A Distinct Approach to Odour Impact Assessment
Based on a Hybrid Methodology of
Field Measurements, Source Sampling, and Dispersion Modelling

Abstract

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This distinct approach of an odour study combines ambient measurements on-site, at the fence-line and in the vicinity of the site with odour emissions sampling, olfatometric measurements, dispersion modelling and impact assessment. The main objective of adding the ambient measurements is to

- Achieve a better understanding of the odours originating from the site;
- Recognize the common conditions and variabilities;
- Investigate the site and sources prior to conducting source sampling;
- Develop an adapted mitigation plan that is specific to the sources, to the site and to the client objectives.

This approach also answers all requests from authorities and enhances communication routes. Its main goal is to improve the situation through mitigation and odour abatement rather than solely study the impacts using an air quality developed procedure.

1 Introduction

Addressing malodour issues and associated complaints starts by establishing an odour monitoring program and focussing on the understanding of what neighbours smell. Most often odour studies focus on characterising odour emissions of specific sources and conduct dispersion modelling to look into the greatest impacts; however this approach does not look into the more common conditions and can overlook unidentified sources.

This distinct approach helps identifying odour types, odour sources, and at responding to odour complaints. It is nonetheless challenging to quantify ambient odour concentrations because

- Odours are unstable, fluctuating and detected instantaneously.
- Different odours combine and blend together in a synergy that results in an unpredictable odour scent, concentration and intensity;
- The human nose perception level that is most often more sensitive than any chemical analyzers.

Impacts from air contaminants are most often evaluated over 1-hour, 24-hours and annual periods, however odour nuisances is a matter of frequency of volatile exposures that are often originating from a synergy of undetectable/unmeasurable volatiles. Heavy VOCs for example emanating from asphalt and bitumen are considered negligible in terms of air quality fugitives, however they are major contributors to odour issues.

To well comprehend a situation, recognize the odours, the sources, and the extent of impacts, proceeding solely with source characterisation and dispersion modelling is not sufficient.

2 Approach and Methodology

This distinct approach is divided into 4 phases:

- Step 1 - Odour surveying and patrol of baseline odours;
- Step 2 - Odour emissions characterization
- Step 3 - impact assessment that includes odour emission sampling, olfactometric analyses, dispersion modelling and impact assessment;
- Step 4 - Mitigation Plan development and implementation.

In opposite to standard studies for which efforts are mostly put on Phase 2, this distinct approach adds a Phase 1 for baseline odour patrol or in other words, ambient baseline odour monitoring. Though results can be of great interest to regulating agencies, its main objective is not intended for reporting to authorities, but rather to helping the industry develop a well-adapted odour mitigation plan. Data can also be used to refute assertions where the facility is not responsible for the odors.

2.1 Phase 1 - Odour Patrol

The core element of this distinct approach is the odour patrol program. An odour patrol serves to qualifying and quantifying the odours reported by external receptors. It allows setting baseline levels and most of all, provides

- Better understanding of the level of annoyances;
- Better understanding of the impacted areas and variances of odours throughout a site and beyond;
- Odour impact monitoring in relation with on-site operations and upset conditions;
- Analysis of types of odours perceived;
- Quick response in view of ensuring and enhancing communication with authorities and potentially impacted receptors.

The patrol is conducted by a minimum of 2 patrollers (to assess sample precision and for guaranty insurance measurements) which monitor pre-determined monitoring points; the points are established so that odours are monitored at the peripheral of the site, in various sectors within the site, as well as at distance (beyond property line) where odours may have historically been perceived, plumes from elevated sources may be prone to impact ground-level and where sensitive receptors are located.

At specific determined locations, the patrollers record three elements:

- Description of odours perceived, conditions and any event or incidents observed;
- Measure ambient odour concentrations using a state-of-the-art portable field olfactometers that follows international standards (EN 13725[i]);
- Measure local wind speed and direction.

Site information and meteorological conditions are considered when assessing results from up-wind and downwind odours.

