A conscious scheme for remediation of odour nuisance at sewage treatment plants

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Abstract A standard methodology is presented to remediate odour nuisance at sewage treatment plants. The basic procedure of this methodology is formed by a conscious scheme which integrates all relevant steps in the remediation process (investigative actions, migitating measures, communication, etc.). The aim of this methodology is to obtain a realistic plan of action, keeping count with local boundary conditions (available resources, available knowledge, certainty about the causes, etc.). In this way, the methodology functions also as a backbone when a well defined odour regulation is lacking, as is the case in Flanders for the moment.

Keywords Wastewater; sewage; odour; nuisance; remediation; management

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Introduction

Aquafin has been commissioned to pre-finance, design, construct and operate the sewage collection and treatment infrastructure in Flanders (about 5.9 million inhabitants in 1997), one of the three regions in Belgium. At the moment, Aquafin operates 164 sewage treatment plants (STPs) and this number is increasing by one each month. Aquafin prevents odour nuisance around new STPs by considering the risk in the planning phase (e.g. choice of location) or the design phase (e.g. covering process units in combination with air treatment in the case of nearby residents, sludge loading rate <0.05 kg BOD kg^{-1} SS d^{-1}, etc.). However, since Flanders is a very densely populated region (436 inhabitants km^{-2} in 1997), public awareness is growing and the number of treated population equivalents increasing, Aquafin must be on the alert for the risk of odour nuisance and how to remediate it. From this attitude and based on experience gained by treating odour nuisance at older STPs, Aquafin has standardised a methodology for remediation. This standardisation forms the basis of a conscious remediation process with involvement of local stakeholders (residents, authorities, press, etc.). The methodology functions also as a backbone when no regulations exist which allow us to put forward an objective measurable odour target, as is the case in Flanders for the moment (Van Broeck and Van Langenhove, 1999). This paper gives an overview of the most important aspects of the method developed.

Methodology

Basic procedure

Figure 1 presents the basic procedure of the methodology:

- Screening of the problem is triggered by complaints. An internal complaint (e.g. by operators) is a potential forerunner of external complaints and thus considered as a potential external complaint.
- The screening of the problem must allow us to evaluate whether the problem is caused by a once-only short term situation (e.g. exceptional maintenance works). If this is not the case, a plan of action must be developed. The plan of action can consider pragmatic or deterministic actions or combine both. Actions are defined deterministic when considerable effort is made to collect additional data in order to further underpin proposed

