

Development of a Screening Model for Hydrogen Sulphide Emissions and Receptor Concentrations During Landfill Excavation

Source-Term Formulation, Receptor Screening and Control-Performance Requirements

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Technical note

A transparent order-of-magnitude model for converting landfill-gas H₂S concentrations and disturbance assumptions into source terms, concentration-distance profiles, screening concentrations at defined receptors and control-performance requirements.

Abstract

Intrusive work in landfilled waste can create hydrogen sulphide releases that are not adequately represented by annual landfill-gas generation forecasts or by routine surface-flux measurements alone. This technical note develops a screening model that separates diffuse emissions from exposed waste, gas liberated during waste disturbance and short-duration releases from gas-rich zones or damaged extraction infrastructure. Each mechanism is converted into a transparent H₂S mass source, adjusted for event duration and any directly demonstrated containment, and transferred to defined on-site and off-site receptors using a simplified Gaussian relationship.

The model is intended for early-stage engineering decisions. It generates concentration-distance profiles and screening concentrations at specified worker, on-site and public receptors under selected release-duration, source-dimension and wind-speed assumptions. It identifies the assumptions that control the result and quantifies the direct source reduction required to meet a selected comparison level. A synthetic worked example shows that short localised events can dominate the screening result even where routine diffuse emissions are modest. The calculation does not replace occupational hygiene, atmospheric dispersion modelling, field monitoring or a task-specific safe system of work. Its purpose is to determine when those measures are needed and to prevent general landfill-gas collection efficiency from being misapplied as evidence of capture at an active excavation face.

Keywords

Hydrogen sulphide; landfill gas; waste excavation; source term; surface emissions; Gaussian screening; occupational exposure; odour; gas collection.

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1 Introduction

Hydrogen sulphide can occur at high concentration in landfill gas where sulphur-bearing wastes, reducing conditions and suitable moisture and temperature coincide. The concentration measured in a well or collector does not by itself define the atmospheric source. Risk depends on how much gas is released, how quickly it is released, how long the release continues, whether it is intercepted at source and how the plume is diluted before reaching a worker or public receptor.

Landfill excavation changes each of these conditions. Cover is removed, pore spaces are opened, waste is broken and moved, extraction pipework may be isolated or severed and gas held within connected voids can be released over minutes rather than months. Published landfill studies provide useful evidence on diffuse H₂S flux and working-face behaviour [1-4], but a project assessment still needs an explicit bridge between source concentration, release mechanism and receptor exposure.

The method set out here provides that bridge. It retains a deliberately simple calculation chain so that each assumption can be challenged, replaced by measurement and subjected to sensitivity testing. It is designed to answer three questions:

- What gross H₂S mass rate could the proposed activity release?
- Could a routine or short-duration event exceed a relevant worker, public-health or odour comparison level?
- What direct source reduction would be required before the activity could be considered further?

2 Conceptual model

The model separates evidence, release mechanism, source strength, dispersion and control. This prevents a measured gas concentration from being treated as an emission rate and prevents whole-site collection efficiency from being credited automatically at an excavation face.

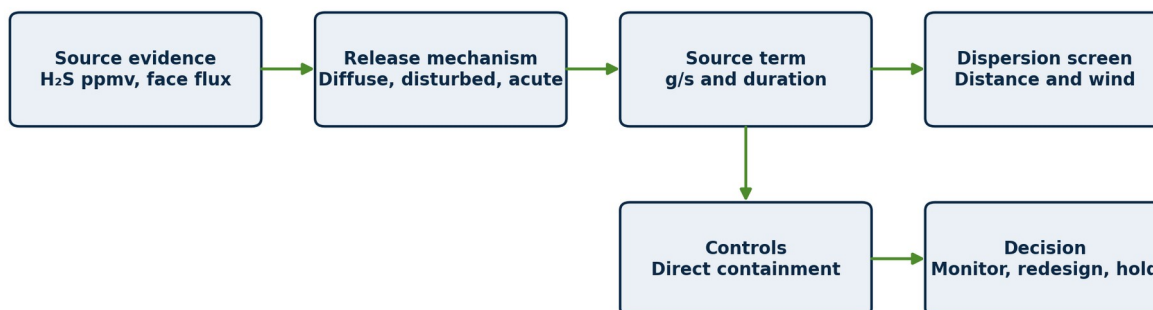


Figure 1. Calculation structure from source evidence to engineering decision.

Table 1. Source mechanisms retained in the screening method.

