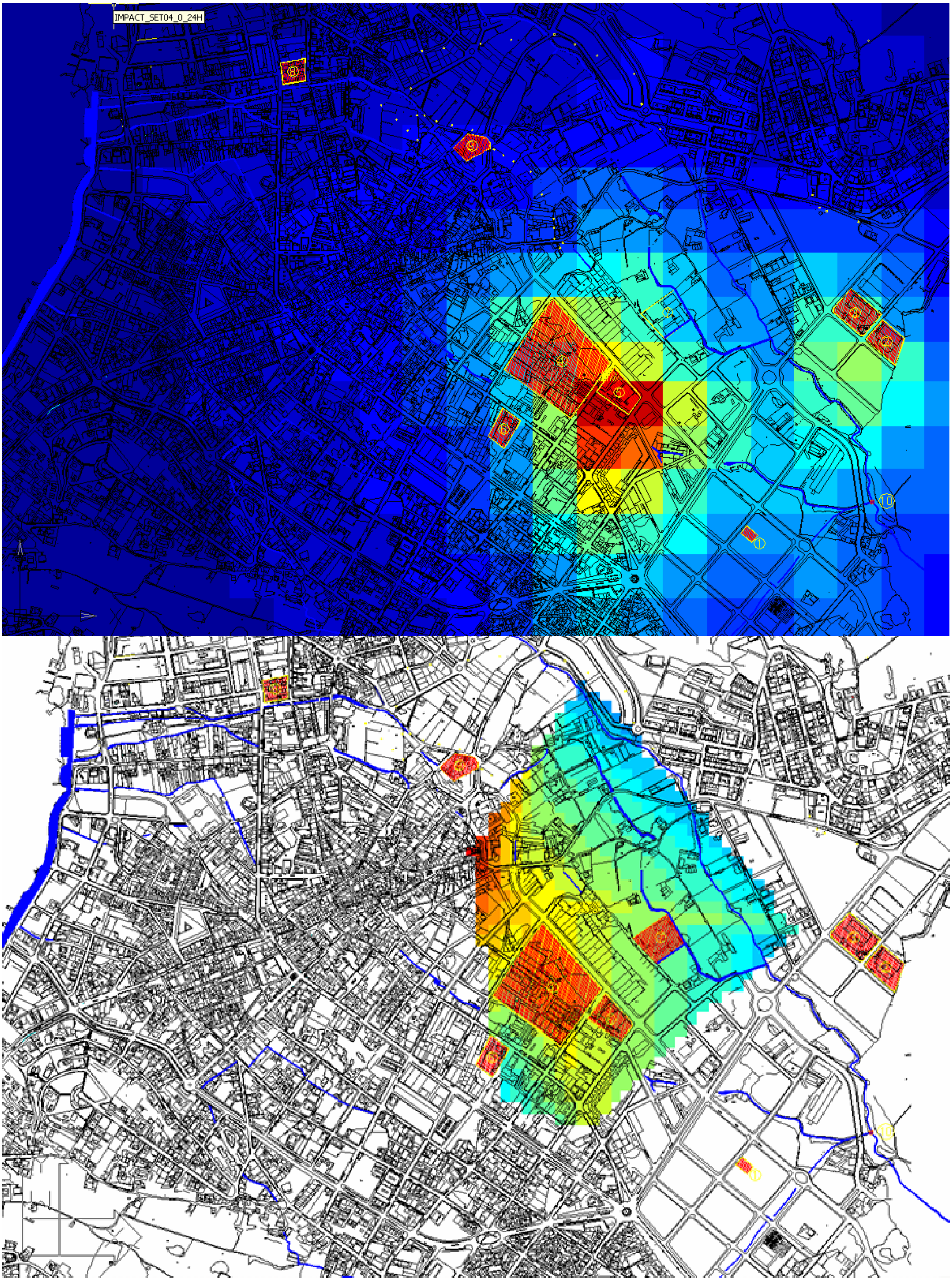


Figure9. Impact map obtained from mathematical model and annoyance index map for September 2004.