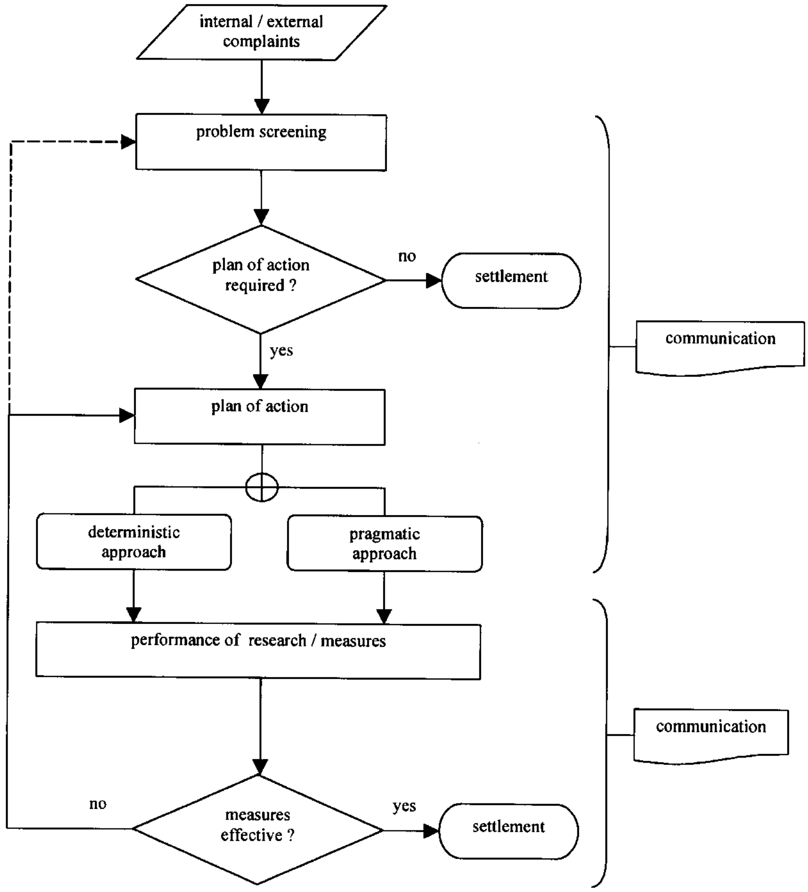

Figure 1 Basic procedure of the methodology for remediating odour nuisance at STPs

measures. Actions are defined pragmatic if they are based on unconfirmed or a limited amount data and common sense or experience.

- The plan of action, defining the measures and eventually further research to be undertaken, is implemented and the effectiveness of the measures is evaluated. If the evaluation is negative, the plan of action is changed or the problem is again screened.
- Remediation of the odour nuisance problem must not only consider technological actions. Also communication with the local stakeholders (residents, authorities, press, etc.) is considered as an important aspect of the remediation process.

The following aspects will be discussed in more detail: (i) problem screening, (ii) plan of action, (iii) evaluation of effectiveness and (iv) communication.

Problem screening (investigative methods)

The problem must be screened from a holistic point of view (including collection and treatment processes). The holistic approach allows us to make a discrimination between processes that are responsible for (i) the presence of odorous compounds in the waste water or sludge (e.g. long-lasting anaerobic sludge conditions) and (ii) the release of the present odorous compounds into the ambient air (e.g. sludge dewatering). Discrimination between presence and release of odorous compounds allows a better definition of possible process integrated measures (preventing the presence of odorous compounds). The problem

Table 1 Typical critical processes with respect to sewage collection and treatment

–industrial discharges of odorous compounds or odorous precursors
–industrial peak discharges of readily biodegradable organic compounds
–long sewage residence time in pressure mains
–accumulation of deposit in gravitary collectors
–co-settlement of primary and secondary sludge in primary clarifiers
–pumping sulphide loaded sewage with screw pumps
–recirculation of sludge waters o the influent pit
–sludge accumulation in the primary or secondary clarifiers
–processing external sludge or septic material
–uncompleted sludge fermentation
–limited ventilation of trickling filters
–sludge accumulation in trickling filters
–etc.

screening must also pay special attention to possible discontinuous or sporadic processes (e.g. overflow of a sludge buffering tank). The holistic approach in combination with the attention to discontinuous or sporadic processes minimises the risk for developing an irrelevant plan of action.

A holistic screening of the problem can, however, require a significant amount of time. Especially if the problem screening was triggered by the escalation of a nuisance problem with a long history, local residents will expect feed-back and measures of the amount of time solely used for screening of the problem. To limit the amount of time used for the screening of the problem, only the following types of research are incorporated.

- Complaint inventories: the frequency of complaints is evaluated. Also the distance to the complaining residents is checked. This information can help to get a view on the magnitude of the problem.
- Interview with the operators: the experience of the operators is of prime importance to gather information with respect to the following aspects:
  – the occurrence of process operations which show a high odour emission;
  – any recent changes in process operation or process circumstances;
  – any discontinuous or sporadic process operations or incidents.
  It is clear, however, that some of these aspects are difficult to judge if the STP is unmanned.
- Theoretical evaluation: the sewage collection and treatment process is theoretically evaluated with respect to basic process operating parameters (sludge loading, sludge residence times, etc.). In addition a list of typical critical process operations is checked (Table 1). These critical processes are mostly related to unwanted anaerobic conditions that result in the production of hydrogen sulphide (H_2S).
- H_2S measurement: using a handheld device, the H_2S concentration in the ambient air near to the different process units is measured. However, most electrochemical H_2S sensors are not sensitive enough to quantify low concentrated emissions (<1–2 ppm H_2S). In these cases, (expensive) gold plated sensors are required which allow to measure H_2S concentrations in the ppb-level (Wijcherson, 1994). These type of measurements allow also to make an H_2S map of the STP (e.g. Hobson, 1997). Yet, it should be kept in mind that besides H_2S, other compounds (e.g. industrial sewer discharges) can be involved in the nuisance problem.
- Informal sensory observations: the ambient air near the different process units and over the whole STP site is evaluated by informal smelling.