In parallel to conducting odour monitoring, chemical compound concentrations are also interesting to measure for seeking chemical tracers, for obtaining information of odours origins, and for cumulating valuable information for future odour abatement devices and future mitigation systems. Depending on the plant and process, chemicals of interest vary and may include:

- Total Reduced Sulfurs (monitored individually);
- Hydrogen sulfide (H_2S);
- Volatile organic compounds (VOCs): Total VOCs, heavy and semi VOCs, alkanes, BTEX, others;
- Methane (CH_4);
- Ammonia (NH_3).

2.1.1 EQUIPMENT

The equipment used for measuring ambient odour concentrations during the odour patrols is Scentroid's SM100 infield olfactometer (Figure 2-1).

Figure 2-1 Scentroid's SM100 Infield Olfactometer

Scentroid's SM100 portable olfactometer allows users to quantify ambient odor concentrations. It is a state-of-the-art device that offers an easy-to-use approach to measure ambient odor levels. It allows to:

- Conduct daily odor emissions monitoring of industrial operations;
- Determine odor source contributions;
- Evaluate odor emission impact on neighboring residents;
- Determine odor mitigation effectiveness over time;
- Monitor emissions compliance;
- Verify lab results and dispersion model predictions.

The device draws a sample of ambient air via venturi vacuum pump and dilutes it using fresh odorless air from a high pressure compressed air cylinder. Operators use an adjustable sliding valve to control the ratio of fresh to ambient air. The mixed air is sent through a flexible hose to a disposable (or personal) face mask. Operators slowly increase the concentration of the mixture until the odor of ambient air is detected. A scale on the sliding valve indicates the dilution to threshold ratio.

2.1.1.1 Chemical Compounds Monitoring

Analyses of chemicals can be conducted using various available devices developed for monitoring air ambient contaminants. Scentroid's Odotracker (**Error! Reference source not found.**) with PID is a good and handy instrument to use as it follows all aspects of US EPA regulation for chemical analyses and is a portable multi-sensor device that can measure up to 4 selected compounds in ppb levels. Standard contaminants measured seek odorous compounds such as Hydrogen Sulfide (H_2S) in ppbs, Ammonia (NH_3) in ppm, and total VOCs (VOCs) in ppm. Depending on the type of site, its problematic, sources and process, other compounds can also be monitored such as methane (CH_4), Ammonia (NH_3), BTEX, sulfur dioxide (SO_2) or others volatiles and semi-volatile organic compounds.

The portable instrument logs the chemical data as well as temperature and humidity of the samples and GPS coordinates where the measurement was conducted, and transfers all information to the user's smart device via Bluetooth.

2.2 Phase 2 – Odour Impact Assessment

The odour impact assessment conducted in phase 2 involves characterising odour emissions through emission sampling, olfactometric analyses and dispersion modelling using the well-recognised and standardized approaches.

2.2.1 Odour Emissions Characterisation

Odour characterisation involves emission sampling and olfactometric analyses to determine odour concentrations and odour emission rates from several specific sources. Other parameters such as volumetric flow rates and temperatures should also be measured.

2.2.1.1 Odour Sampling

The approach used to sample odours depends on the types of sources: ducted point sources (stacks) or surface sources. Point sources require the use of a stack diluting sampler (Figure 2-2) while surface sources require the use of a dynamic flux chamber in order to accurately determine the surface flow rates emitted from water sources or ground material sources (Figure 2-3).

All sampling material in which sampled gases are in contact should be clean and made of Teflon, glass, and stainless steel so that they are not impregnated with odours.

Samples should be preserved, and the new Scentroid's PTFE sample bags (Figure 2-2**Error! Reference source not found.**) are of great interest as they provide a good compromise from Teflon or nalophan material bags, as they are odorless and well preserve the samples, they do not get easily contaminated and they can be cleaned, purged and re-used.

Odour concentrations of the samples should be measured within 24-hrs and following international standards (e.g. EN13725) to determine the efficiency of odour abatement. A minimum of 2 samples per source is necessary to overcome olfactometric measurement variability and ensure recurrences.

Figure 2-2 Scentroid's Stack Diluting Sampler

Figure 2-3 Scentroid's Dynamic Flux Chamber

2.2.1.2 Olfactometric Analyses

Olfactometric analyses consist of determining the olfactory perception threshold of a gaseous sample from which odour concentrations of the samples are obtained.