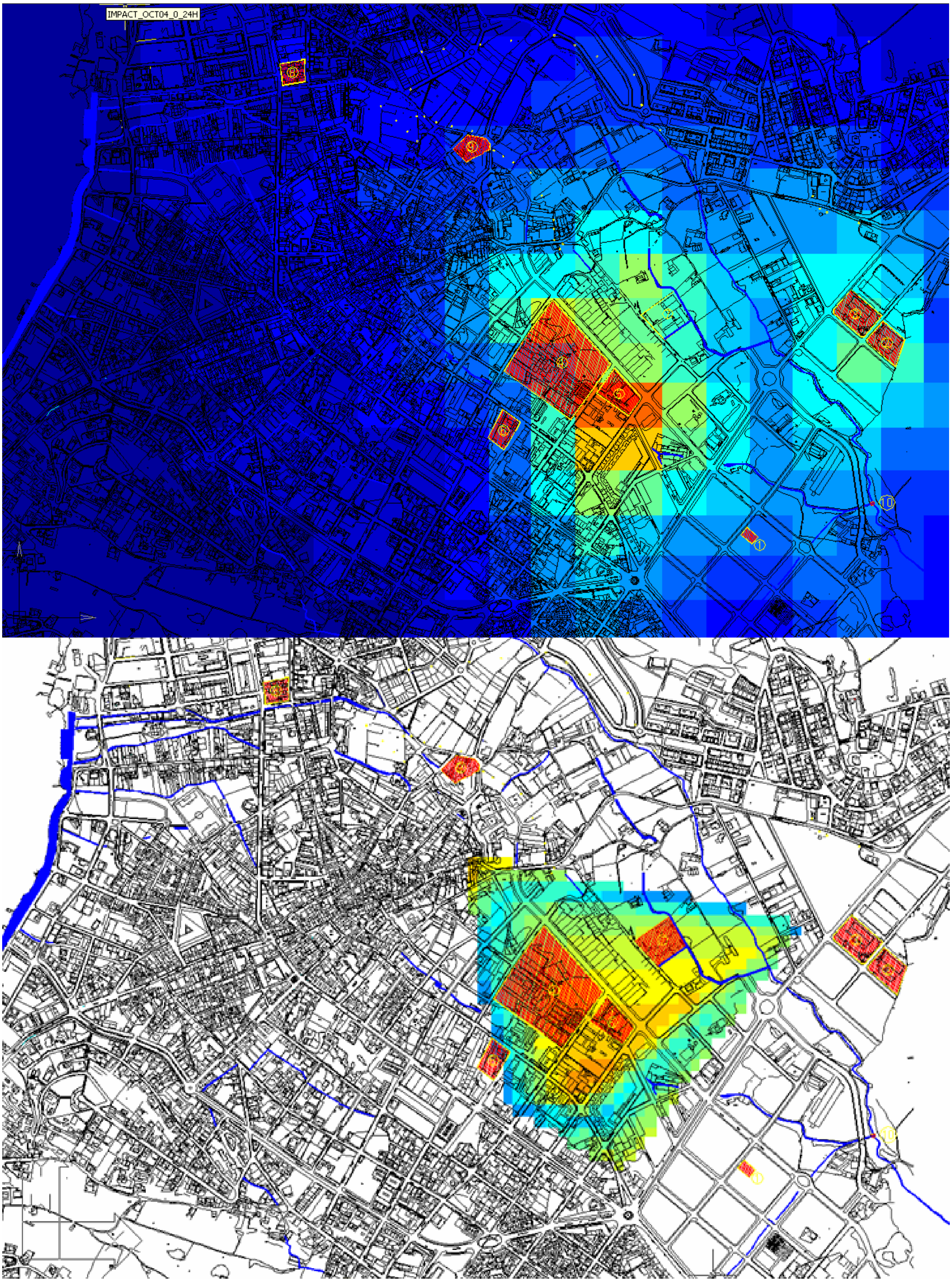


Figure10. Impact map obtained from mathematical model and annoyance index map for October 2004.