The measurement of ambient H_2S concentration or informal sensory observations aim to detect or confirm the most important odour emission sources on the STP. In this respect, attention must be paid to the following facts.

- The potential dynamic character of odour emission by a STP implies that measurements should[redacted]e repeat[redacted] over a certain time period. In an ideal situation, measurements should be perform[redacted]t the moment that nuisance occurs.
- The odo[redacted]ct of the STP on its environment is determined by the odour emission $E=Q$ [redacted]where [redacted]is the concentration and Q the flow rate of the emitted air stream. Measurement of concentration C gives thus only a rough indication of the potential odour impact. Determination of the emission E is discussed further in this paper.

Conclusions of the problem screening are reported in a standard document. This document states the hypothetical causes for (i) the presence and (ii) the release of odorous compounds. To each cause a corresponding level of certainty is attributed (possible, probable, most likely). The discrimination in certainty allows us to define priorities in the subsequent plan of action.

It is possible that more sophisticated or specialised research methods (Lindvall hood measurements, sniffing measurements, GC-MS analysis, etc.) are required. This is the case if e.g. the hypothetical causes are considered to be all uncertain or if odour (related) parameters have to be quantified in the light of determining the effectiveness of the measures (see further). These more sophisticated research methods (analytical methods) are incorporated into the plan of action to limit the screening phase in time.

Plan of action (analytical methods and migitating measures)

Deterministic or pragmatic approach. A problem screening does not always lead to the definition of hypothetical causes with a high level of certainty. This can be the case if the odour nuisance only occurs sporadically or during a short period in the year (e.g. during a warm period in the summer). In these cases, handling an odour nuisance problem can be very time consuming if measures have to be minimised and underpinned by detection of the specific causes. Consequently, it has to be evaluated if it is appropriate to handle the problem either in a deterministic, pragmatic or combined approach. The choice between these options depends on several factors as presented in Figure 2. These factors should be evaluated in accordance with the available resources or own experience. For example, the factor "certainty of measurement effectiveness" can be considered high if the process unit is covered

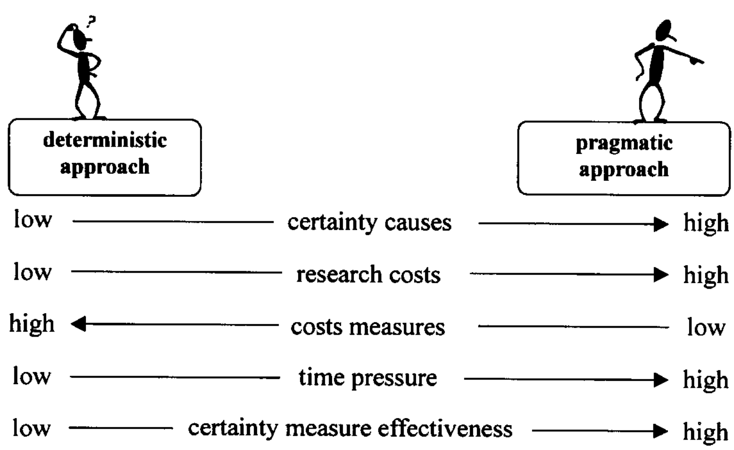

Figure 2 Factors determining the choice for a deterministic or pragmatic plan of action. The factors are evaluated on a relative scale in accordance with the available knowledge or resources

Figure 3 Results of sniffing measurements around the STP of Turnhout (Van Elst and Van Langenhove, 1995). The shading indicates the area in which the odour of the STP could be observed

