Sewer Odour Monitoring and Abatement: A Survey of the Australian Industry

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Executive Summary

Under the Australian Research Council Sewer Corrosion and Odour Research (SCORe) linkage project, key members of the Australian wastewater industry have committed to enhancing the understanding of sewer odour related issues through the *Odour measurement and assessment, evaluation of odour treatment technologies* subproject (SP3). This subproject focuses on addressing existing knowledge gaps in the monitoring, operation, and design of odour abatement processes through literature reviews, field work, and experimental studies.

Understanding the existing context in which this work will fit is essential for achievement of the subproject objectives. A survey of participating industry partners (Barwon Regional Water Corporation, Gold Coast Water, Hunter Water Corporation, Melbourne Water Corporation, South Australia Water, South East Water Limited, Sydney Water Corporation, United Water International, and Water Corporation Western Australia) was conducted between June and September, 2009 to provide a baseline understanding of current industry odour assessment and abatement practices.

The results of the survey confirmed the appropriateness of SP3's focus on activated carbon, biotrickling filter and biofilter odour abatement processes, and indicated several trends within the industry:

- high level of use of adsorption based odour abatement processes (76.5% of processes);
- slightly over half of the adsorption based odour abatement processes were zeolite based filters (51.9%), although these units were used by only one industry partner;
- activated carbon based odour abatement processes are well distributed across nearly all industry partners;
- mixture of domestic and mixed sewage odour sources, minimal industrial only sites;
- most processes are passive flow;
- most sites are maintained in some form, but most are not being routinely maintained;
- activated carbon media is generally replaced in a reactive manner following failure

and the receipt of complaints;

- media saturation and moisture impacts are the dominant sources of odour abatement process failure, with other reported failures primarily mechanical in nature;
- many processes are being monitored solely through community complaints;
- H_2S is the dominant online and offline odour abatement process monitoring parameter, and the only monitoring parameter directly related to odours;
- significant variability in online H_2S monitoring instruments used across the industry;
- low level of process control being used in the industry, but given the dominant types of processes this is to be expected;
- H_2S is the dominant non-process monitoring parameter (although significant odour monitoring was reported);
- Apptek OdaLog instruments are widely used across the industry for non-process H_2S monitoring; and
- limited reports of non-H_2S odorant analysis (VOCs and reduced sulfur compounds).

There were significant limitations in the industry's ability to provide fundamental process data such as process age and treated gas flow for processes supplied by forced ventilation, in addition to process design data (design criteria and input characterisation), operating costs data, and process monitoring/complaints data. Furthermore, the industry partners were unable to identify the selection/design rationale for existing odour abatement processes, nor provide abatement process monitoring data. While it is likely that some of this data exists within the industry partners, it does not appear to be centrally stored in a readily accessible manner for use in decision making, planning, or abatement process design.

While the lack of existing data will not significantly impair the ability of SP3 to meet its objectives, the source of these data gaps warrants further consideration. While SP3 will provide insight into odorants/interferents present in sewer emissions and into the design and operation of odour abatement process operation during its lifetime, this knowledge is not static in nature and will continue to evolve long past the end of the project. The benchmarked monitoring tools developed as part of SP3 represent a valuable contribution to the continuing development of understanding and improving the design and operation of odour abatement processes. However, if the existing systematic gaps in data availability/storage continue into the future (past the end of SP3), these gaps will limit the benefits derived from the industry's ongoing collection of more comprehensive odour, odorant, and interferents data in addition to current, ongoing process and operational monitoring.

Recommendations

Based on the outcomes of the industry survey, several recommendations have been provided. With regards to the scope of SP3 and achieving the subproject's objectives, the following is recommended:

- due to the reported lack of industrial sewage dominated sewers (identified in the research plan) , SP3's focus should be adjusted to include mixed sewers in their place, in roughly equal proportion to domestic sewage dominated sewers; and
- with moisture being reported as a significant cause of activated carbon based odour abatement process failure, the planned activated carbon testing (which focuses on the impact of non-H2S odorants and interferents on process performance) should be supplemented to provide additional understanding of moisture related treatment failures (this can be conducted within the existing project budget).

While not explicitly required to achieve SP3's objectives (and beyond the current scope of SP3), the results of the industry survey have allowed the identification of several areas where additional effort could yield practical benefits to the industry:

- given the high variability in online H_2S instruments used across the industry, instrument benchmarking tests could be useful in assessing the comparability of the results and identifying if instrument standardisation is warranted;
- Apptek Odalog instruments are widely used across the industry partners for both offline and non-process H_2S monitoring purposes, with existing knowledge gaps in regards to specific sensor interferences and cross sensitivities, it would be beneficial to

further evaluate these instruments' performance;

- while the identified gaps in existing industry data (with regards to odour abatement processes and odour/odorant monitoring) will not directly impair the ability for SP3 to meet its objectives, enhancing data collection, storage and availability in these areas to enable the provision of more complete datasets to better support process selection and design (including providing a source of process evaluation independent of manufacturer claims) would be of benefit to the industry. For example improved tracking of process costs, performance, and key operating and design parameters such as odorant source characteristics, gas flow treated, odorant loading, and sorbent type/quantity (for adsorption processes) could allow for the identification of odour abatement process with superior performance in terms of odorant removal as well as operating cost and maintenance requirements. While this will be done for investigated process during SP3, odour abatement technology is not static and the industry would benefit from continuing to collect and assess this data following SP3's completion; and
- opportunities exist to enhance the handling of complaints data (for example correlation to local sources, data management/access, consistent descriptors, training in recognition), which would yield benefits to the industry through supporting process maintenance and troubleshooting.

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1.0 Introduction

The complex nature of sewer odours provides many challenges with regards to the management and control of these emissions, particularly in the design and operation of odour abatement processes. Under the Australian Research Council Sewer Corrosion and Odour Research (SCORe) linkage project, key members of the Australian wastewater industry have committed to enhancing the understanding of sewer odour related issues, and improving the design, operation and monitoring of odour abatement processes.

In particular, the industry has identified the following knowledge gaps with regards to the abatement of sewer odours:

- effective assessment of treatment efficiency for H_2S and VOC removal for existing odour abatement processes (activated carbon beds, biotrickling filters and biofilters);
- mechanism of failure/contamination of odour abatement technologies by VOCs, methane and organic sulphur compounds;
- cost effective assessment tool to establish removal efficiencies of organic sulphur compounds and VOCs;
- assessment methodology to consistently select, design and assess appropriate odour abatement technologies for the different sewer conditions and levels of odour compounds; and
- information to assess new odour abatement technologies.

Towards addressing these knowledge gaps, the *Odour measurement and assessment, evaluation of odour treatment technologies* subproject (SP3) has been developed with the objectives of developing an integrated monitoring and assessment protocol, developing a cost effective protocol for routine monitoring, providing information leading to improved odour abatement process design and operation, and evaluating the performance of selected odour treatment technologies.

SP3 incorporates literature reviews, field work, and experimental studies to achieve its objectives. Understanding the existing context in which this work will fit is essential for achievement of the subproject objectives. In particular, understanding existing industry practices with regards to odour assessment and abatement allows the identification of key areas of potential improvement to provide focus for ongoing research effort. Furthermore, it provides information to support the development of standardised assessment protocols, gives insight into current data storage and accessibility within the industry, and provides information on existing odour abatement processes to support the development of the field and experimental program.

A survey of participating industry partners (Barwon Regional Water Corporation, Gold Coast Water, Hunter Water Corporation, Melbourne Water Corporation, South Australia Water, South East Water Limited, Sydney Water Corporation, United Water International, and Water Corporation Western Australia) was conducted to provide the necessary baseline understanding of current industry odour assessment and abatement practices. Specific survey methodologies and overall response statistics are presented in **Section 2**. Current industry practices with regards to odour abatement and odour monitoring are discussed in **Sections 3** and **4**, respectively. These discussions will focus on the identification of trends in existing industry practices and knowledge gaps in the available information. A summary of existing knowledge gaps and key industry challenges, along with concluding remarks are provided in **Section 5**.

2.0 Methodology

Two surveys (one on odour abatement processes and one on odour monitoring practices, presented in Appendices A and B, respectively) were developed and distributed in June 2009 to the nine participating industry partners:

- Barwon Regional Water Corporation
- Gold Coast Water
- Hunter Water Corporation
- Melbourne Water Corporation
- South Australia Water
- South East Water Limited
- Sydney Water Corporation
- United Water International
- Water Corporation Western Australia

Combined, these industry partners serve over 8.4 million people and operate over 59,000 km of sewer networks, representing a major portion of the Australian wastewater industry.

Following survey distribution, a conference call was held with representatives from each of the participating industry partners to provide clarification of survey questions as needed. Surveys were completed and returned to the University of New South Wales (UNSW) between June and September 2009. Seven completed odour abatement surveys (78% response rate) were received, while the odour monitoring survey had a slightly lower response (6 responses, 67% response rate). It should be noted that these surveys only included odour abatement processes treating emissions from sewer networks, and not those installed at wastewater treatment plants.

Data from the surveys was collected by UNSW and merged into a database to allow information extraction, and the terminology used by the respondents was standardised to facilitate analysis. Analysis focused on extracting trends, although the depth of the analysis was limited by gaps within the dataset, which will be discussed along with the observed trends in industry odour abatement and odour monitoring practices in **Sections 3** and **4,** respectively.

3.0 Odour Abatement

The completed surveys indicated a significant number (204) of odour abatement processes being operated by the industry partners at 187 sites (some sites had multiple processes operating in parallel). A wide range of odour abatement processes were reported by the industry partners. Based on the fundamental process mechanisms (**Figure 1**), adsorption based processes such as activated carbon and zeolite based filters were dominant (76.5%), followed by biological processes (21.1%). This is likely indicative of the distributed nature of odour abatement in sewer networks and the requirement to treat at a large number of geographically separate sites, where the cost effectiveness and desire for a low maintenance solution favours adsorption based processes.

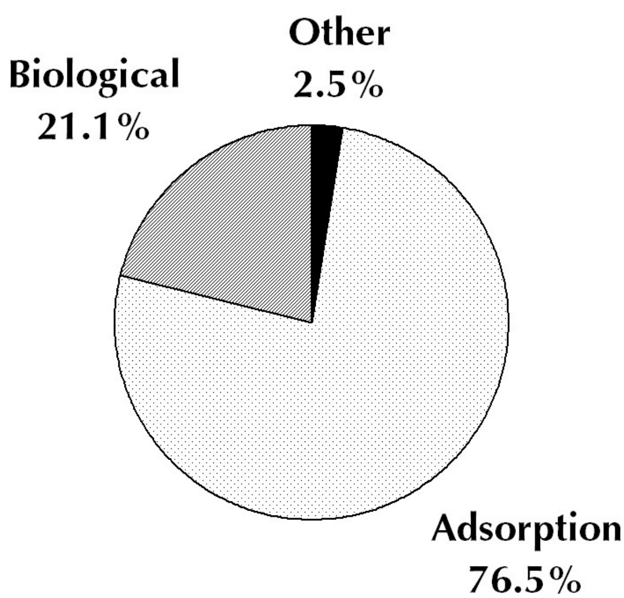

Figure 1 Overview of abatement process types (n=204).

In general, there was a similar distribution of odour abatement processes across all of the industry partners, although some used more biological processes than others, and one utility purely used adsorption based processes (zeolite filters). It should be noted that for all of the presented figures the sample size (i.e. number of odour abatement processes considered) is noted in brackets immediately following the caption, with 204 being the full odour abatement process dataset.

A very small minority (2.5%) of the reported processes did not fit into these two categories (such as chemical scrubbers and thermal processes) and were lumped into the "other" category. As these processes are not a focus of SP3 and are not in the direction industry is currently taking with regards to the installation of more sustainable processes, they will not be discussed further. A breakdown of the two dominant process categories (adsorption and biological) is provided as **Figure 2**.