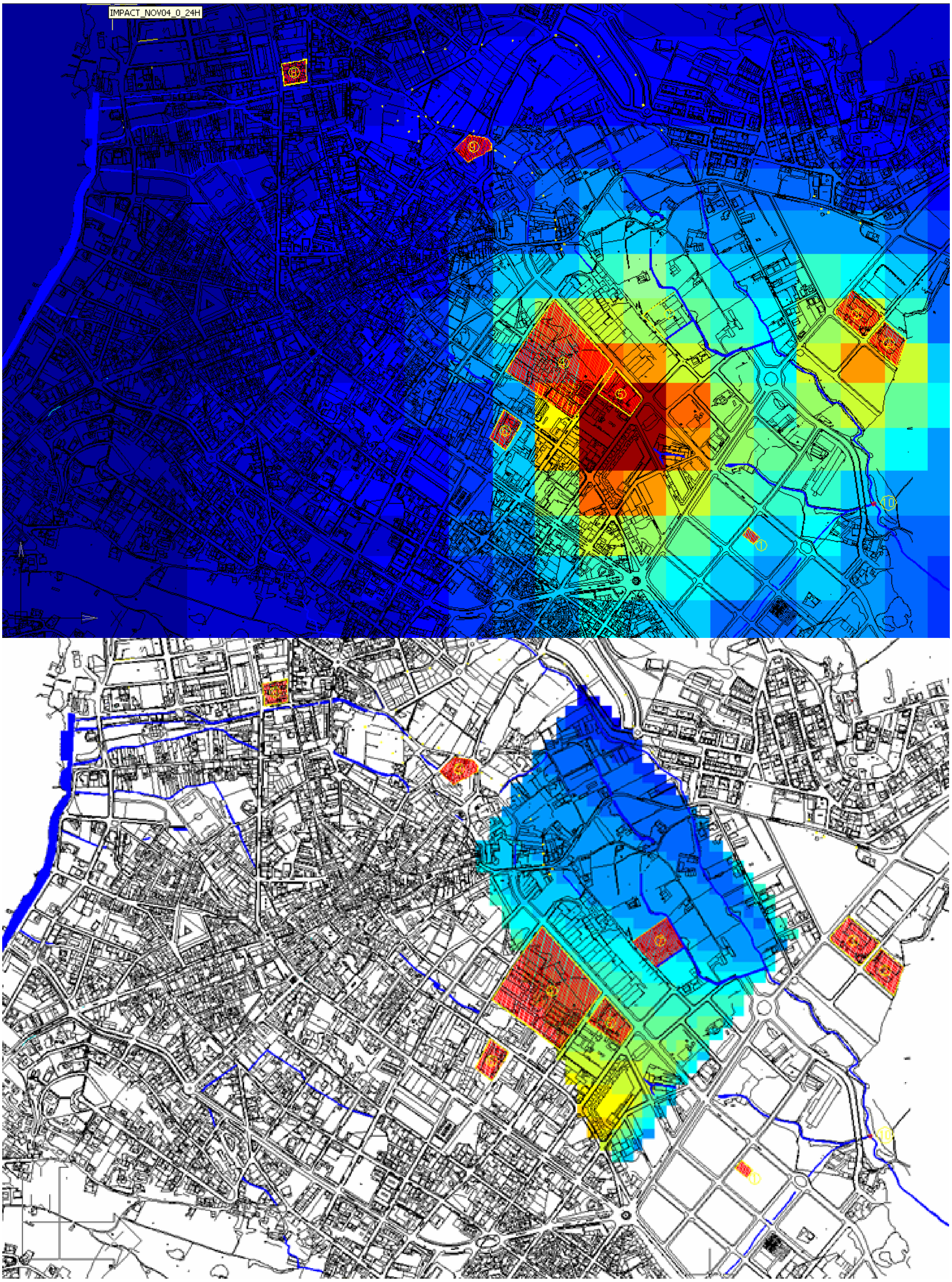


Figure11. Impact map obtained from mathematical model and annoyance index map for November 2004.