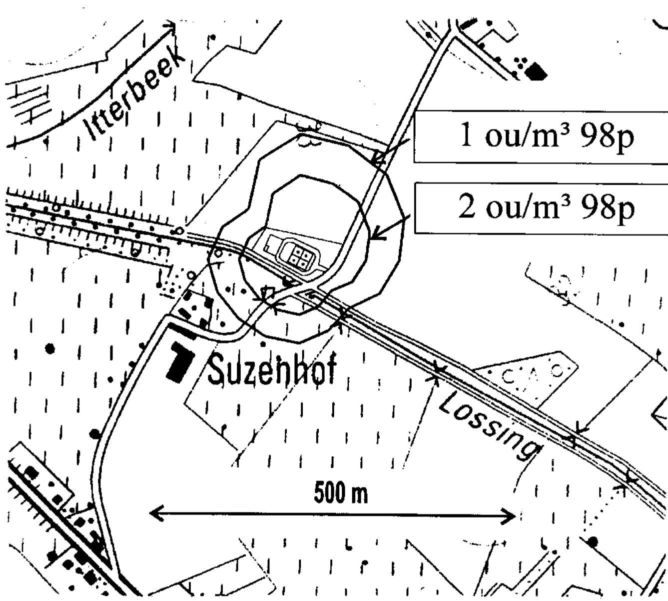

Figure 4 The 1 and [redacted]ou/[redacted]^3 98 percentile contour around the STP Kinrooi-Molenbeersel for a one year period (Moortgat and [redacted]angenhove, 1997). Based on nine sniffing measurements the odour emission rate was equal to 16.6 [redacted]^6 ou/h[redacted]emark: one sniffing unit is considered to correspond to one odour unit)

and the head-space is ventilated in combination with air-treatment. On the other hand, the "certainty of measure effectiveness" is low and tests are required if odour neutralising agents are sprayed around the process unit.

Research (analytical methods). Research activities in a plan of action will in most cases be limited to one or more of the following aspects.

(i) Determination of odour impact.

Probably the most objective and elegant way to characterise the odour impact is the use of sniffing measurements (Van Broeck and Van Langenhove, 1999). These measurements allow us to visualise the area around the STP in which the odour can be observed (Figure 3). In combination with odour dispersion calculations, the odour emission rate and the likely dispersion over a period of one year can be calculated (Figure 4).

Yet, the procedure for making sniffing measurements and dispersion calculations still requires standardisation (selection of sniffing persons, meteorological data-set for long term dispersion calculation, etc.). Therefore, these type of measurements and data treatment are reliable only on a relative scale.

It is important to define the operating conditions during which sniffing measurements are performed. It is possible that the nuisance is caused during specific operating conditions, e.g. the discharge of external sludge. Specific conditions allow the engineering to characterise the short-term impact of the critical operating conditions, but does not allow an evaluation of the long-term impact of the overall STP-operation. also the critical operating conditions should last at least 30–60 min to make simultaneous sniffing measurements feasible.

(ii) Determination of the major odour emission sources.

The major [redacted]dour em[redacted]sion sources can be indicated if the odour emission of the different process units [redacted]e STP is known. Determination of the odour emission (E) of a process unit requires [redacted]asurement of the concentration (C) and the flow rate (Q) of the emitted air: E=C [redacted] Most [redacted]dour emitting sources on a STP are diffuse or surface sources. Especially for diffuse sources it is very difficult to quantify the flow rate (Q) of the emitted air. Surface sources, on the other hand, can be sampled using a Lindvall hood, yet extrapolation of the odour emission rate measured with a Lindvall hood to the total area of the surface source is still under discussion (van Belois and Anzion, 1991; Medrow *et al*., 1993; Güdelhöfer *et al*., 1995). Interpretation of Lindvall hood measurements is thus limited to the comparison of different surface sources. With respect to the operating conditions during sampling, the same remark accounts as for a sniffing measurement.

(iii) Selection or optimisation of a suitable treatment technology.

Once the major odour emission sources are indicated and a curative air or water treatment technology seems required, the treatment technology must be selected or optimised towards the local boundary conditions: e.g. if the air stream contains must organic sulphur compounds (based on GC-MS analysis), it can be important to conduct pilot biofilter experiments; if ferrous chloride has to be dosed, the dosing rate must be determined, etc.