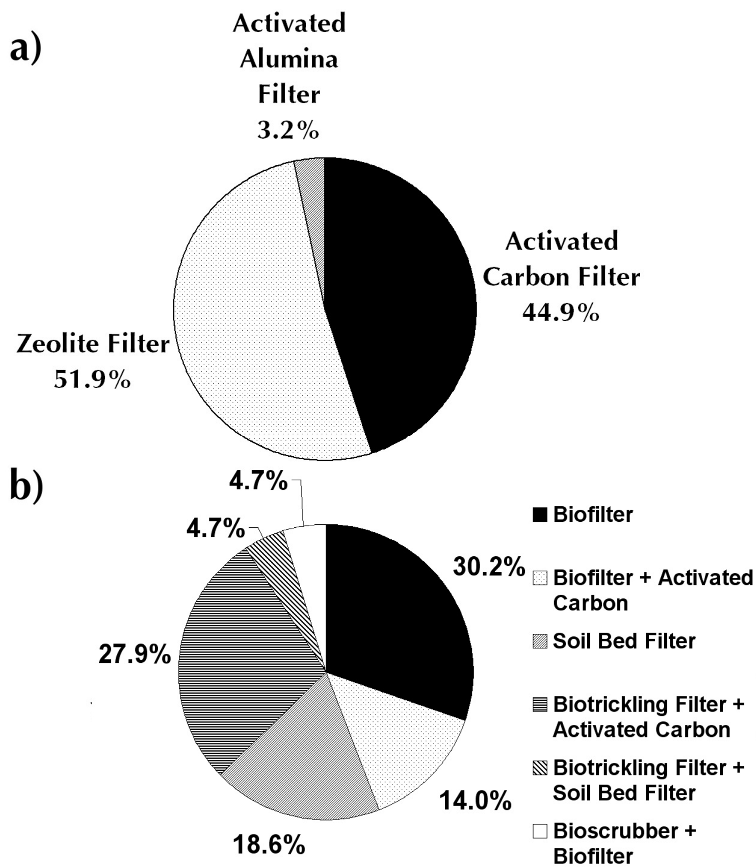

Figure 2 Odour abatement process types: a) adsorption (n=156); b) biological (n=43).

The **adsorption based processes** were dominated by two process types, zeolite filters and activated carbon filters. However, while activated carbon filters were employed by six of the seven responding industry partners, zeolite filters were only used (albeit extensively) by one industry partner. The widespread nature and high level of use of activated carbon processes (70 activated carbon processes compared to a total of 43 biological processes), confirms the relevance of SP3's objective of enhancing the understanding and design of activated carbon based odour abatement processes.

For **biological based processes**, biofilters were the dominant process at 44.2% of total biological processes, 62.8% if soil bed filters are included in this number. This likely reflects the less active nature of these processes and the prevalence of smaller, contained processes which are more suitable for distribution to multiple sites and require less ongoing supervision and maintenance than more complex biological odour abatement processes like biotrickling filters and bioscrubbers (32.6% and 4.7% of biological processes, respectively). All of the reported biotrickling filters and bioscrubbers utilise polishing processes (most commonly activated carbon) to ensure treatment integrity. While they will be reported separately based upon the polishing process in **Table 1** for the sake of completeness, all biotrickling filters and all bioscrubbers will be lumped regardless of the polishing process for the remaining analyses. The relatively high level of use of biofilters and biotrickling filters relative again supports SP3's focus on these two odour abatement process types.

Given the relatively small numbers of biological based odour abatement processes currently operated by the industry (**Table 1**), in particular for biotrickling filters (only 10 reported across all of the industry partners), there will be challenges in obtaining a statistically significant sample size to allow for the development of conclusions instead of being simply case studies. It may be necessary to supplement with odour abatement processes being operated at wastewater treatment plants (preferably those where the headworks are responsible for a significant amount of the emissions being treated) to provide a sufficient sample size. The need for supplementation will be discussed in the *SP3 Field and Experimental Plan*.

Table 1 Summary of surveyed odour abatement processes.

Process Type		Survey Sample Size (Number of Processes[1])
Adsorption	Activated carbon	70
	Activated alumina filter	5
	Zeolite filter	81
Biological	Biofilter	13
	Biofilter + activated carbon	6
	Soil bed filter	8
	Biotrickling filter + activated carbon	12
	Biotrickling filter + soil bed filter	2
	Bioscrubber + biofilter	2

[1]The number of processes refers to the number of discrete odour abatement processes being operated; some sites have multiple processes operating in parallel

Gas supply (type and flow rate) is a fundamental parameter for odour abatement process design and can have a significant influence on process selection and operation. A summary of process **feed types** is provided in **Figure 3**. Most processes are treating a passive sewer gas flow with a minority supplied by forced (fan driven) flow. While interesting, it is more useful to look for correlations between feed type (forced or passive ventilation) and process type (**Figure 4**).

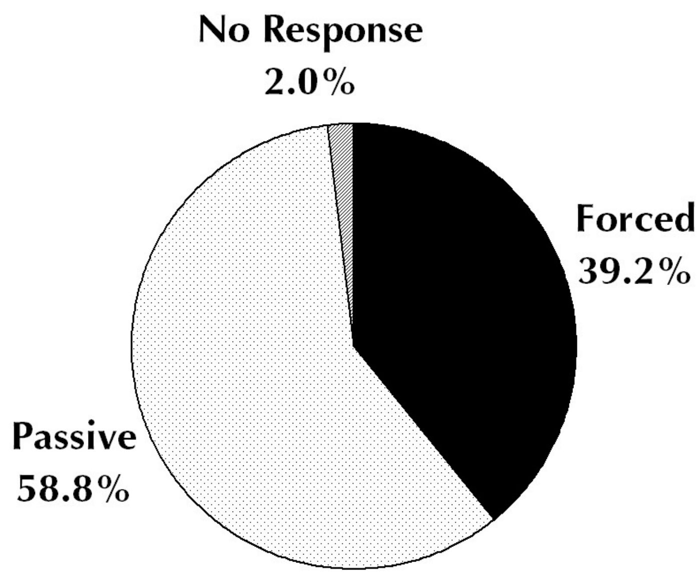

Figure 3 Odour abatement process feed supply type (n=204).

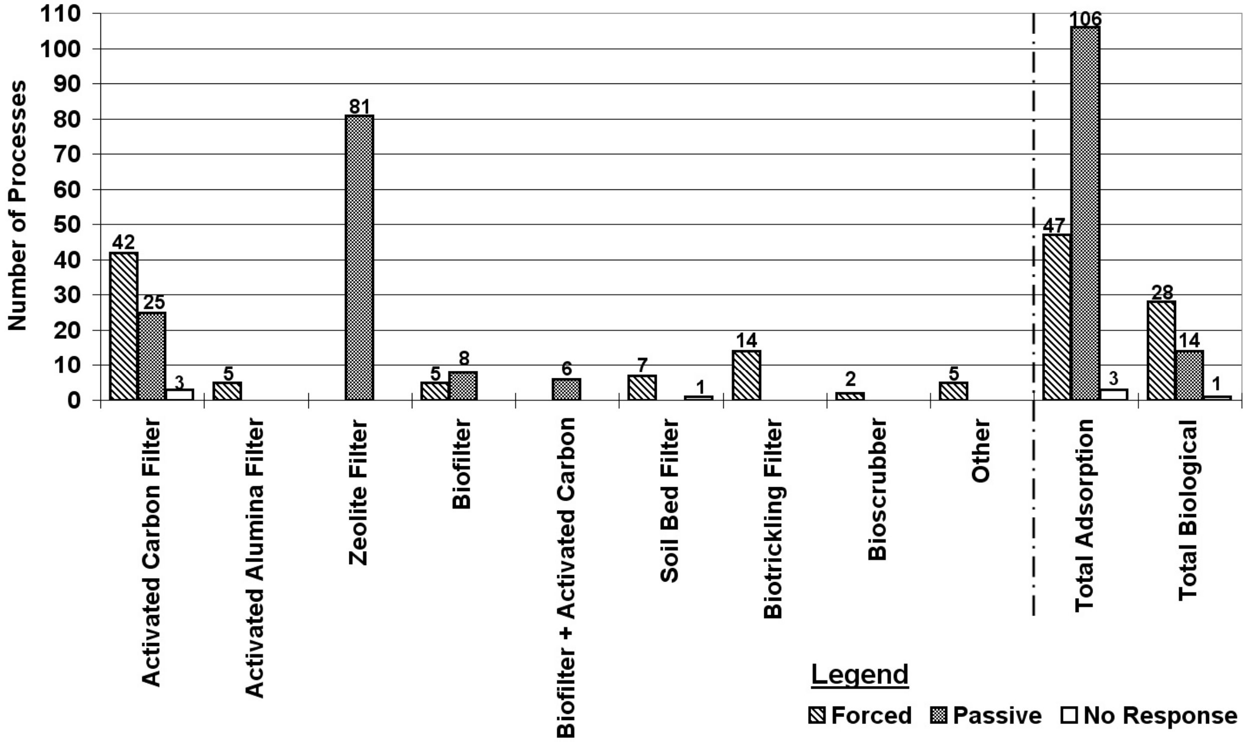

Figure 4 Analysis of odour abatement application by feed type (n=204).

Generally, adsorption processes were supplied via passive ventilation, along with a few of the lower maintenance types of biological processes (biofilters). This likely reflects the lower maintenance needs and better suitability for application at small, distributed sites. More technologically complex and controlled biological processes (such as biotrickling filters and bioscrubbers) are supplied through forced ventilation, though a large proportion of the reported activated carbon filters are also supplied using forced ventilation.

As a fundamental sizing parameter, the response to the **flow** survey questions was surprising. Only for 22.1% of the processes were the industry partners able to specify the flow through the abatement process. A breakdown of reported flow rates is provided in **Figure 5**, but the sample size (45 processes) is small when spread across individual processes. It had been intended to provide an additional dimension to the data analysis by assessing response trends with respect to process size, but the dataset was too small to allow any meaningful conclusions to be drawn from such an analysis. While it would be expected that providing flow data for passively ventilated sites would be problematic (indeed only 11.6% of passively ventilated sites had flows reported), a high response rate was expected for the forced ventilated sites where fans are operated since this data should be readily available. However, flow data was only provided for a minority (38.8%) of forced ventilated sites. This lack of fundamental data suggests limitations in either data storage or data availability.

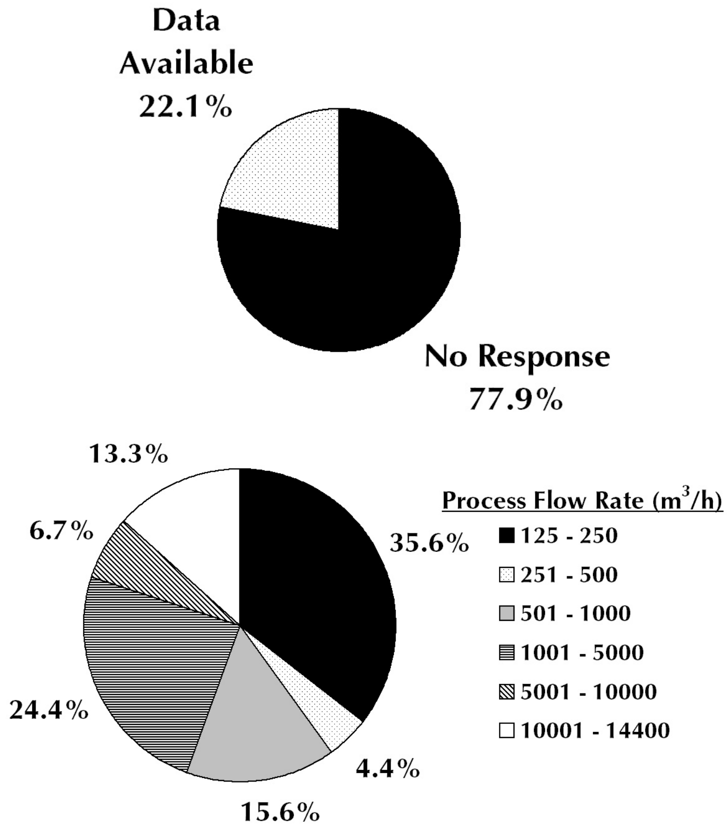

Figure 5 Odour abatement process size: data availability (left, n=204); process size (right, n=45).

The industry survey also requested information with regards to the **dominant sewage type** (domestic, industrial, or mixed) responsible for the emissions being treated by each odour abatement process. Overall, the industry had an excellent (97.5%) response rate to this question (**Figure 6**).

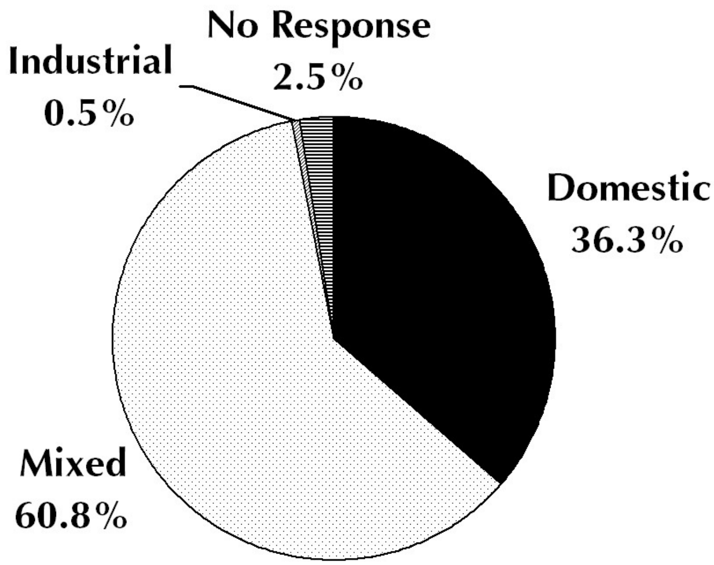

Figure 6 Dominant sewage odour source for abatement processes (n=204).