Odour measurements are completed using a dynamic dilution olfactometer and should meet the most applied international standardized practices (e.g. ASTM (E679-91)[ii], European standards EN 13725, NVN2820[iii], VDI 3881[iv], GB/T14675-93[v], etc.) for determining odour thresholds and odour concentrations.

2.2.2 Odour Impact Assessment

An odour impact assessment is the complete compilation and analysis of all source characterization data and allows displaying the general portrait of the odour print, determining the extent of the odour nuisances in the local and regional area surrounding the plant.

It also provides details on the contribution of each source which is foremost important information for source prioritization and the elaboration of odour mitigating plans.

2.2.3 Odour Dispersion Modelling

An odour impact study is based on a scientific, systematic approach to evaluating and analyzing the impacts in terms of atmospheric emissions. It is designed and prepared using a similar approach to that of an air quality impact study with the difference that odour-specific methods and tools are used. The dispersion modelling is most often conducted using the AERMOD software unless regulatory requirements disclose other directives. Dispersion modelling uses a minimum of 3-year meteorological data from the closest airport meteorological station. All sources identified odorous are modelled.

Dispersion modeling results in the maximum odour concentrations averaged on a 4-min time period, which consists of the shortest time period that can be calculated and obtained. The shortest time period is used because odours are detected instantaneously. The evaluation of the 98th and 99th percentiles as well as the frequency of odour perception thresholds exceedances should also be calculated.

The dispersion model looks at the impacts on-site and in the vicinity of the site up to 10 km away, or more depending on the site and geographical settings. The grid receptors on which odour concentrations are predicted is denser at close proximity of the site. Specific points should also be identified and added for their sensitivity, ex. Schools, hospitals, parks, etc.

2.2.4 Source Prioritisation

The odour impact assessment highlights the sources that, at the time of the campaign, sources have the greatest impacts off-site, as well as those that disperse the farthest. With these results, source prioritization can be completed and should also take into account the odour patrol results and observations, the historical event analyses, discussions with the site personnel, etc.

Source prioritization is the basis for the development of a mitigation plan.

3 Data Analysis

An odor patrol should be performed for a number of times: the longer the program, the more in-depth data is obtained, statistical analyses are more robust and a better understanding of the conditions, sources and site is acquired. This in-depth study is foremost important with sizeable industrial sites that have various sources and processes. It allows:

- observing patterns of odour concentrations;
- associating patrol points together to create “ambient odour zones”;
- distinguishing abnormal odour patterns in areas that were initially thought up-wind;
- distinguishing greater or lesser impacts from sources initially thought to be the most problematic and greater impacts from sources initially thought secondary; and/or
- distinguishing odours variances that do not follow yet understandable patterns.

An example of ambient data and analysis that can be done with such information is as follows.

3.1 Combining fence-line monitoring with wind direction

With ambient odour concentrations taken several times all-around a fence-line, analysing the odour concentrations in parallel with wind direction can reveal the influence of on-site sources/zones, and of from neighboring sources. Figure 3-1 presents an example of the variations of 3 points monitored over 3 days with the wind rose respective of the times monitoring was conducted.