Measures (migitating measures). Possible measures are the following.

(i) Measures at the waste water source.

Measures at the waste water source (i.e. more stringent consents) are required when the odour nuisance is caused by industrial discharges (e.g. specific odorous compounds, peak discharges of readily biodegradable organic compounds inducing anaerobic conditions, etc.).

(ii) Process integrated measures.

These kinds of measures are in most cases directed towards the elimination of unwanted anaerobic conditions by optimising the process operation. Possible process integrated measures are: separation of streams (e.g. primary and secondary sludge), decreasing residence times (e.g. sludge residence time in the presettlement tank) and promoting (e.g. nitrate rich streams) or avoiding (e.g. concentrate of sludge dewatering towards influent pit) return streams.

(iii) Curative measures.

These kind of measures are in most cases directed towards the treatment of an air or water stream:

- In the water line chemicals can be dosed for oxidising (e.g. H_2O_2) or precipitating ($FeCl_3$) odour compounds or for eliminating anaerobic conditions (e.g. NO_3^- in the sewerage). Recently there is also an emerging market for odour neutralising agents. These chemicals are most commonly sprayed around the odour source.
- Covering process units is frequently combined with ventilation and treatment of the created ventilation air flow. The treatment of air comprises in most cases biofiltration.
- The use of odorous air as aeration air in the waste water treatment process is another option, but subjected to the following boundary conditions: the aeration capacity must be sufficient for continuous take-up of the air flow rate, the aeration equipment must be corrosion resistant and the odorous compounds may not be too water insoluble.
- An interesting alternative can be to strip the odorous compounds at the beginning of the waste water treatment process in combination with treatment of the generated stripped air. This alternative should carefully be evaluated using pilot experiments. It should be kept in mind, however, that also odorous compounds may be produced and released during the further treatment of the sewage or sludge.

The choice for these different kinds of measures must be made depending on the available budget, time and certainty about the hypothetical causes and effectiveness of the measures. Measures at the waste water source or process integrated measures are preferred.

Evaluation of effectiveness (evaluation of migitating measures)

The effectiveness of the measures can be evaluated at the level of the processed streams or at the level of nuisance:

- processed streams: e.g. reduction of H_2S concentration a a result of $FeCl_3$ dosing, reduction of odour concentration in a treated air stream, etc;
- nuisance: most appropriate (objective) way to evaluate a possible reduced nuisance is the use of sniffing measurements. Effective measures must result in shrunk odour percentile contours (cf. Figure 4). The (subjective) experience of the local residents, however, cannot be ignored.

Normally the effectiveness of measures is evaluated by comparing the situation before and after measures have been taken. The quantification of the initial situation, however, requires time and can thus implement a delay of measures. In some cases, this delay will not be accepted. Also when the odour nuisance occurs only sporadically it can be difficult to characterise the initial situation.

Communication

Local stakeholders (residents, authorities, press, etc.) must be involved in the remediation process and thus informed about the causes of the odour emission and the actions that will be undertaken to investigate and to remediate the situation. Obstruction of this information exchange will result in increasing tension and decrease the time available for remediation. The following information must be communicated: (i) the conclusions of the problem screening and the plan of action and (ii) the conclusions of the evaluation of the effectiveness of the measures. It is advisable to communicate only information which shows a high level of certainty. Yet, at the initial phase of the remediation process it is not unusual that uncertainty (about the causes) is the only certainty!

Conclusions

A standardised methodology is proposed to remediate odour nuisance problems at STPs. The basic procedure of this methodology is formed by a conscious scheme which integrates all relevant steps in the remediation process (investigative actions, migitating measures, communication, etc.). Based on local boundary conditions (available resources, available knowledge, certainty about the causes, etc.), a case specific plan of action for remediation is defined. This plan of action forms a backbone when a well defined odour regulation is lacking. Also the involvement of the local stakeholders (residents, authorities, press, etc.) is considered.

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