Existing odour abatement processes are operating on predominately (60.8%) mixed sewers (containing both domestic and industrial wastewater), with the remainder of the processes operating on domestic sewers. Only one site was reported as being an industrial sewer across all of the respondents. With a lack of industrial sewers, the provision in the SP3 research plan for Phase 4 (odour abatement process and sewer monitoring campaign) for selection of sites with "sewerage composition being predominately domestic or industrial" must be modified to focus the monitoring on domestic and mixed sites instead. 81 of mixed sites were reported by a single industry partner (100% of their sites), for the other partners domestic sites were dominant (60.2%), with a lesser proportion of the sites being reported as mixed (35%). Given the potential bias in the data, it is recommended that the selected monitoring sites be equal distributed between mixed and domestic sites.

To assess the impact of sewage type on process selection (potential link for common feed types to typical odorants) a breakdown of odour abatement processes compared to sewer type (domestic or industrial) is provided as **Figure 7**.

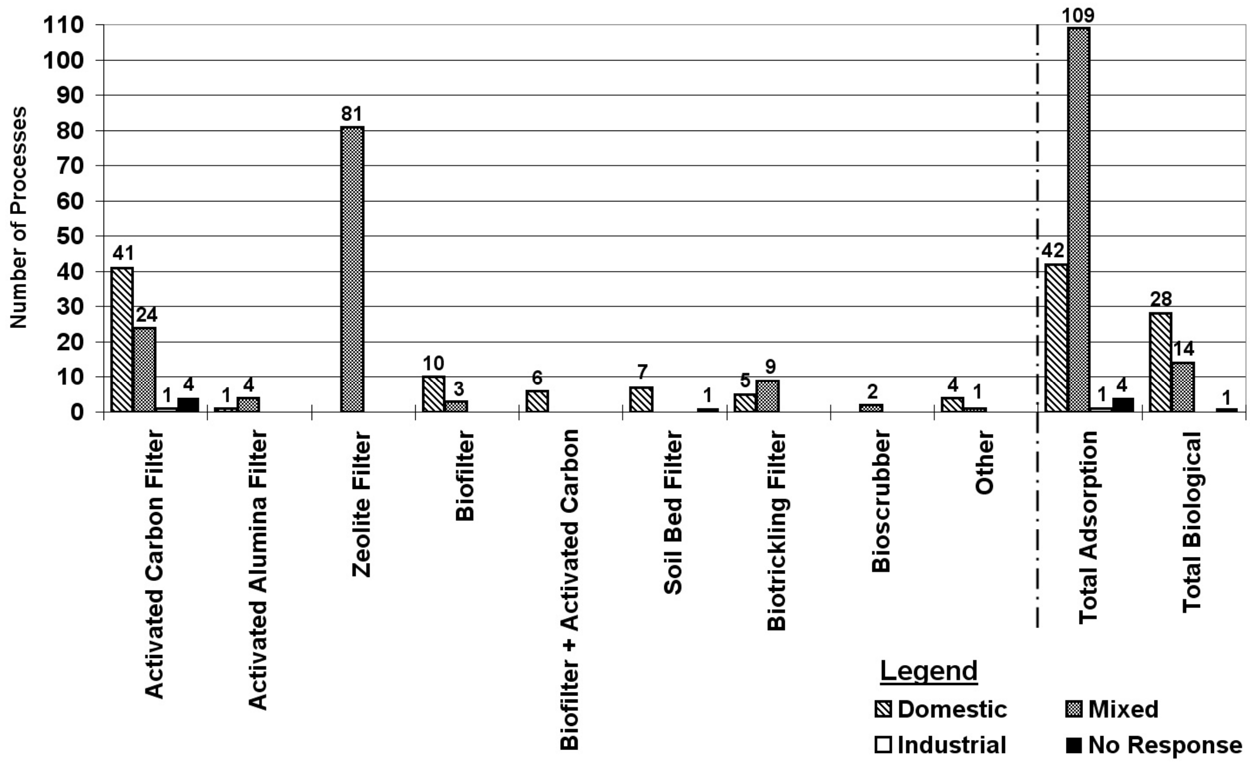

Figure 7 Analysis of odour abatement application based on sewage type (n = 204)

With the small sample sizes for most of the individual process types, the practices of a single industry partner or process designer have the potential to strongly bias the results. The sample size for total adsorption and biological based processes and for activated carbon processes are more substantial and were assessed for trends. There is strong application of adsorption based processes on mixed sewers, while activated carbon and biological based odour abatement processes are mainly applied on domestic sewers. This distribution is reflective of the source distribution for the industry partners reporting these process types and given the lack of design information (discussed in **Section 3.1**), it is likely that the source sewage type is not being considered in odour abatement process selection and design. It is possible this is the direct result of the current lack of understanding of specific odorants in sewer emissions and with the impact of sewage type on odorants, in addition to the lack of tools to obtain information to address these gaps.

The final general process information question in the survey requested the **age** of installed odour abatement processes. This was a fundamental piece of process information which tested basic data collection and accessibility with regards to the installed odour abatement processes. The response was quite poor, only 33.3% of sites had the process age identified. Anecdotally some industry partners have noted that many of the sites from the 1980s do not have any specific information. Looking at sites compared to installation year (**Figure 8**), there appears to be a trend towards increasing application of odour abatement technology in sewer networks, but given the large number of sites with no data and that more recently constructed sites would be those most likely to have their age identified even if record keeping is poor (due to presence of staff involved in their installation), it is likely that the dataset is inherently biased towards newer processes and no conclusions can be drawn with regards to temporal trends in the application of odour abatement processes in the industry. Again, the results demonstrate gaps in industry record keeping/availability of fundamental process data.

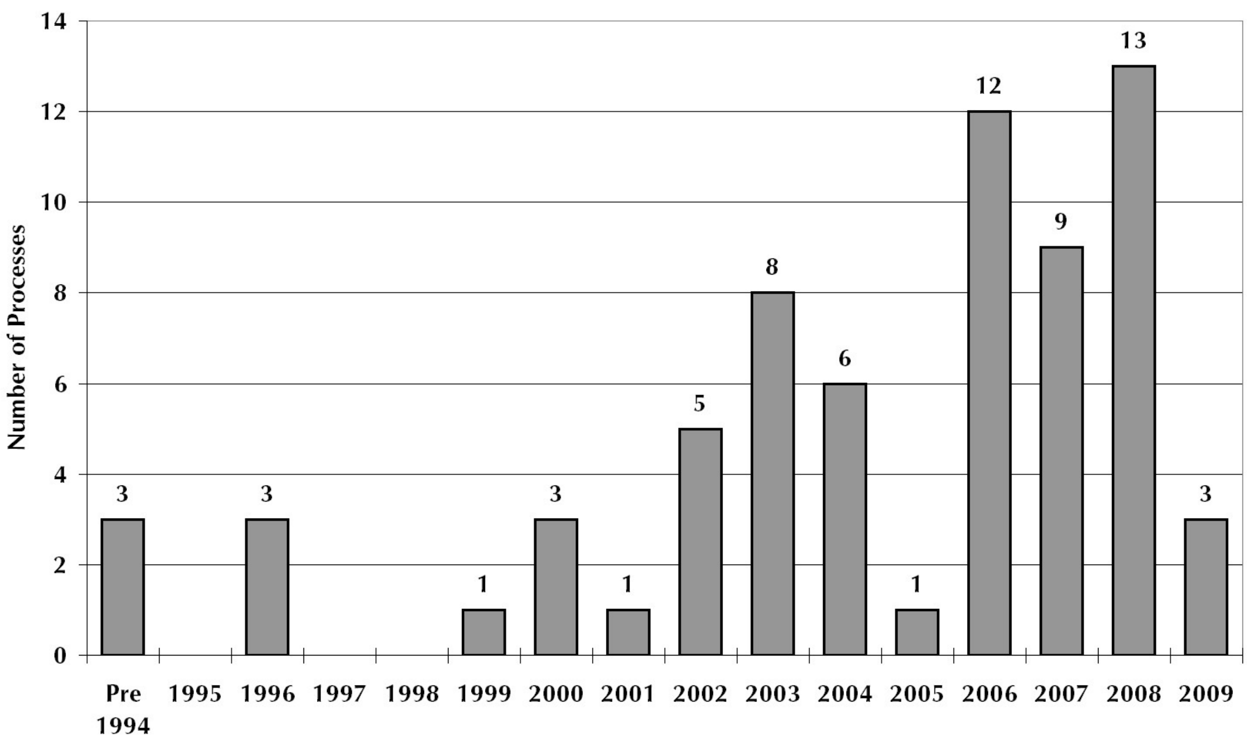

Figure 8 Odour abatement process installation year (n=68).

3.1 Design and Selection

As one of the key objectives of SP3 is to provide enhanced data to allow for the improvement of odour abatement process design, current industry design practices are of interest to understand the context into which the SP3 project objectives must fit. The first aspect of interest is the **performance criteria** used to evaluate odour abatement processes (**Figure 9**).

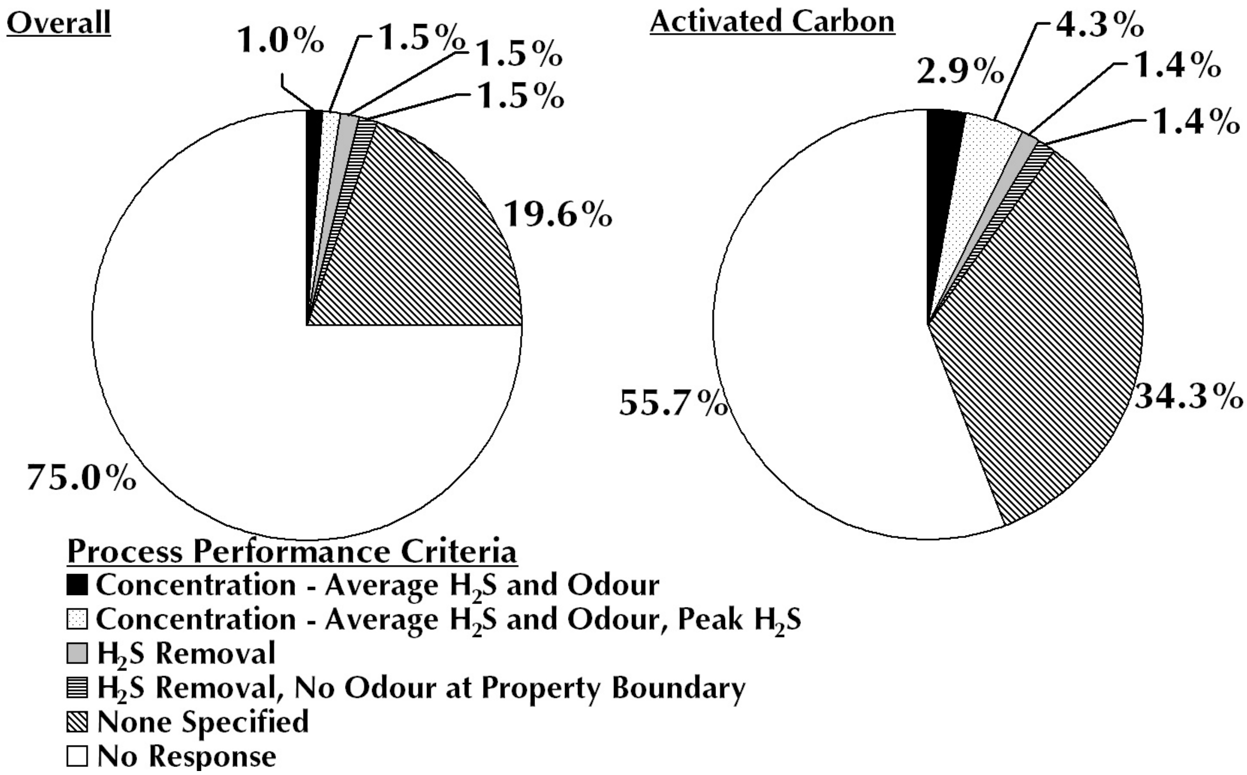

Figure 9 Odour abatement process design performance criteria: overall (left, n=204); activated carbon (right, n=70).

The overall results once again demonstrate significant gaps with regards to data storage and collection within industry partners, with no response being given for over 75% of odour abatement processes. It was confirmed that no performance criteria were specified for 19.5% of the processes leaving a staggeringly low (5.5%) of processes with identifiable performance criteria. With small sample sizes for most processes, only activated carbon based processes (**Figure 9**), which are well distributed across 6 of the 7 responding industry partners, can be assessed on their own. Although with slightly better data availability than the other odour abatement process types (data was provided for 44.3% of the activated carbon based processes), once again a large proportion of the processes have been designed without performance criteria. It is not possible to draw any significant conclusions about specific design criteria being used since they were only reported by three of the seven respondents for a small number of their odour abatement processes.