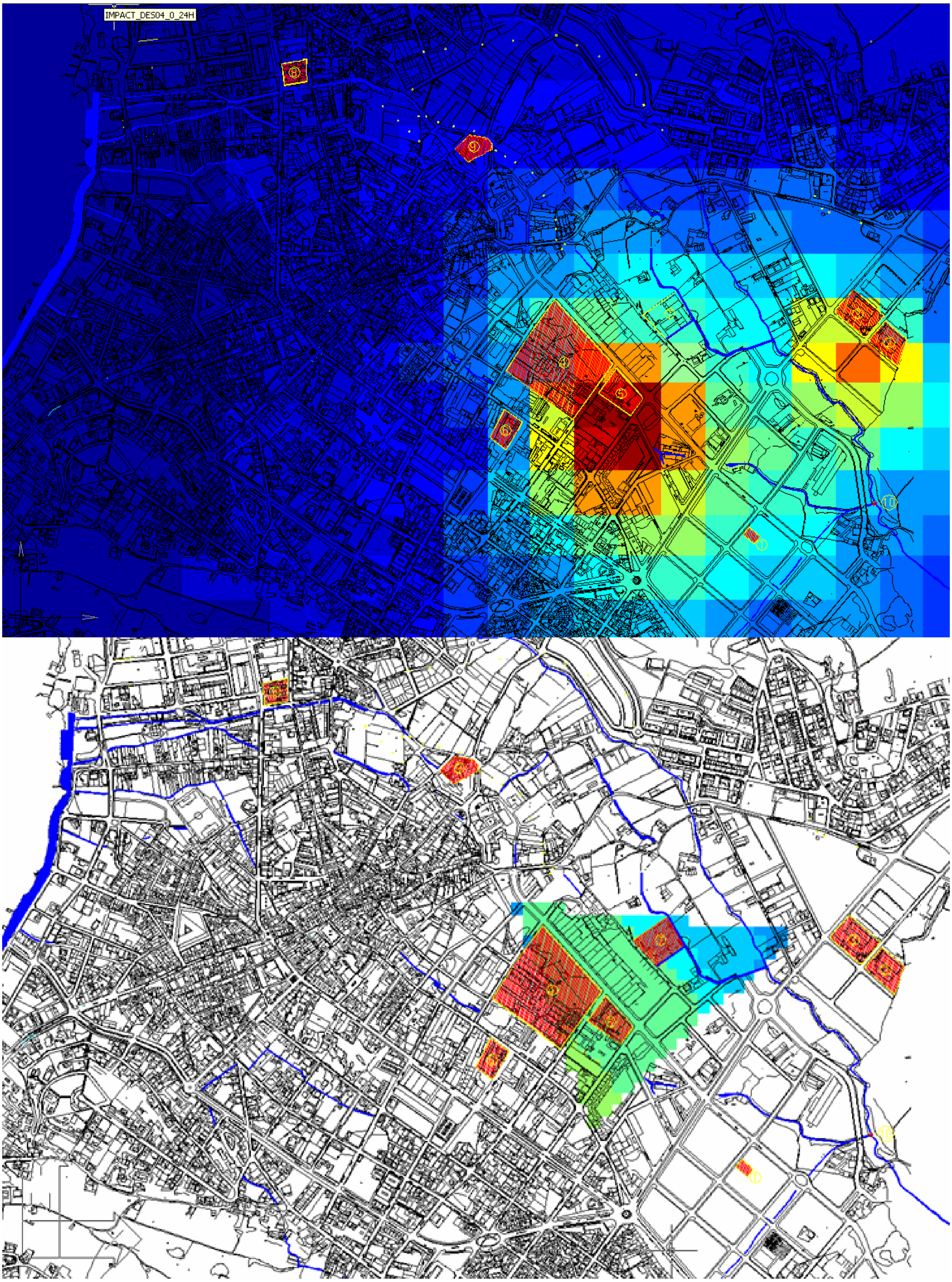


Figure12. Impact map obtained from mathematical model and annoyance index map for December 2004.