Component	Representation	Controlling evidence
Diffuse face	H ₂ S mass flux over an exposed area	Surface condition, area and published or measured flux
Disturbed waste	Gas liberated as waste is excavated, loaded or placed	Waste throughput and gas volume liberated per unit waste
Localised event	Direct gas release from a void, pocket or damaged collector	Gas flow, duration and source dimensions

Component	Representation	Controlling evidence
Direct containment	Interception at the release point	Demonstrated local performance, not whole-field efficiency

3 Source term development

3.1 Conversion from ppmv to mass concentration

For an ideal gas at a stated temperature and pressure, the H₂S mass concentration is:

$$C_{h2s} = (x / 10^6) \times (MW_{h2s} / V_m)$$

where x is the H₂S concentration in ppmv, MW_{h2s} is 34.081 g/mol and V_m is the molar volume in m³/mol. At 20°C and one atmosphere, V_m = 0.024055 m³/mol. A concentration of 5,000 ppmv therefore corresponds to approximately 7.084 g H₂S/m³ of landfill gas.

3.2 Diffuse emissions from an exposed face

Where a surface-flux value F is available in mg/m²/h, the diffuse source is:

$$\dot{m}_{\text{surface}} = F A / 3.6 \times 10^6$$

where A is the exposed area in m² and $\dot{m}_{\text{surface}}$ is in g/s. Published landfill measurements span several orders of magnitude because waste composition, surface condition, temperature, moisture, extraction state and measurement method differ [1-4]. Published values should therefore define sensitivity cases rather than a single universal emission factor.

3.3 Gas liberated during waste disturbance

For a waste handling rate R_w in m³/h and a gas-liberation factor Y_g in m³ landfill gas per m³ waste, the liberated gas flow is:

$$Q_{\text{gas}} = R_w Y_g / 3600$$

The corresponding H₂S mass rate is C_{h2s}Q_{gas}. The gas-liberation factor is normally the least certain input. It should be treated as a range informed by waste condition, depth, degree of saturation, connected porosity, extraction state and trial evidence.

3.4 Localised direct releases

A gas pocket or opened collector is represented directly by gas flow Q_d. If Q_d is entered in m³/min:

$$\dot{m}_{\text{direct}} = C_{h2s} Q_d / 60$$

This rate applies only during the event. The total H₂S mass released is the instantaneous rate multiplied by the event duration. A short event can produce a severe acute peak while making a comparatively small contribution to a daily average.

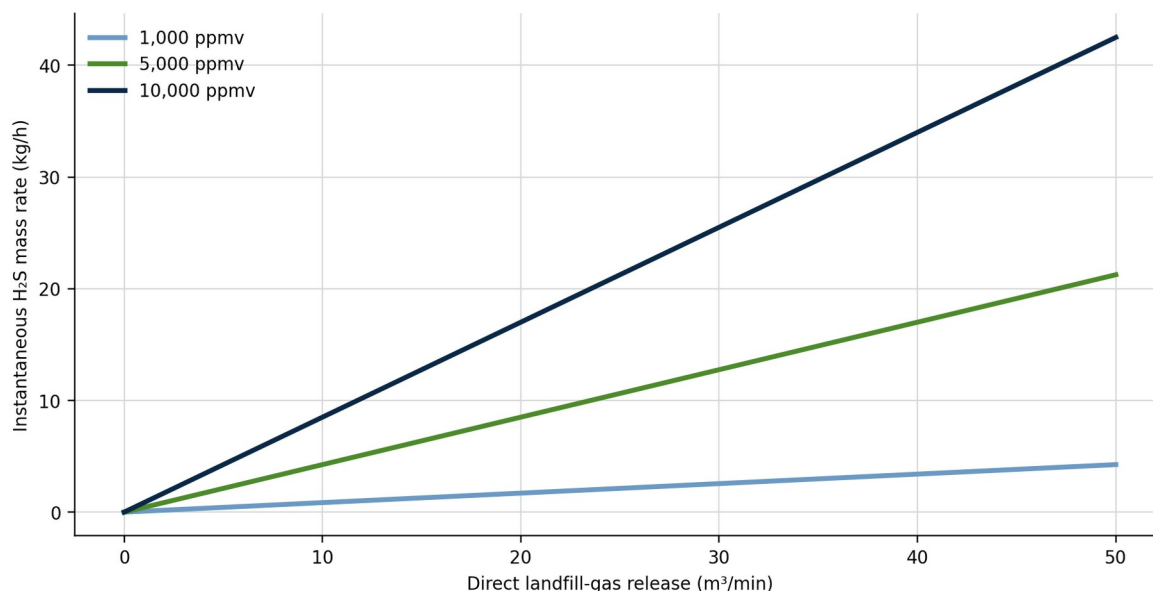


Figure 2. Instantaneous H₂S mass rate for direct gas releases at three source concentrations.