The use of **performance guarantees** (**Figure 10**) for odour abatement processes installed on sewer networks was limited (reported for 4.9% of processes). The sample size is insufficient to asses any trends or impacts on process performance related to the use of performance guarantees. Of the ten reported processes with performance guarantees (reported by two of the industry partners), seven met the guarantees, while two did not and no compliance data was provided for the remaining process.

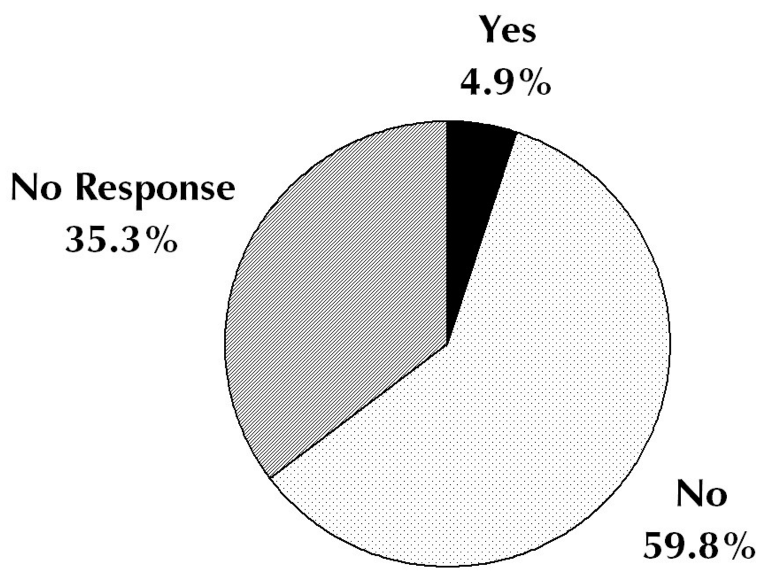

Figure 10 Use of performance guarantees for odour abatement processes (n=204)

With regards to **data supplied for design purposes**, there were once again significant gaps in response from most of the industry partners. Overall, no response was provided for 75% of the sites, while it was reported that no data was provided to the designers for 19.6%, leaving a small minority (5.4%) of odour abatement processes where design data was provided. These results mirror the performance criteria results in terms of data availability.

Supplied design data for activated carbon based odour abatement processes are summarised in **Figure 11**. It should be noted that the results are presented as the percentage of the processes with a specific data type provided and multiple data types can be supplied for a single process, i.e. the overall sum of the responses can be greater than 100%.

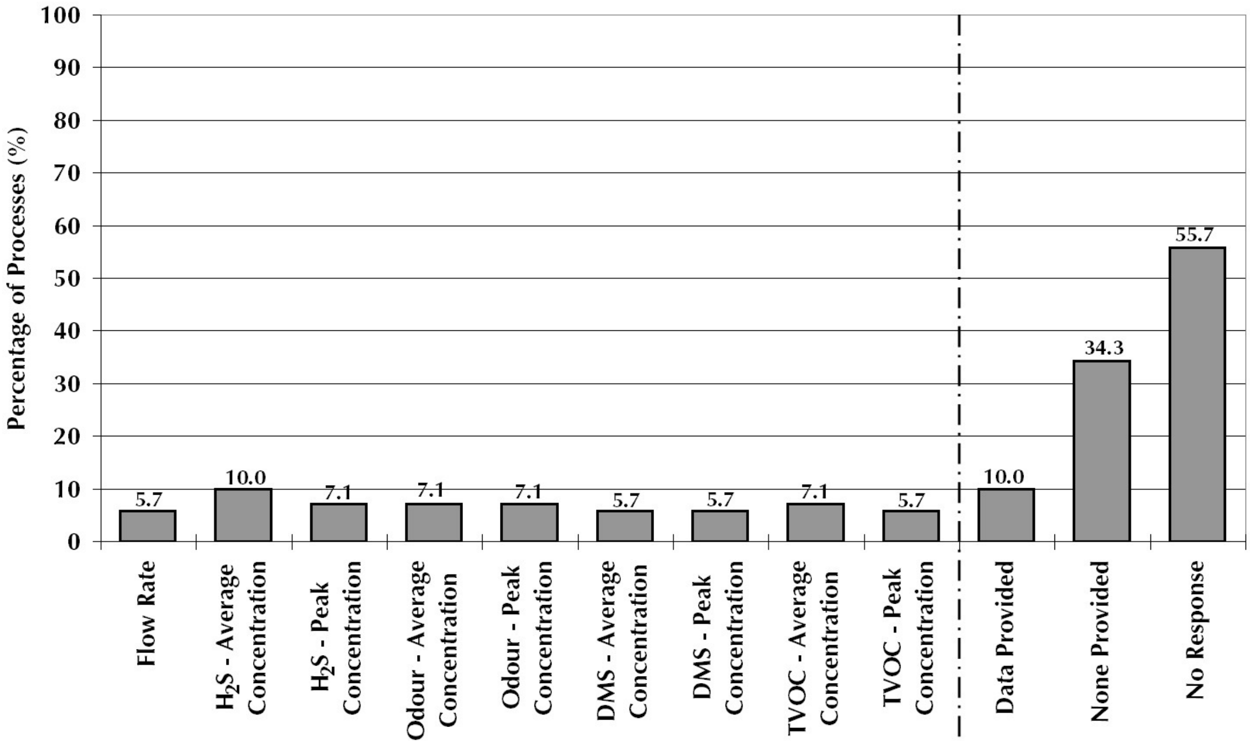

Figure 11 Data provided to designers for activated carbon odour abatement processes (n=70).

There appears to be a fairly even distribution of the types of data being provided (H_2S, odour, dimethyl sulfide (DMS) and total volatile organic compound concentrations (TVOC)). It should, however, be noted that design data was only provided for 10% of the activated carbon based odour abatement processes, all of which were reported by two of the industry partners. Like the general case, the majority of the activated carbon processes were designed with no data (34.3%), or no response was provided (55.7%). Of the processes where design data was identified (all of which were supplied using forced ventilation), inlet flow data (a fundamental design parameter) was only provided for slightly more than half (57%) of them.

A summary of the design provided for other process types in included as **Table 2**. A reduced range of data types were used for non-activated carbon based processes. Due to the small sample sizes for individual processes, no significant conclusions can be drawn with regards to the results.

Table 2 Data provided to designers for non-activated carbon odour abatement processes (n=134).

Process Type	% of Processes Where Data Type Was Provided to Designer				
	Flow Rate	Average H_2S Concentration	Average Odour Concentration	None Provided	No Response
Activated Alumina Filter	0	0	0	0	100
Zeolite Filter	0	0	0	0	100
Biofilter	0	0	0	76.9	23.1
Biofilter + Activated Carbon	0	0	0	100	0
Soil Bed Filter	0	0	0	0	100
Biotrickling Filter	14.3	28.9	7.1	0	71.4
Bioscrubber	0	0	0	0	100
Other	0	0	0	0	100

3.2 Operation and Maintenance

Industry partners were also questioned during the survey about the operation and maintenance of existing odour abatement processes. Overall there was a good response rate (84.8%) throughout the industry with regards to providing maintenance information (**Figure 12**, left). However, for these same processes, routine maintenance programs (**Figure 12**, right) were in the minority (16.7%). While there were many activated carbon based odour abatement processes reported as being routinely maintained (inspections or a set media replacement frequency), as expected there was a very high level of routine maintenance programs reported for the more complex and maintenance demanding process types (biotrickling filters and bioscrubbers). The overall low level of **routine maintenance** programs in the industry reflects the "set and forget" approach currently being applied to many adsorption based odour abatement processes, which are often only maintained in a reactive manner when there is evidence of a process failure (often by complaints). This approach will be further evidenced in **Section 4.3** when looking at offline process monitoring practices.

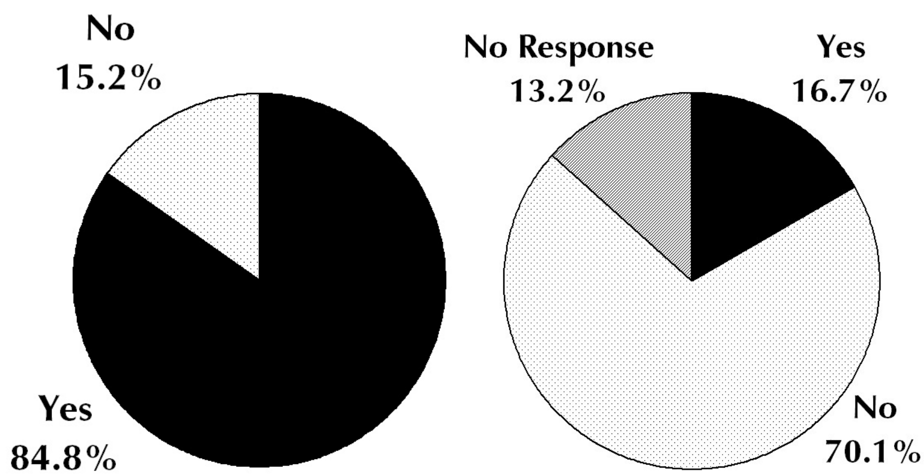

Figure 12 Odour abatement process maintenance: data availability (left, n=204); routine maintenance program (right, n=204).

Odour abatement process **maintenance/operating cost** data was provided for a subset (28%) of the reported processes (predominately by one respondent), but given the variable nature of the type of data provided (for some processes total costs were reported, while for others media costs only) and the lack of fundamental sizing information (e.g. flow treated, media volumes) for most odour abatement processes, it was not possible to assess the relative operating costs of the installed processes and draw any meaningful conclusions with regards to their cost effectiveness.

Overall, there appeared to be a low level of tracking/data availability with regards to specific odour abatement process installation, operation and maintenance costs. The availability of cost data for installed, full scale odour abatement processes would be a very powerful tool to support the evaluation and selection of odour abatement processes and assist in identifying underperforming processes.

The industry data did provide a significant amount of information with regards to **media replacement frequency** for activated carbon based odour abetment processes. A summary of this data is provided as **Figure 13**.

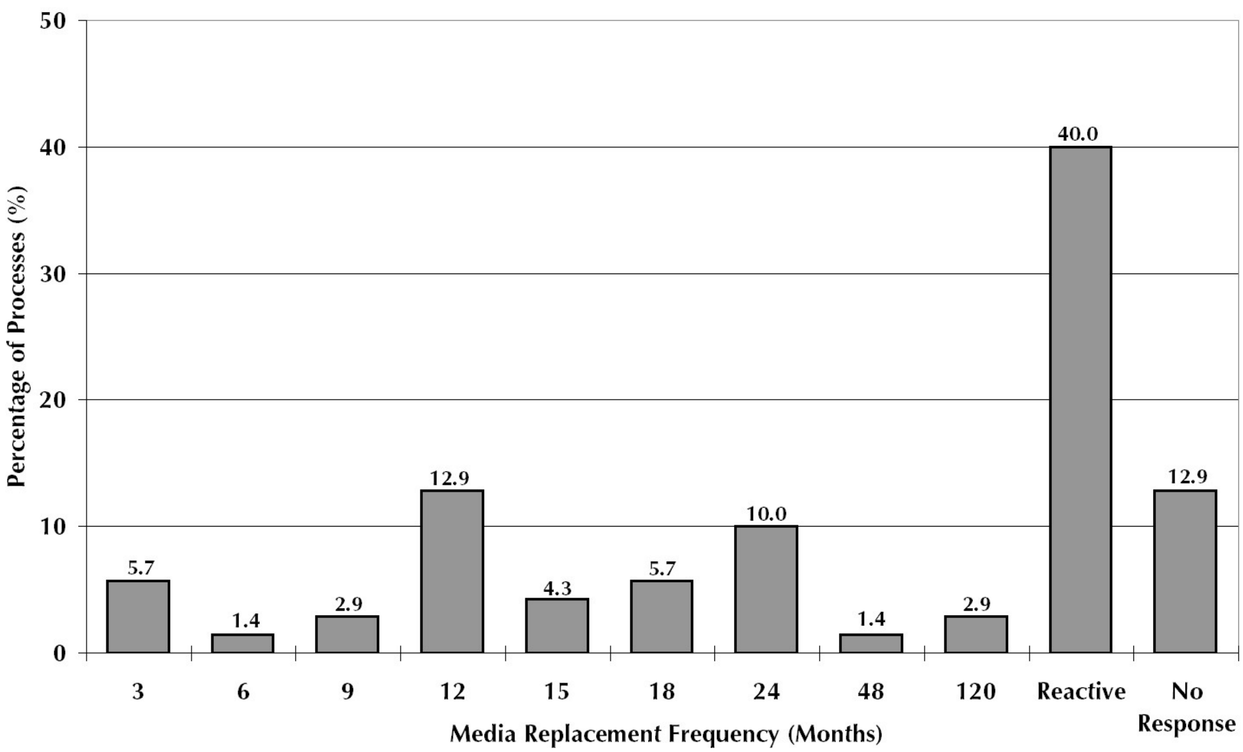

Figure 13 Media replacement frequency – activated carbon odour abatement processes (n=70).