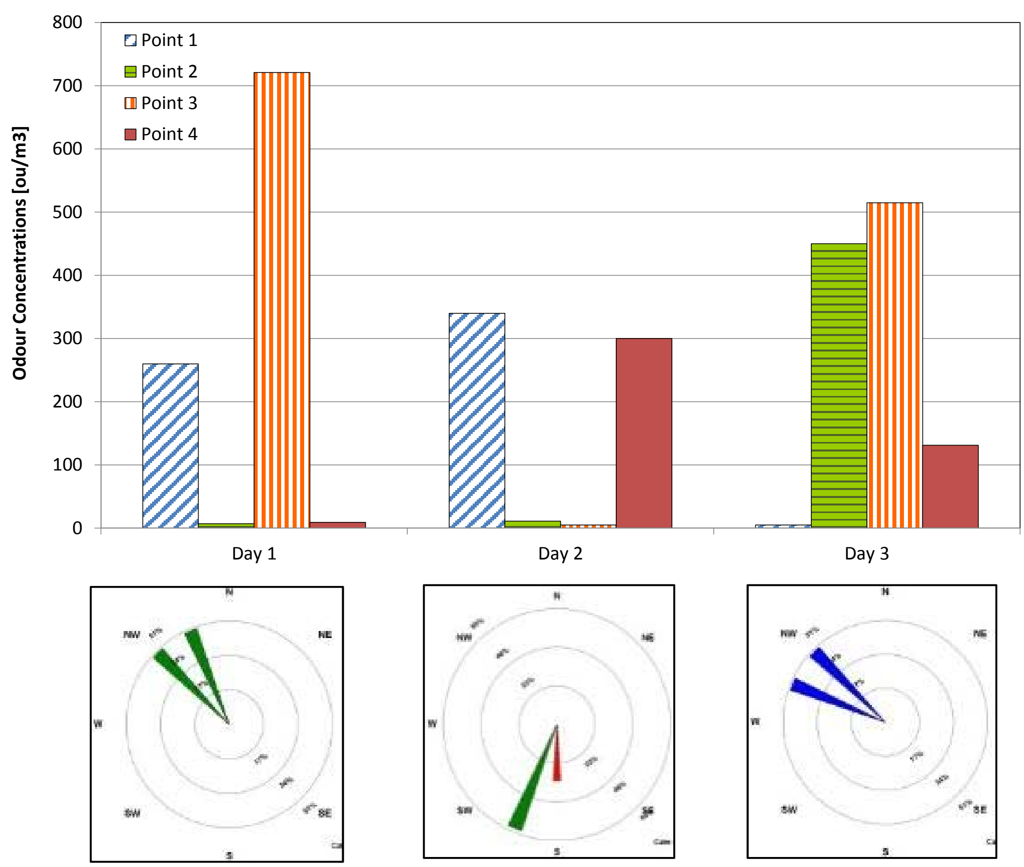

Figure 3-1 Example of Fence-line Odours with Wind Direction

During the three-day monitoring periods, changes in wind direction was observed which greatly influenced the ambient odour concentrations measured on the perimeter of the site. Some points for example were odorous one day but were not on other days. This divulged the level of importance and influences of:

- On-site sources with consideration of their locations and variations;
- On-site turbulence;
- External sources with consideration of their location around the site, their types and heights;
- Etc.

3.2 Analyzing long-term variances

Studying long-term variations of ambient odours is of great importance not only for studying variances of odour emissions, but mostly for studying real odour levels, discovering unknown sources or the synergy of various sources mixed together, the importance of atmospheric turbulences and meteorological conditions, etc. Rarely can ambient odours be measured with great recurrence because these are instant measurements as opposed to averages over some periods of times that are studied for air contaminants.

Such ambient monitoring can serve at establishing baseline levels based on real data rather than modelling results. Figure 3-2 illustrates how such graph can look like.