3.5 Averaging and direct containment

For an isolated event of duration t_e evaluated over averaging period T , the time-averaged source contribution is multiplied by $\min(1, t_e/T)$. Repeated events must be represented explicitly; they must not be hidden within one isolated-event calculation.

Where a directly demonstrated containment fraction η is applied, the residual source is $\dot{m}_{\text{residual}} = \dot{m}_{\text{gross}}(1 - \eta)$. The fraction represents interception of the release being modelled. It is not the overall collection efficiency of the landfill gas field.

4 Screening dispersion calculation

The receptor screen uses a Gaussian centreline relationship with a ground-level reflection term. Initial source dimensions prevent the plume from collapsing to an unrealistically small cross-section near the release. For distance x , effective source width W and effective vertical dimension H :

$$\sigma_y = \sqrt{[(W/4)^2 + (\alpha_y x)^2]} \quad \sigma_z = \sqrt{[(H/2)^2 + (\alpha_z x)^2]}$$

$$C(x,z) = [\dot{m} \times 1000 / (\pi u \sigma_y \sigma_z)] \exp[-z^2 / (2\sigma_z^2)]$$

Here C is in mg/m^3 when $\dot{m}$ is in g/s , u is wind speed in m/s and z is receptor height in metres. The exponential sign is explicitly negative and the squared height term is enclosed in parentheses. This avoids spreadsheet operator-precedence errors. The calculated concentration is capped at the source-gas mass concentration and then adjusted for event duration and direct containment.

Table 2. Illustrative screening assumptions.

Input	Illustrative value	Meaning
α_y	0.12	Lateral plume-growth coefficient used for screening
α_z	0.08	Vertical plume-growth coefficient used for screening
Receptor height	1.5 m	Representative breathing-zone height

Input	Illustrative value	Meaning
Wind speed	1, 2 and 5.6 m/s	Sensitivity cases, not occurrence frequencies
Background	0 $\mu\text{g}/\text{m}^3$	Modelled contribution kept separate from measured background
Wind direction	Directly downwind	Independent adverse alignment for each receptor

The coefficients above are model parameters, not universal atmospheric constants. A site-specific assessment should replace this screening relationship with a suitable dispersion model where terrain, buildings, stability, calm conditions, dense-gas behaviour or regulatory determination materially affect the decision.

5 Synthetic worked example

The following example is deliberately generic. It demonstrates the calculation sequence and relative importance of different release mechanisms. It does not represent a particular landfill or proposed operation.

Table 3. Synthetic example results at 5,000 ppmv H_2S , 1 m/s wind and zero background.

Scenario	Gross rate kg/h	Duration min	Event mass kg	250 m 30-min $\mu\text{g}/\text{m}^3$	Reduction to 7 $\mu\text{g}/\text{m}^3$
Routine disturbance	0.044	30	0.022	6.3	0.0%
Localised release	2.125	5	0.177	52.0	86.5%
Major localised release	10.626	10	1.771	519.8	98.7%