In general, many (40%) activated carbon based odour abatement processes are operated in a purely reactive manner where media is replaced following evidence of odour breakthrough. A slightly larger number (47.1%) are operated in a more proactive manner with media replacement frequencies ranging from three months up to ten years. Most processes had their media replaced on an annual or biannual basis, although some processes were reported to have frequently media replacements (every three to six months) and may be either be undersized, impacted by non-H_2S odorants or interferents, or are being saturated with moisture from the gas being treated. Lacking process sizing and design data, is not possible to draw any specific conclusions with regards to specific activated carbon based processes. While not requested in the survey, obtaining and tracking data with regards to the designed media lifespan (based on H_2S) compared to the actual media replacement frequency for the installed process would provide additional insight into activated carbon performance.

Participating industry partners also provided information on the **identified sources of odour abatement failure events** (**Figure 14**). It should be noted that multiple failure sources were identified for some processes and thus the sum of the counts in the figure are greater than the total sample size.

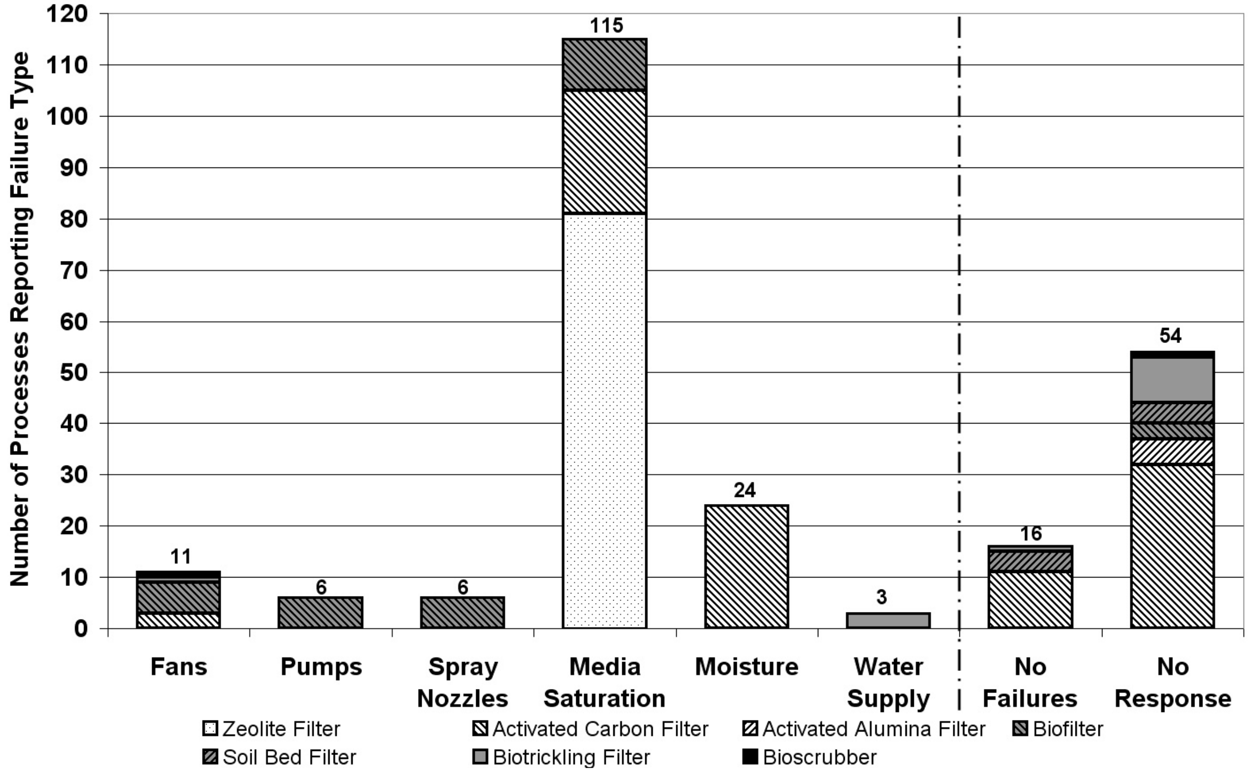

Figure 14 Reported sources of odour abatement process failure (n=204).

As seen in **Figure 14**, media saturation is the dominant reported source of odour abatement failure. This reflects the dominance of adsorption based processes (activated carbon and zeolite filters), for which media saturation would be the expected primary source of failure. No information provided for a large number of processes (54 process, equivalent to 28% of the reported processes). Fan failure was identified as a failure source for a number of odour abatement processes supplied via forced ventilation, and other mechanical sources of failure (pumps, spray nozzles, water supply) were identified for biofilters, biotrickling filters, and bioscrubbers. While moisture build-up in activated carbon was also identified as a failure mechanism by one industry partner (for 24 activated carbon processes), anecdotal evidence indicates that this issue may be more widespread in the industry than indicated in the survey. Investigation of activated carbon media saturation by odorants (VOCs and sulfur compounds) and interferents (non-odorous substances which interact with the absorbent) is currently planned as part of SP3. Additional assessment of the impact of moisture on activated carbon may be warranted.

Overall, application of process control in the industry (**Figure 15**) is quite limited (3.4% of processes) and restricted to biotrickling filters and bioscrubbers. This would be expected given the makeup of the industry's odour abatement process portfolio, which is dominated by processes with few to no control handles such as adsorption processes and biofilters. Very little data was provided with regards to the specific control methodologies applied, i.e. whether off-gas H_2S data is being used as an odour surrogate and process operating parameters are being adjusted to maintain as desired level of removal, or instead (and most likely) if existing process control is purely focused on maintaining specific operating parameters (such as pH or water levels) at the desired settings.

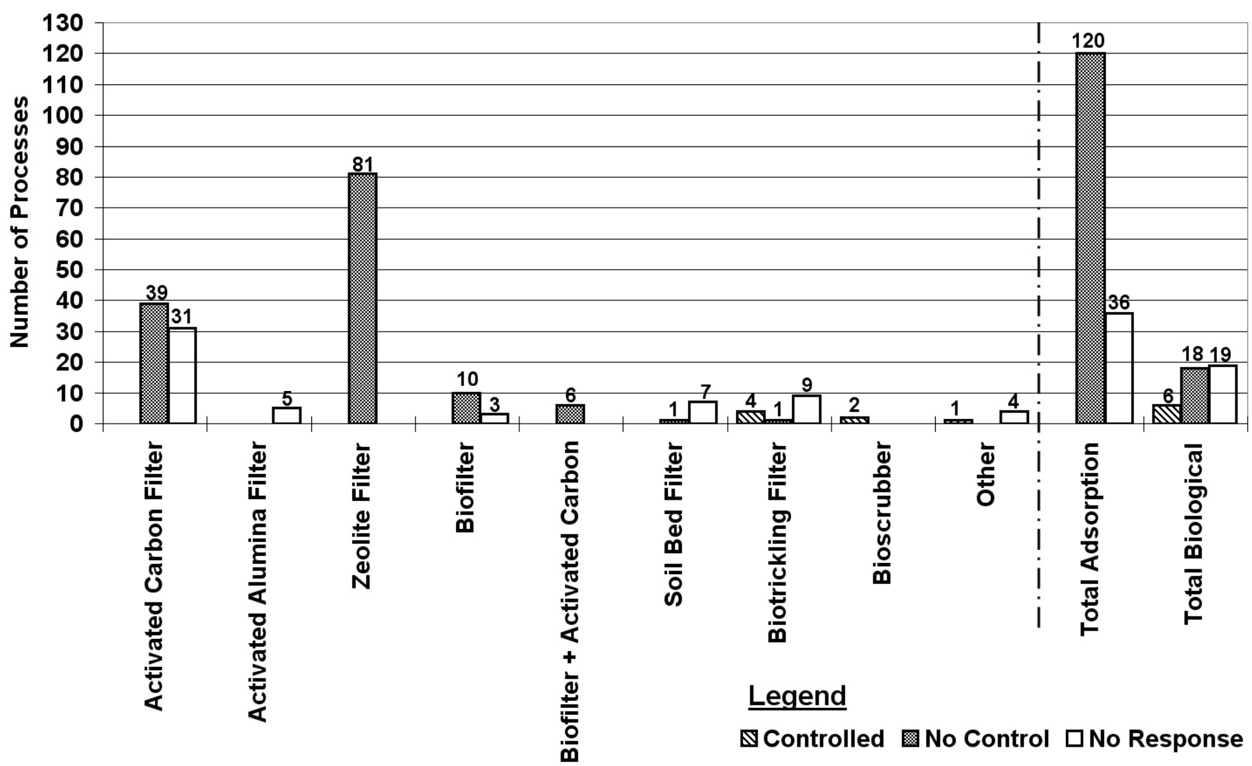

Figure 15 Odour abatement process control (n=204).

Odour abatement process performance data was also requested in the survey. No inlet/outlet H_2S monitoring data or any other performance data was provided by any of the respondents. This was despite industry assertions that such data was readily available, and (as will be presented in **Section 4.0**) many sites having been identified as being routinely monitored. The lack of readily available process monitoring data highlights limitations in data handling within the industry partners.

Despite significant anecdotal evidence of complaint data, only four of the industry partners provided complaint data (for a small subgroup of their processes), and of that only three industry partners had paired pre and post installation odour complaint data. These paired data sets, however, only represent a small portion of the reported processes (19 processes, 9.3%) and are not sufficient to draw conclusions with regards to process performance. It is unknown if the lack of data is an issue of storage (retention) or accessibility within organisations, or if complaints are not being linked to potential sources in the relevant geographical area. Enhancements to complaint data handling procedures (including data management and accessibility, developing a set of consistent odour descriptors, and training both staff handling complaints and those working on/around odour abatement processes to understand and recognise the key odour descriptors) could provide the industry with additional tools to better support the maintenance and troubleshooting of odour abatement processes, particularly for processes that are being monitored solely through community complaints.

4.0 Odour Monitoring

Odour monitoring practices were evaluated as part of the odour abatement monitoring survey (focusing on process monitoring) and as a separate odour monitoring survey (encapsulating all other odour monitoring activities).

4.1 Odour Abatement Process Monitoring

A wide range of process monitoring options exist, from online and offline instrumentation, to sensory assessment and community complaint data, along with combinations thereof. An overview of odour abatement process monitoring employed by the industry respondents is presented as **Figure 16**.

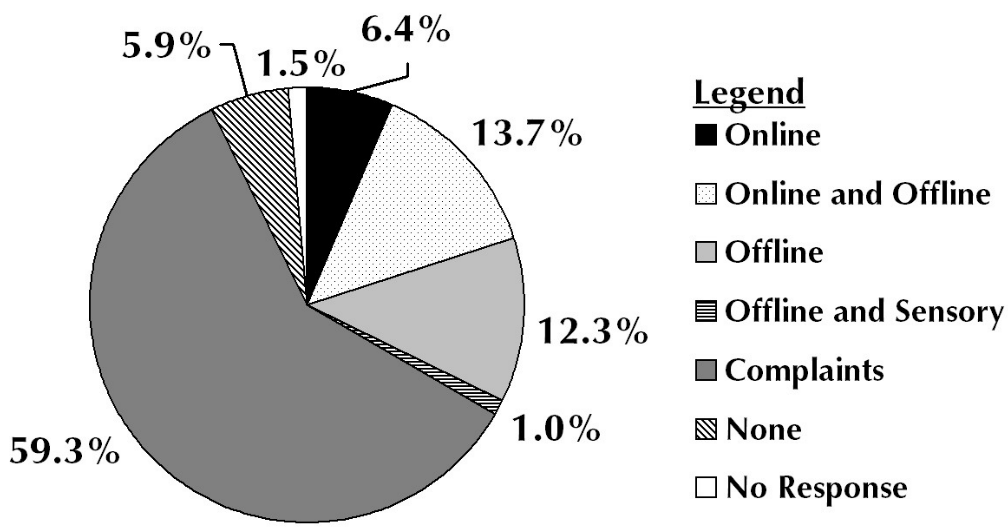

Figure 16 Overview of odour abatement process monitoring (n=204).

Online monitoring was reported for 20.1% of existing odour abatement processes, offline monitoring for 26% of processes, and 5.9% of the processes were completely unmonitored. 59.3% of the odour abatement processes were reported as being solely monitored through complaints from the surrounding community, reflective of the "set and forget" approach to odour abatement discussed previously in **Section 3.2**.