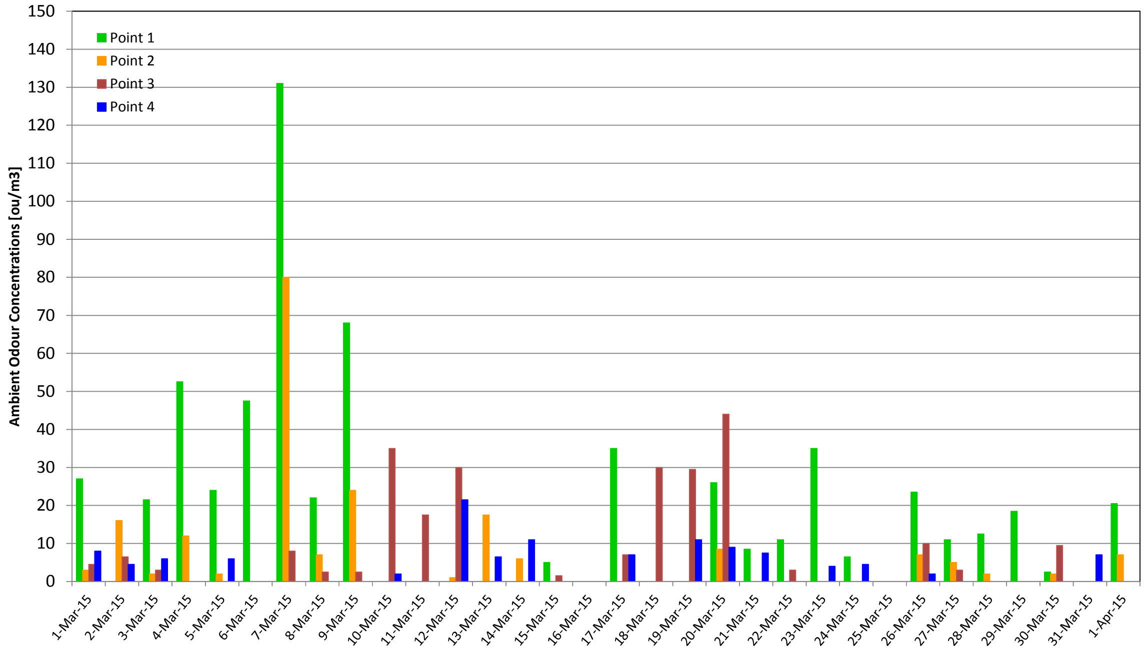

Figure 3-2 Example of Odour Data Time-Series for 4 Points over 1-month

The great importance of such graph is to link these results to the location where these odours were monitored and study them in relation with close/further away, ground/elevated sources, etc. Once this analysis has been conducted, it is of great importance to go on-site with this new acquired vision of the site, this “odour level frame”; to investigate with new eyes the tangible existing apparatuses and processes. Than a palpable hands-on of the odour sources can be achieved.

3.3 Setting Baseline Levels

From the precedent levels of 1-month data, their analysis can provide percentiles, baseline levels, etc. Figure 3-3 presents an example of an odour data distribution chart with some marked percentiles.

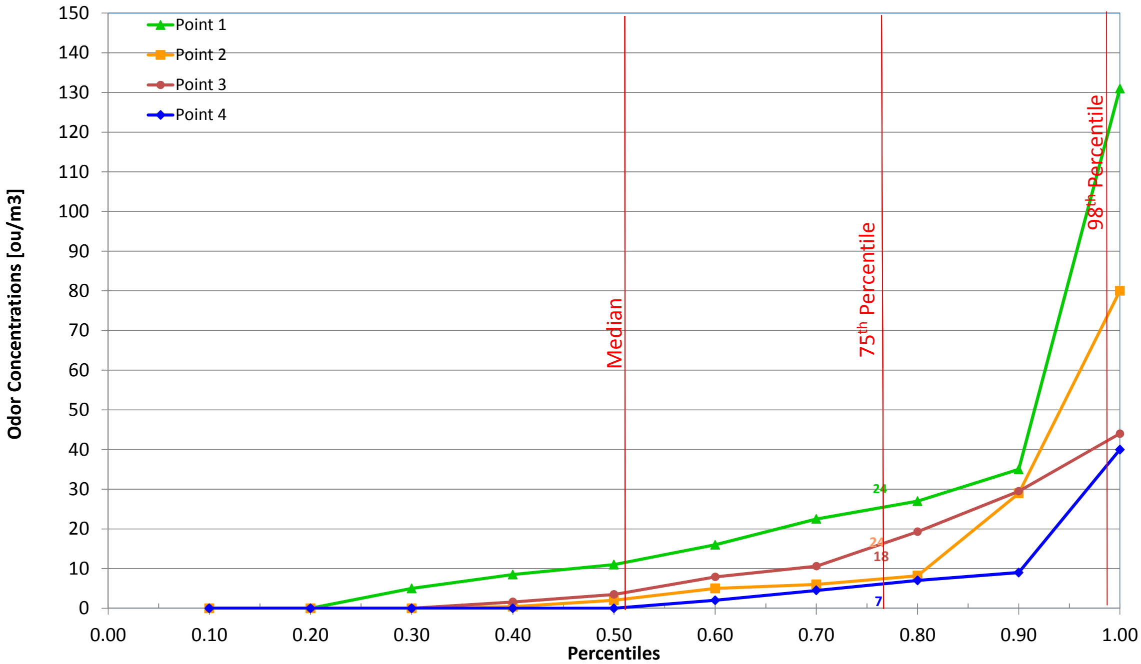

Figure 3-3 Example of Odour Data Distribution

In this graph, we can observe the magnitude for industries of having the 98th percentile as a set value for legislation. This graph and the cumulation of ambient data allow getting a new perspective of odour level variances and the set guidelines. For a nuisance perspective, the use of the 98th can be justified, but acquiring such data and graphs gives great information on the situation, it allows setting progressive goals and obtaining a realistic image of the situation.