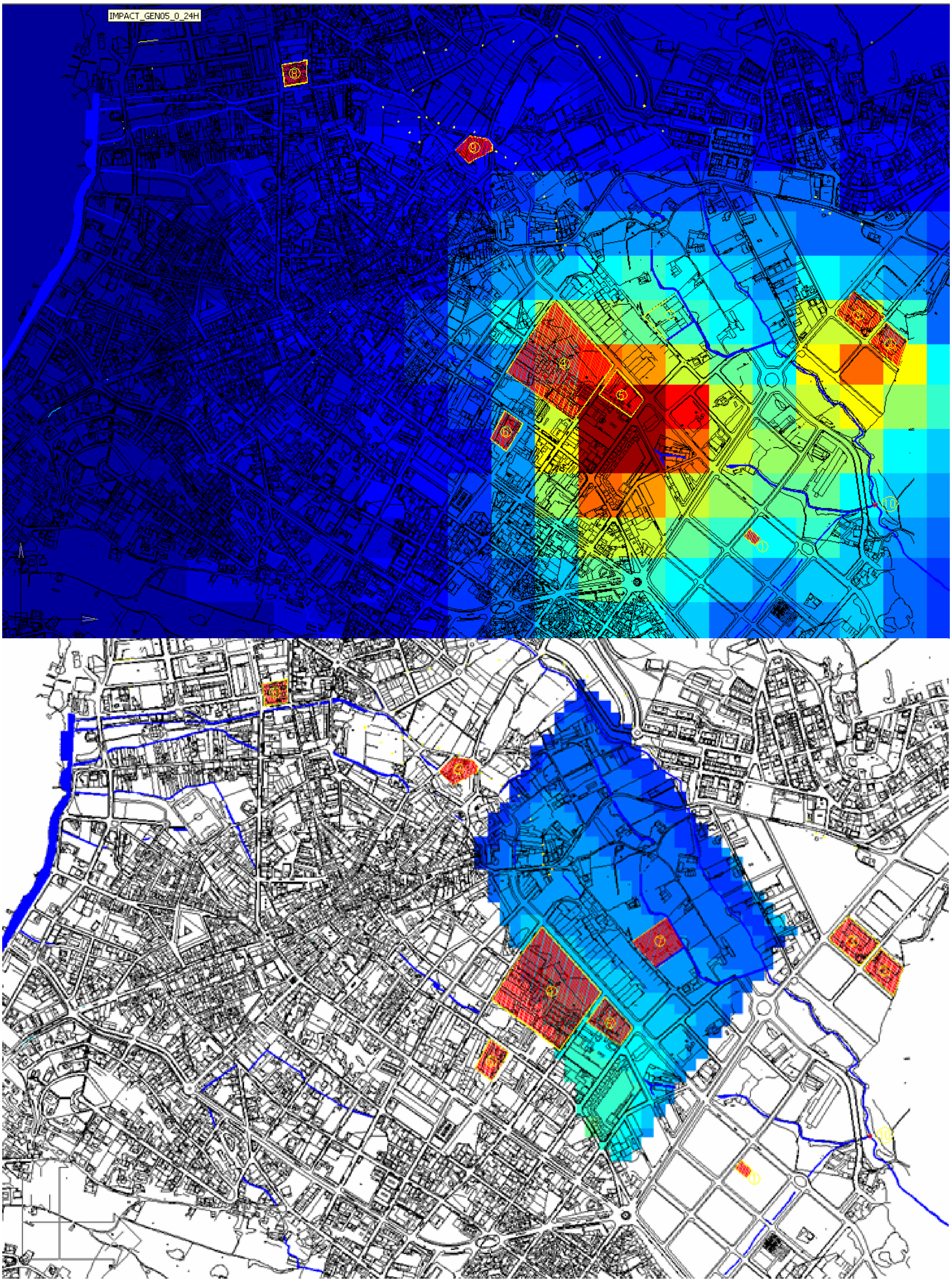


Figure13. Impact map obtained from mathematical model and annoyance index map for January 2004.

The annoyance index maps have are limited to the points where there are odor receptors, and when the social participation diminishes the differences between calculated and experimental maps increases. This can be seen in the figures of the last months of the period, December 2004 and January 2005.

CHEMICAL ANALYSIS

Chemical analysis begins with the air capture using the equipment in figure 14, in which forced air is passed through a multisorbent tube. This air is later analyzed by combining thermal desorption with high-resolution gas chromatography and mass spectrometry detection (TD-GC-MS) method.

Figure14. Air capture equipment.

The analysis of air has been done during all the period of study. More than two hundred chemical compounds have been analyzed, and only a dangerous substance has been found in a concentration that could be dangerous when the most stringent policies are applied, in a punctual situation.

The maps of concentration for each one of the substances indicate its possible origin.