With a high response rate (98.5%), it was possible to assess the process monitoring type data in greater depth (versus process type). A summary of monitoring conducted for adsorption based odour abatement processes is presented as **Figure 17**.

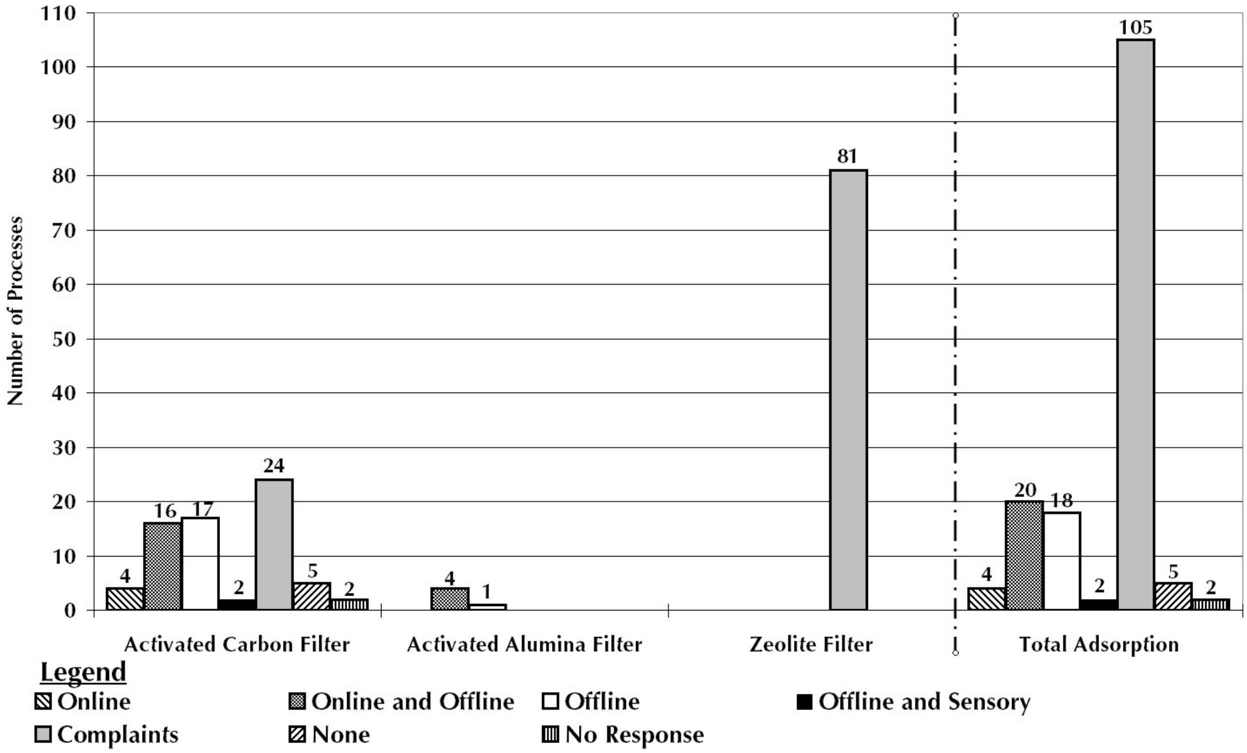

Figure 17 Adsorption based odour abatement process monitoring (n=156).

Overall, the adsorption based odour abatement process monitoring responses was dominated by zeolite filters, which are wholly monitored using odour complaints. This is a much more even distribution amongst activated carbon based processes. Lacking process size data, it was not possible to explore potential linkages between process size and the level/complexity of process monitoring and instrumentation.

A different process monitoring distribution was reported for biological based odour abatement processes (**Figure 18**). The relative increase in the application of online and offline process monitoring compared to adsorption based processes is likely a result of the relative complexity of many of the biological processes and the associated monitoring demands. Process monitoring for biofilters, on the other hand, was similar to adsorption based processes, primarily through complaints data only.

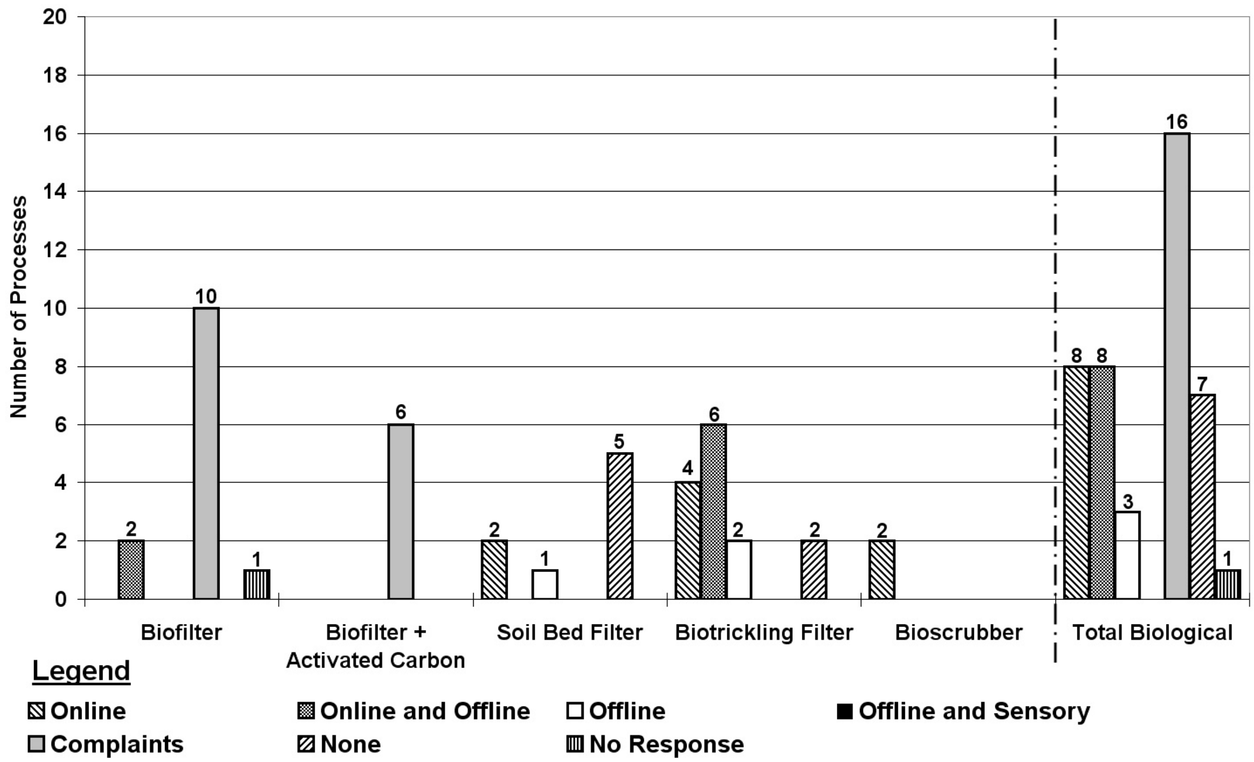

Figure 18 Biological odour abatement process monitoring (n=43)

With the broad trends in process monitoring established, a more in depth analysis of online (**Section 4.2**) and offline (**Section 4.3**) process monitoring is presented next.

4.2 Online Process Monitoring

As noted in the previous section, online process monitoring was reported for 20.1% of existing odour abatement processes, and for nearly all process types. A breakdown of specific parameters reported as being monitored online is provided as **Figure 19**. These results are presented as a percentage of total sites with where online process monitoring was reported. As multiple parameters are simultaneously monitored at some sites, the total presented in **Figure 19** is greater than 100%

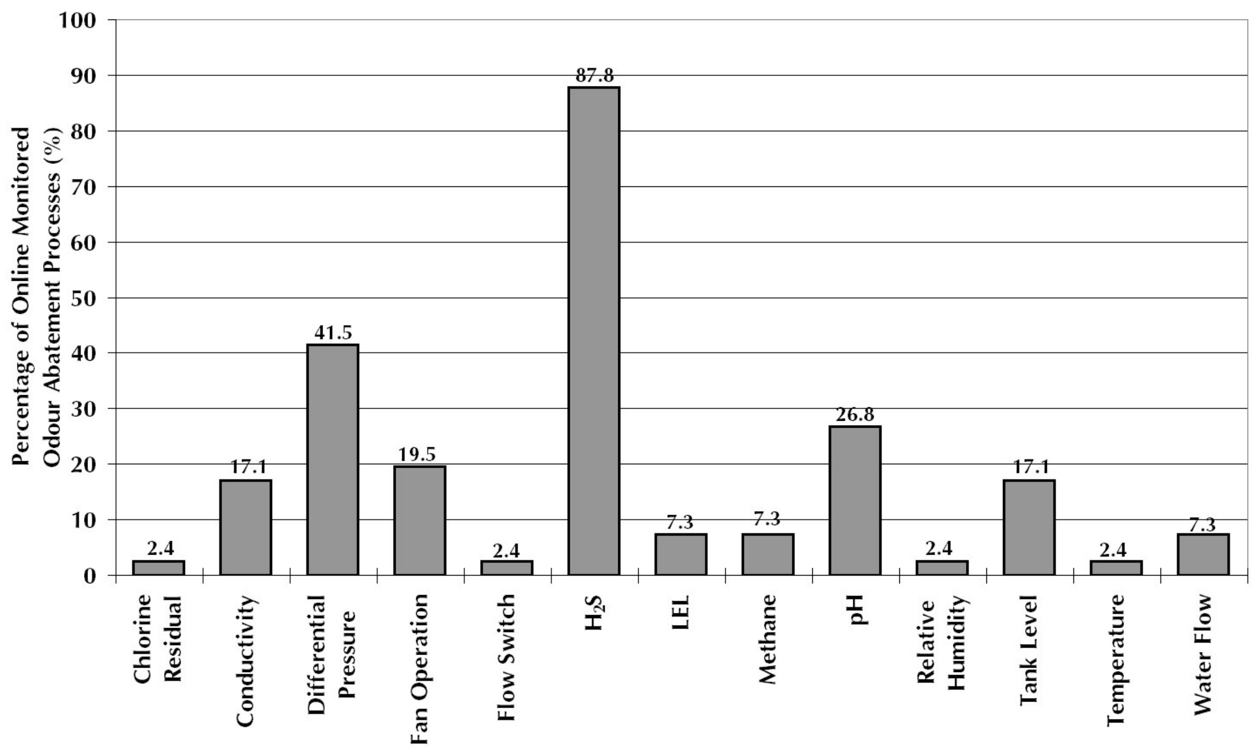

Figure 19 Online monitoring parameters (n=41).

While a range of monitoring parameters were reported, H_2S was the dominant monitoring parameter, used for 87.8% of online monitored processes. H_2S was also the only reported monitoring parameter with the potential to be directly related to odour emissions. This is in line with industry practice in most other jurisdictions, where H_2S is also the dominant sewer odour abatement process monitoring parameter. The remaining process monitoring was focused on specific operating parameters, with the sole exception of methane (a non-odorous substance, but one that has potential to impair abatement performance). No specific details were provided with regards to the use/rationale for online methane monitoring.

Information was also requested with regards to how the online data was utilised (**Figure 20**). Generally a single response was given for each process, which did not indicate the use of the individual parameters when multiple parameters were indicated for a single process (often the case), thus an analysis could not be conducted with regards to the use of specific parameters. Respondents indicated that the dominant use of the data was for decision making and diagnosis purposes (70.7%). For 24.4% of the processes, the respondents did not indicate how the information was being used, and the online process monitoring data was leveraged for process control for only in 14.6% of the processes.