3.4 Correlation with air contaminants

H_2S is often pointed out as being responsible for odours, though rarely can good correlations be found between these two contaminants. However it is possible to search for a possible chemical tracer; such quest must however be completed for each individual sites and cannot be extrapolated. The Table 3-1 presents an example of H_2S and odour measurements conducted in parallel, and the comparison of data from 2 different waste water treatment plants.

Table 3-1 Example of Odour and H_2S results at 2 different Wastewater Treatment Plants

Sources	WWTP-1 (Industrial)		WWTP-2 (Sanitary)	
	Odours [ou/m^3]	H_2S [ppm]	Odours [ou/m^3]	H_2S [ppm]
Sludge Dewatering building	290,000	0	208,000	135
Sludge Thickening tanks	70,000	0	184,575	135
Primary Sedimentation Tanks	16,425	5	94,850	52
Screen House	9,500	0	35,000	117
Clarifier	7,800	0	5,000	105

For WWTP-1, it is interesting to see that though odour concentrations are great at some sources, H_2S levels are negligible; this may be attributed to the fact that WWTP-1 treated industrial waters where there is hardly any decomposition of organic matter. In comparison, WWTP-2 had great H_2S concentration levels measure though no correlation is apparent between odours and H_2S.

3.5 Odour Dispersion Modelling Results and Comparison with Odour Patrol Results

It is important to conduct source sampling, olfactometric measurements and dispersion modelling in addition to the ambient patrol measurement. These results provide real actual measurements of the emitted odours with the respective contribution of each source with regard to various local meteorological conditions.

Once the dispersion modelling is completed, results can be stretched to present maximum and percentiles of impacts of each, of all or of certain group of sources. The value and differences of dispersion modelling results also provide

- Contribution and impacts of each sources, group of sources and/or all sources including elevated sources (ambient patrol measures gives common conditions and mostly measures impacts from ground-level or non-elevated sources);
- an indication of the distance of impacted areas;
- source prioritization used into the development of a mitigation plan.

For comparison perspective with the measured ambient patrol data, specific meteorological conditions (or days) could be looked at, and for selected sources. However the analysis should not forget that modelling cumulates the contaminants while odours blend together.

The combination of both dispersion modelling results with ambient measurements improves the understanding of the site, impacted areas, level and types of odours and therefore is required for the elaboration of a specific and adapted mitigation plan.

4 CONCLUSION

The combination of ambient odour measurements (on-site, at the fence-line and off-site) with odour emission sampling, olfactometric measurements, dispersion modelling, impact assessment with prioritization of the sources provides a complete and real study of sources behaviours and odour levels. It allows

- Achieving a better understanding of the problematic of the site;
- Recognizing the common conditions and variabilities;
- Investigating the site and sources prior to conducting strenuous source sampling;
- Developing an adapted mitigation plan that is specific to the sources, to the site and to the client objectives.

This approach also answers all requests from authorities and enhances communication routes. Its main goal is to improve the situation through mitigation and odour abatement rather than solely study the impacts using an air quality developed procedure.

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[i] EN-13725 : European Committee for Standardization has released an odor testing standard in 2001, entitled EN 13725: "Air Quality-Determination of Odour Concentration by Dynamic Olfactometry"

[ii] ASTM (E679-91) : American Society for Testing and Materials the standard practice in 1997 :"Standard Practice for Determination of Odor and Taste Thresholds By a Forced-Choice Ascending Concentration Series Method of Limits"

[iii] NVN2820 : Netherlands Normalization Institute (1996): "Air Quality. Sensory Odour 46 Measurement using an Olfactometer"

[iv] VDI 3881 : Germain" Verein Deutcher Ingenieure: "Olfactometry – Odour Threshold Determination";

[v] GB/T14675-93 :Great Britain's triangular bag method: "Monitoring of Air and Exhaust Odor, Olfactory Distinguish Members Triangle Odor Bag Method"'