In figures 15 and 16 there are the maps of concentration for 2-etil-hexanoic acid, and for octanoic acid, as examples of the results obtained.

At this moment, all this information is being processed in order to validate the methodology used.

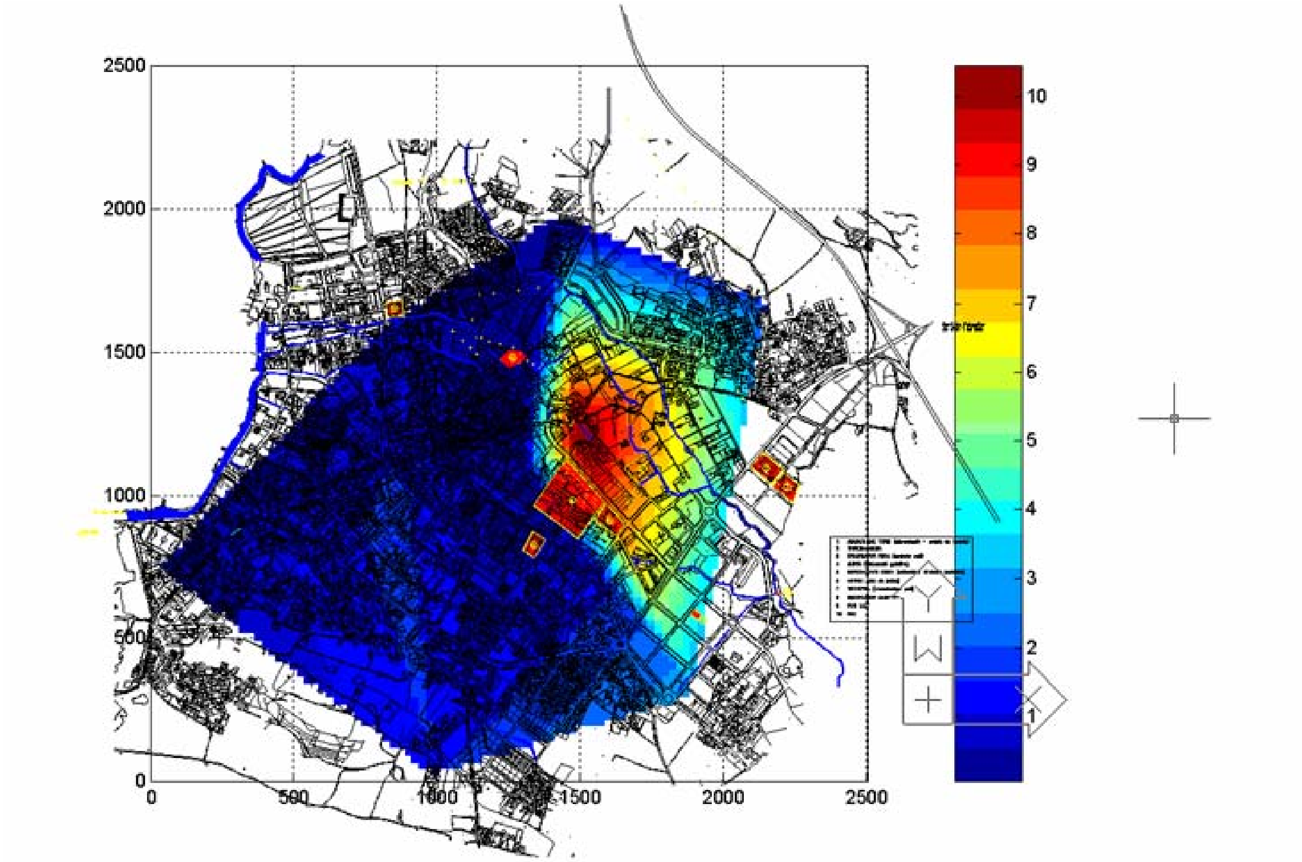


Figure 15. Concentration map for 2-etil-hexanoic acid. Units are microgram per cubic meter or air.