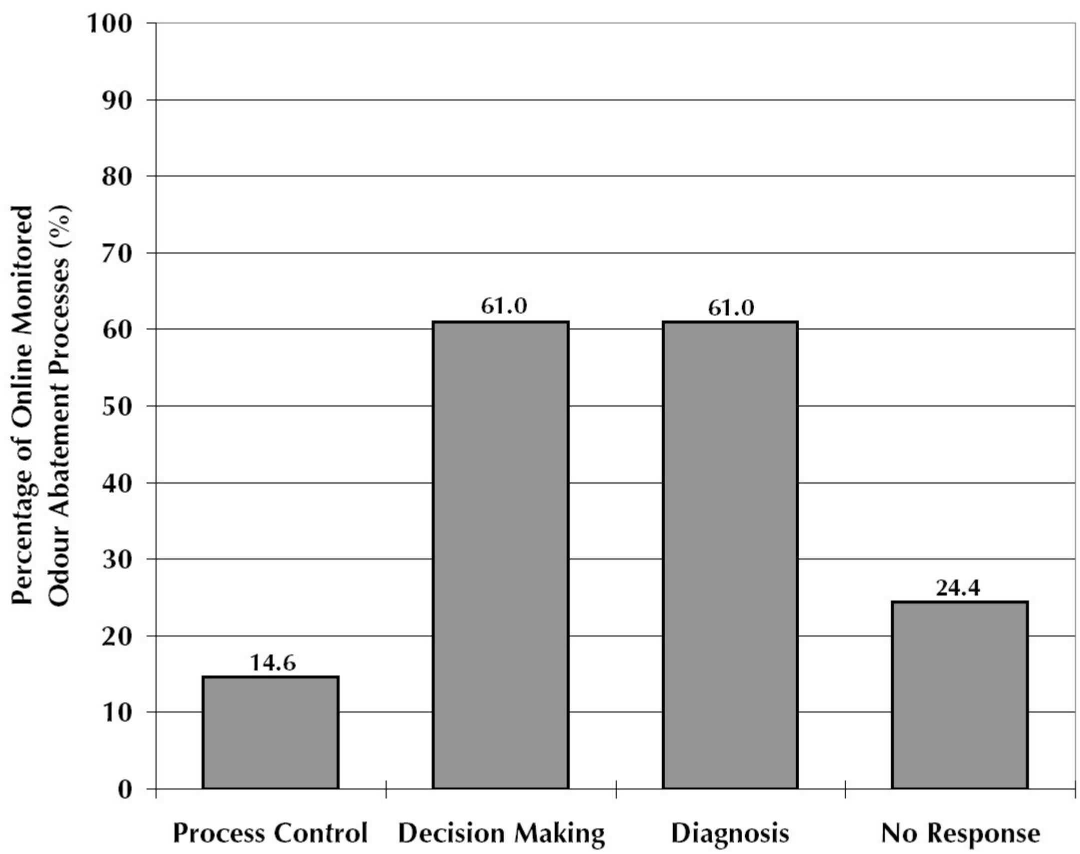

Figure 20 Purpose for conducting online monitoring (n=41).

As the dominant online monitoring parameter for odour abatement processes (and the only performance monitoring parameter), a summary of the specific instrumentation utilised has been provided as **Figure 21**. It should be noted that some sites could have multiple instruments for inlet/outlet monitoring, but were only counted as a single site since specific instrument numbers were not specified.

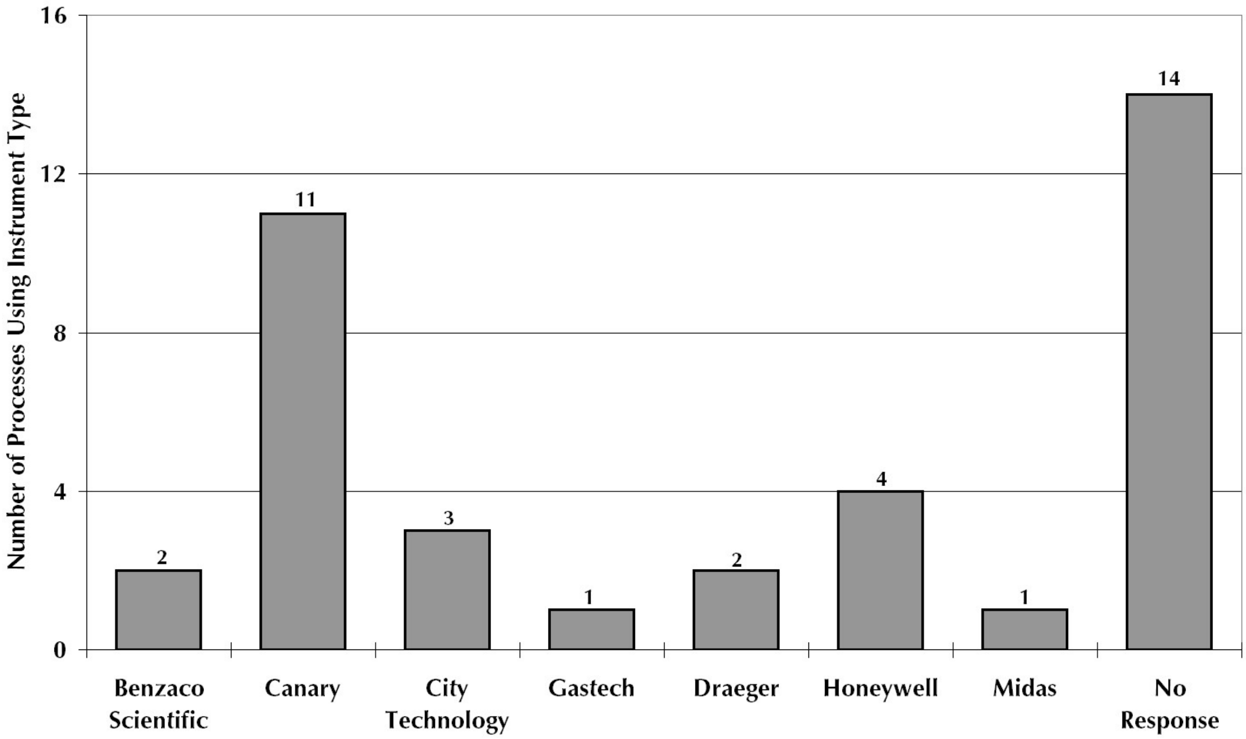

Figure 21 Online H_2S instrument usage by manufacturer (n=36).

Of the 35 sites with online H_2S monitoring, the instrument manufacturer was not reported for 16 sites (45.7%). A range of instrumentation was reported for four of the industry partners conducting H_2S monitoring, however, this data is primarily dominated by one of the industry partners who reported 29 sites (80.5% of reported sites) and all of the Canary H_2S monitors.

With questions being raised in regards to H_2S sensor cross sensitivities and interferences during the review of odour monitoring instruments (SP3 report: *Review of Sewer Odour Assessment Techniques, Volume 1: On-site and Field Instrumentation*), irregardless of suitability of H_2S as a monitoring parameter, potential differences in instrument cross sensitivities would limit the comparability of performance data across processes using different instruments. Developing a better understanding of instrument limitations and/or standardizing the instruments used across the industry would improve the comparability of the data and facilitate the transfer of results between sites and industry partners.

4.3 Offline Process Monitoring

A similar set of information requests were made with regards to offline process monitoring practices for odour abatement processes. A summary of reported offline process monitoring parameters is presented as **Figure 22**, once again multiple parameters were reported for some sites and the totals in this figure thus exceed 100%.

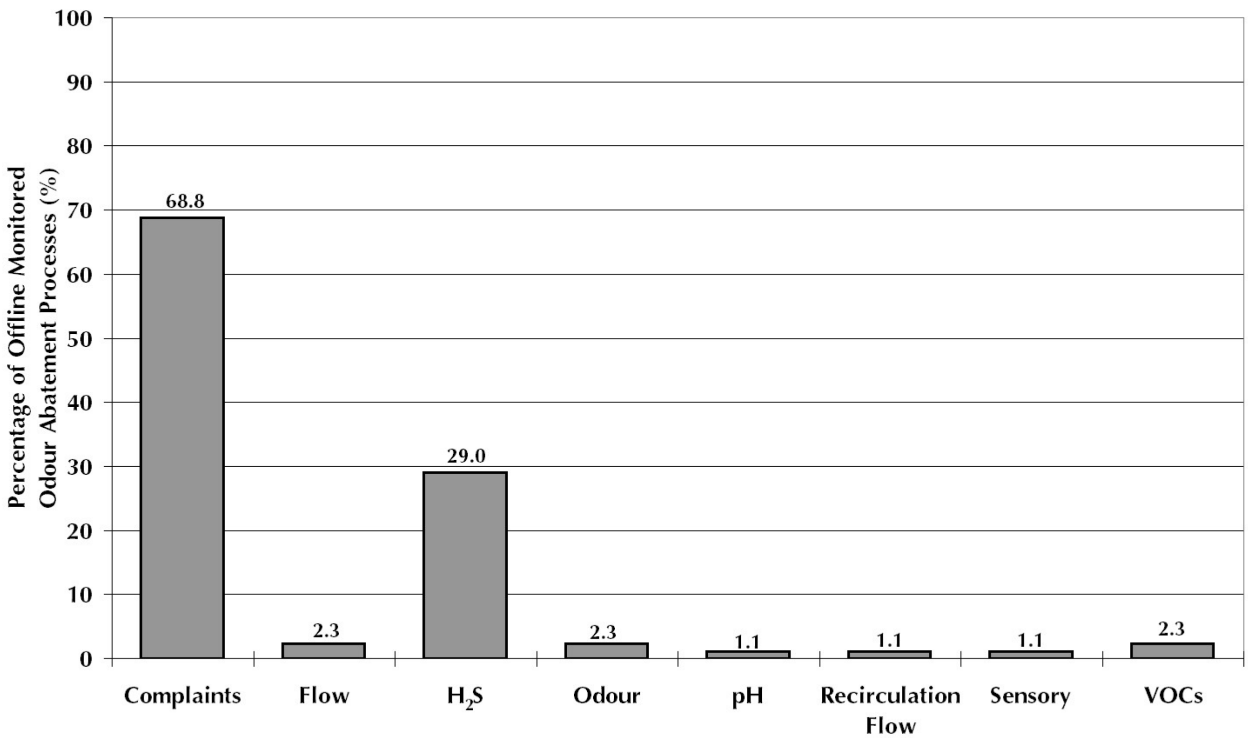

Figure 22 Offline monitoring parameters (n=176).

While not instrumentation based (or objective), community complaints is the dominant form of offline process monitoring being employed, and is the primary reported process monitoring technique for two of the industry partners. Of offline process monitoring conducted using instrumentation, H_2S is once again the dominant monitoring parameter, although there is some indication of VOC monitoring at a few sites (but no data has been provided).

Overall there was very little response with regards to the use of offline monitoring data (**Figure 23**), with only 29% of sites having an indicated data use. Dominant uses were once again decision making and diagnosis, however, given that none of the sites where complaint monitoring was used provided data usage responses (accounting for nearly 68.7% of the offline monitored abatement processes), and that typically this complaint data is used in a decision making capacity to initiate maintenance (media change), the decision making percentage in reality should be much higher (~93.7%)

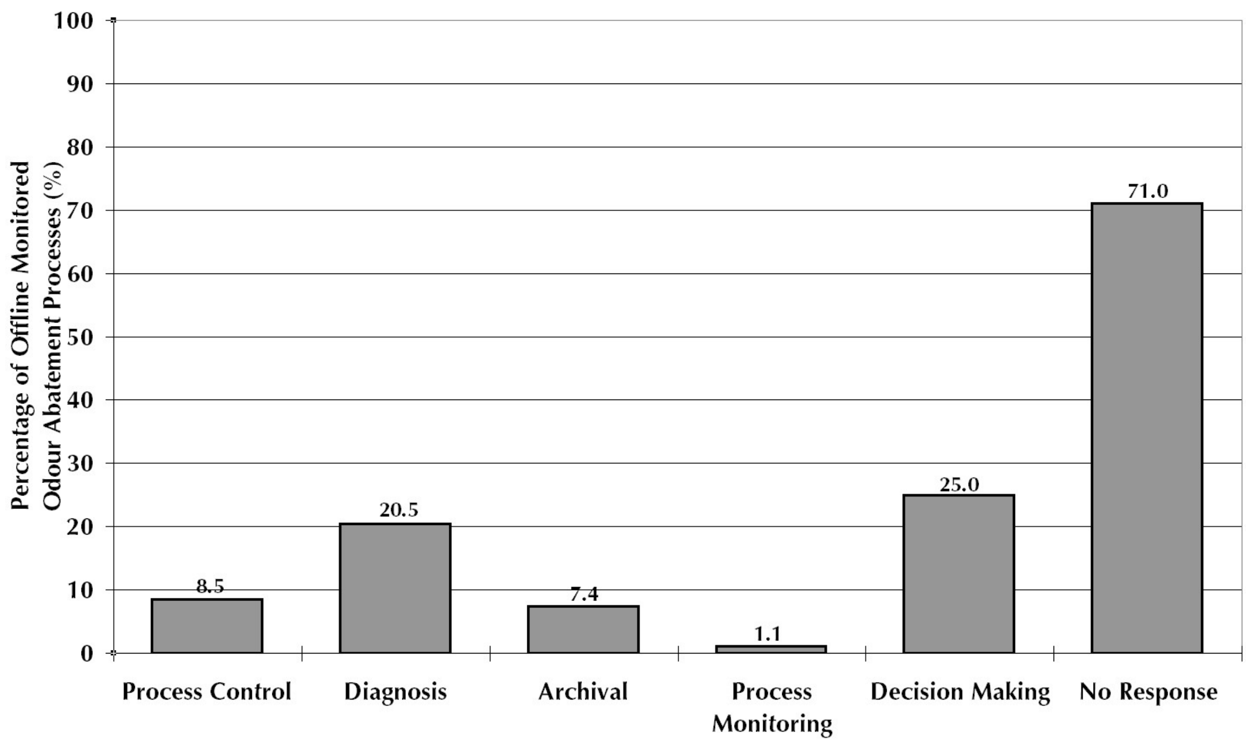

Figure 23 Purpose for conducting offline monitoring (n=176).

With regards to H_2S instrumentation, only two manufacturers were reported, Apptek (OdaLog) and Honeywell (used at 15 and 36 sites, respectively). This data was entirely based on the responses from two of the industry partners, one reporting OdaLogs exclusively, the other reporting Honeywell instruments exclusively.

4.4 Non-Process Monitoring and Use of External Analysts

Information was also requested with regards to non-process odour/odorant monitoring conducted by the industry partners (in particular sampling and analysis methodologies and instrumentation). Similar trends to offline monitoring conducted for odour abatement processes were observed. All six respondents indicated the primary use of H_2S monitoring for characterisation and diagnostic purposes, confirming that very little assessment of non-H_2S odorants. Sampling was generally done from a single point (assumed to be representative of the general flow); however, no significant sampling and analysis methodologies (or methodologies specified by external providers) were indicated, with only industry partner reporting Standard Operating Procedures for sample collection and analysis (although copies of these procedures were not provided).

All of the responding industry partners reported the use of Apptek Odalog instruments for their H_2S monitoring, and most indicated the instruments had a high level of reliability when maintained in accordance with manufacturer specifications (including 6 monthly factory calibration). Given the high level of use of this instrument type (both for odour abatement process monitoring and non-process monitoring purposes), it could be beneficial to the industry to further evaluate this instruments' performance with regards to sensor interferences and cross sensitivities.

Three industry partners reported the use of external service providers to conduct testing (primarily odour and H_2S sampling/analysis, with one partner also conducting VOC and reduced sulfur compound analysis). No detail was provided with regards to sample storage/transport protocols (standard practices). Limited analytical cost data was provided by survey respondents, and as a result typical analytical costs across the industry could not be assessed. Despite indications by all of the respondents that additional odour/odorant monitoring is being conducted outside of abatement process monitoring, only one industry partner provided data.

5.0 Summary and Conclusions

A survey was conducted of existing odour abatement processes and odour/odorant monitoring practices of the nine industry partners participating in the SCORe project. The survey results confirm the appropriateness of SP3's focus on activated carbon, biotrickling filter and biofilter odour abatement processes. While a more detailed analysis is presented in **Sections 3** and **4** (for odour abatement processes and odour/odorant monitoring, respectively), a number of trends have been identified in the data:

- high level of use of adsorption based odour abatement processes (76.5% of processes);
- slightly over half of the adsorption based odour abatement processes were zeolite based filters (51.9%), although these units were used by only one industry partner;
- activated carbon based odour abatement processes are well distributed across nearly all of the industry partners;
- mixture of domestic and mixed sewage odour sources, minimal industrial only sites;
- most processes are passive flow;
- most sites are maintained in some form, but most are not being routinely maintained.
- activated carbon media is generally replaced in a reactive manner following failure and the receipt of complaints;
- media saturation and moisture impacts are the dominant sources of odour abatement process failure, with other reported failures primarily mechanical in nature;
- many processes are being monitored solely through community complaints;
- H_2S is the dominant online and offline odour abatement process monitoring parameter, and the only monitoring parameter directly related to odours;
- Significant variability in online H_2S monitoring instruments used across the industry;
- low level of process control being used in the industry, but given the dominant types of processes this is to be expected;
- H_2S is the dominant non-process monitoring parameter (although significant odour monitoring was reported;
- Apptek OdaLog instruments are widely used across the industry for non-process H_2S

monitoring; and

- limited reports of non-H_2S odorant analysis (VOCs and reduced sulfur compounds).

There were significant limitations in the industry's ability to provide fundamental process data such as process age and treated gas flow for processes supplied by forced ventilation, in addition to process design data (design criteria and input characterisation), operating costs data, and process monitoring/complaints data. Furthermore, the industry partners were unable to identify the selection/design rationale for existing odour abatement processes, nor provide abatement process monitoring data. While it is likely that some of this data exists within the industry partners, it does not appear to be centrally stored in a readily accessible manner for use in decision making, planning, or abatement process design.

While the lack of existing data will not significantly impair the ability of SP3 to meet its objectives, the source of these data gaps is warrants further consideration. While SP3 will provide insight into odorants/interferents present in sewers and into the design and operation of odour abatement process operation during its lifetime, this knowledge is not static in nature and will continue to evolve long past the end of the project. The benchmarked monitoring tools developed as part of SP3 represent a valuable contribution to the continuing development of understanding and improving the design and operation of odour abatement processes. However, if the existing systematic gaps in data availability/storage continue into the future (past the end of SP3), these gaps will limit the benefits derived from the industry's ongoing collection of more comprehensive odour, odorant, and interferents data in addition to current, ongoing process and operational monitoring.

Recommendations

Based on the outcomes of the industry survey, several recommendations have been provided. With regards to the scope of SP3 and achieving the subproject's objectives, the following is recommended:

- due to the reported lack of industrial sewage dominated sewers (identified in the research plan) , SP3's focus should be adjusted to include mixed sewers in their place, in roughly equal proportion to domestic sewage dominated sewers; and

- with moisture being reported as a significant cause of activated carbon based odour abatement process failure, the planned activated carbon testing (which focuses on the impact of non-H2S odorants and interferents on process performance) should be supplemented to provide additional understanding of moisture related treatment failures (this can be conducted within the existing project budget).

While not explicitly required to achieve SP3's objectives (and beyond the current scope of SP3), the results of the industry survey have allowed the identification of several areas where additional effort could yield practical benefits to the industry:

- given the high variability in online H_2S instruments used across the industry, instrument benchmarking tests could be useful in assessing the comparability of the results and identifying if instrument standardisation is warranted;
- Apptek Odalog instruments are widely used across the industry partners for both offline and non-process H_2S monitoring purposes, with existing knowledge gaps in regards to specific sensor interferences and cross sensitivities, it would be beneficial to further evaluate these instruments' performance;
- while the identified gaps in existing industry data (with regards to odour abatement processes and odour/odorant monitoring) will not directly impair the ability for SP3 to meet its objectives, enhancing data collection, storage and availability in these areas to enable the provision of more complete datasets to better support process selection and design (including providing a source of process evaluation independent of manufacturer claims) would be of benefit to the industry. For example improved tracking of process costs, performance, and key operating and design parameters such as odorant source characteristics, gas flow treated, odorant loading, and sorbent type/quantity (for adsorption processes) could allow for the identification of odour abatement process with superior performance in terms of odorant removal as well as operating cost and maintenance requirements. While this will be done for investigated process during SP3, odour abatement technology is not static and the industry would benefit from continuing to collect and assess this data following SP3's completion;

and

- opportunities exist to enhance the handling of complaints data (for example correlation to local sources, data management/access, consistent descriptors, training in recognition), which would yield benefits to the industry through supporting process maintenance and troubleshooting.

Appendix A

Sample Survey: Odour Abatement Processes

Odour Abatement Survey

Part 1: General Information

Please complete and return Part 1 by June 17, 2009
Completed surveys to be submitted by July 17, 2009

Utility:

Contact Information

Name:		
Area of Responsibility:		
Phone:		
Email:		

Overview of Odour Abatement Processes

Sewer Network		
Odour Abatement Process Name/ID	**Process Type**	**Location**

Sewage Treatment Plants	
Plant Name	**Type(s) and Quantity of Odour Abatement Processes**

Odour Abatement Survey

Part 2: Odour Control Processes

Number, type, and approximate cost of proposed future odour control process installations in the next 3 years:

Please complete one column per odour control process. Insert additional columns as necessary

General Process Information				
Odour control process name/ID.				
Process type (e.g. biofilter, chemical scrubber, bioscrubber, activated carbon).				
Location (site name).				
Source Information				
Off-gas emission source (e.g. pump station).				
Primary sewage type (e.g. domestic, industrial, or mixed).				
Off-gas flow treated (volumetric flow rate).				
Feed type (passive or forced ventilation).				
Process Information				
Year installed.				
Cost installed.				
Number of odour control units in process.				
Media type.				
Configuration (e.g. parallel, series, process types).				
Criteria specified to designers (e.g. performance requirements)				
Data provided to designers (include file name and provide data).				
Was a performance guarantee provided by the supplier? If yes, please indicate.				
Operation				
Type of process control employed (include manipulated parameters).				

Media replacement frequency.				
Maintenance requirements (type, frequency, and time estimate).				
Operating costs (break down if possible, e.g. media/maintenance/energy).				
Pre-installation odour complaint frequency (average complaints/year).				
Post installation odour complaint frequency (average complaints/year)				
If possible, describe specific events or conditions resulting in odour complaints.				
Process failure incidents (sources, consequences, frequency).				
If performance guarantees have been provided, have they been met?				
Routine Process Monitoring	(please indicate information for each parameter monitored)			
Online instrumentation				
Parameters monitored.				
Instrument make/model.				
Analytical principle.				
Sampling frequency.				
Sample collection technique (e.g. method, location).				
Data utilization (e.g. archival, process control, decision making, diagnosis).				
Offline Instrumentation - On-Site				
Parameters monitored.				
Instrument make/model.				
Analytical principle.				
Sampling frequency.				
Sample collection technique (e.g. method, location, number of replicates).				
Data utilization (e.g. archival, process control, decision making, diagnosis).				
Offline Instrumentation - External				
Parameters monitored.				
Sampling frequency.				

Sample collection technique (e.g. method, location, number of replicates).				
Analytical method.				
Analyst (indicate name of laboratory).				
Cost per sample.				
Data utilization (e.g. archival, process control, decision making, diagnosis).				
Data*	(please include filename(s) if data is included)			
Inlet monitoring data.				
Performance data.				
Routine monitoring data.				

Odour Abatement Survey

Part 3: Comments

Please include any additional comments

Appendix B

Sample Survey: Odour Monitoring Practices

Odour Monitoring Survey

Part 1: General Information

Utility: ____________________

Contact Information

Name:				
Area of Responsibility:				
Phone:				
Email:				

Completed surveys to be submitted by September 4, 2009

Odour Monitoring Survey

Part 2: Sample Collection Techniques

Please complete one column per sample collection methodology employed.
Insert additional columns as necessary.

Method Overview			
Sample collection method (name/ID).			
Location/situations used.			
Source type (e.g. sewage, off-gas, ambient air).			
Replicates collected (specify quantity if yes)?			
Sample collection equipment used (e.g. pump types, probes, hoods).			
Sample container (e.g. Tedlar bag, Summa canister, sorbent tube [give type]).			
Sample type (grab or composite).			
Sample Collection			
Sample collection points (single point or traverse).			
Collection point selection criteria.			
Does the sample contain liquid droplets or particles? If yes, is isokinetic sampling used?			
Collection rate, total volume and sampling time.			
Storage requirements (e.g. temperature, maximum/typical time before analysis).			
Preservatives.			
Is there a standard procedure? If yes, please provide an electronic copy of the procedure and indicate file name in adjacent cells.			
Describe any deviations from standard procedures.			

Odour Monitoring Survey

Part 3: Sampling Events

Please complete one column per sampling event. Insert additional columns as necessary

Overview			
Sampling event (name/ID).			
Objective (e.g. design, performance evaluation, diagnostic).			
Is this routine sampling, or has this specific methodology been used at other sites? If yes, specify frequency/sites.			
Collection method (name of method described in Section 2).			
Is sample collection conducted internally, or by an external contractor?			
Analysis method (provide method ID if a standard method is used, or a description of the method if it is non-standard).			
Is analysis conducted internally or by an external laboratory?			
For external work, were methodologies specified by the utility, or were they selected by the external contractor?			
Samples			
Location and number of samples.			
Number of replicate samples collected.			
Were quality assurance/quality control samples collected? If yes, list types.			

Part 4: Monitoring and Analytical Equipment

Please complete one column per type of equipment. Insert additional columns as necessary

Instrument Information			
Instrument make/model.			
Location (name of site or laboratory) and quantity.			
Cost installed (per instrument).			
Online or offline measurement.			
Parameter(s) measured.			
Sample collection method (name of method described in Section 2).			
Sample matrix (e.g. liquid or gas).			
Sensitivity (limit of detection and accuracy).			
List known interferences.			
Online Instruments			
Sampling frequency.			
Sample pretreatment requirements.			
Offline Instruments			
Annual throughput and minimum time between samples.			
Operation			
Operating costs.			
Inspection and calibration frequency.			
Maintenance requirements (type, frequency, and time estimate).			
Reliability (source, frequency and duration of downtime events or instrument faults).			
Is there a standard operating procedure? If Yes, please provide an electronic copy and indicate the file name in adjacent cells.			

Odour Monitoring Survey

Part 5: Comments

Please include any additional comments