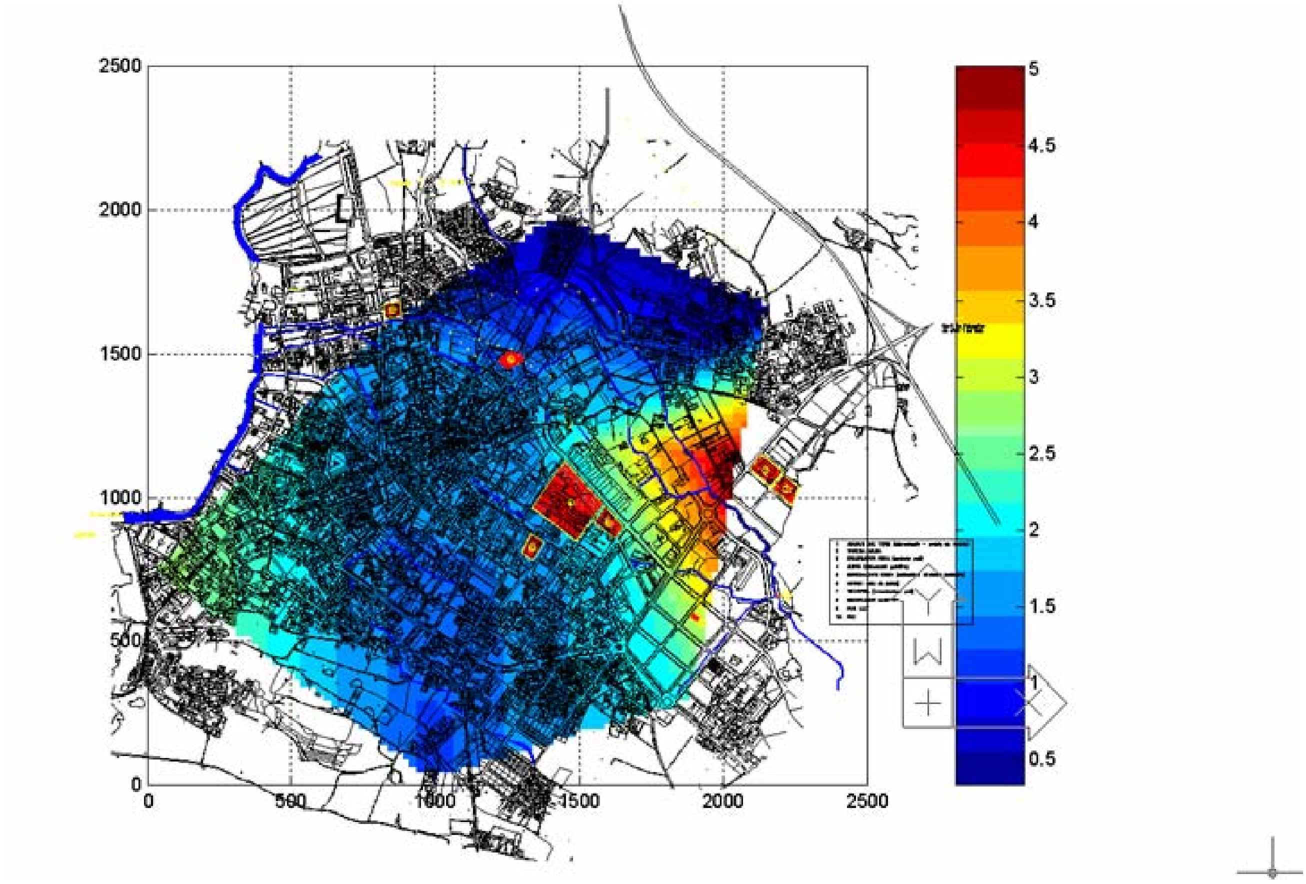


Figure 16. Concentration map for octanoic acid.

CONCLUSSIONS

Despite the great number of variables associated with the experimental characterization of the odor distribution in an urban area, in this work is proposed a methodology that gives promising results.

It combines the dispersion modeling study with the validation/calibration of the dispersion results with the odor nuisance perception by the community, and shows that the impact map obtained gives enough information to estimate the odor map.

When calibrated the model could be extrapolated to other situations with similar type of sources, without the social participation. So it can be used to find a proper location for this type of industries at the planning stage.

With this methodology impact maps of odor can be calculated easily and later it could be calibrated with only a few experimental annotations of odor.