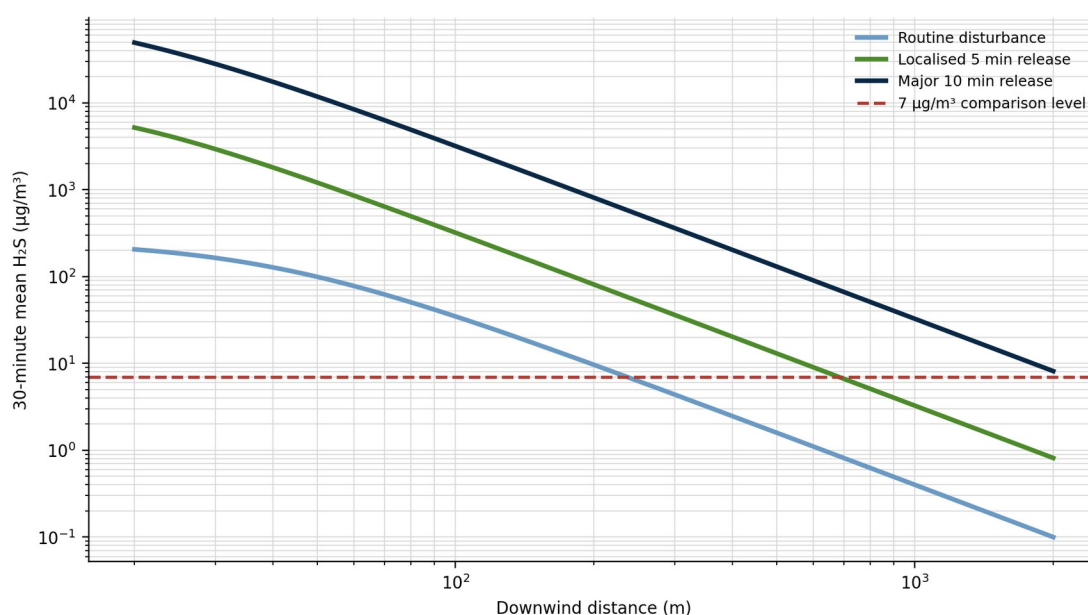


Figure 3. Synthetic 30-minute concentration-distance screening curves at 1 m/s wind.

The routine case combines 600 m² of exposed face at 1.7 mg/m²/h with 300 m³/h of waste disturbance and 0.02 m³ gas liberated per m³ waste. The localised cases use direct releases of 5 and 25 m³/min. The event-duration adjustment reduces their 30-minute mean contribution, but their much larger instantaneous source terms still dominate the result.

6 Interpretation and control sensitivity

The model is most useful as a decision screen, not as a precise forecast. Its central finding is structural: a plausible short-duration release from connected gas volume can outweigh diffuse face emissions by orders of magnitude. Controls designed only around face area, deodorising or routine monitoring may therefore leave the controlling hazard unchanged.

Where a calculated receptor concentration C_0 exceeds a selected comparison level C_t , the direct source reduction required under unchanged dispersion assumptions is:

$$\eta_{\text{required}} = \max[0, 1 - (C_t / C_0)]$$

A calculated requirement above 95% is not evidence that 95% containment is achievable. It is evidence that the proposed activity depends on very high local control performance and should not proceed until the control method has been designed, commissioned and verified. General landfill extraction efficiency cannot substitute for direct interception because excavation can isolate, bypass or damage the network that produced the historical collection figure.

7 Application workflow

1. Define the activity, maximum exposed area, waste throughput, excavation depth, receiving operation and foreseeable interruptions.
2. Measure H₂S with instruments capable of resolving the expected range. Record methane, carbon dioxide, oxygen, pressure, suction and flow so the extraction state is understood.
3. Define separate diffuse, routine disturbance and localised-release cases. Keep measured values, published evidence and engineering assumptions visibly distinct.
4. Calculate gross mass source terms before applying control. State event duration and source dimensions.
5. Screen workers, on-site locations and off-site receptors using matching averaging periods and clearly identified comparison levels.
6. Test direct containment, weather limits, maximum face size and production rate. Do not credit controls whose performance has not been demonstrated.
7. Use the screen to specify monitoring, hold points, trial criteria and the need for detailed dispersion or occupational-hygiene assessment.

8 Limitations

This calculation is an order-of-magnitude screen. Its apparent numerical precision must not be confused with predictive accuracy. Material limitations are:

- Gas liberation from disturbed waste is uncertain and can be dominated by connected voids or infrastructure rather than average pore volume.
- The Gaussian relationship does not resolve complex terrain, buildings, inversions, cold-air drainage, calm conditions, dense-gas behaviour or wind-direction frequency.
- A short event averaged over 30 minutes or 24 hours can remain acutely hazardous during the release.
- Odour comparison levels are not toxicity thresholds. Occupational limits, emergency values and public-health guidelines serve different purposes and averaging periods [5-8].
- H₂S is only one component of landfill gas and landfill odour. Methane, carbon dioxide, oxygen depletion, mercaptans, ammonia and other compounds require separate consideration.
- The method does not demonstrate regulatory compliance, a safe system of work or the performance of any proposed control technology.

9 Conclusions

A defensible H₂S excavation assessment must convert concentration into mass release and must distinguish routine surface emissions from short localised events. The method presented here provides a transparent route from source evidence to a screening decision. It exposes the variables that matter, keeps event duration and direct containment explicit and prevents whole-site gas-field performance from being mistaken for capture at the working face.

The worked example demonstrates why acute localised releases should be tested even when diffuse emissions appear modest. Where the result depends on very high direct containment, low-wind restrictions or rapid response, those requirements become design and commissioning criteria rather than assumptions. The model is therefore most valuable at the point where an excavation concept must either be developed into an engineered method or stopped pending better evidence.

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Appendix A Calculation summary

Table A1. Core equations used in the screening method.

Calculation	Expression	Output
Gas mass concentration	$C = (x/10^6)(MW/Vm)$	g/m ³
Diffuse surface source	$\dot{m} = FA/3.6 \times 10^6$	g/s
Disturbance gas flow	$Q = R_w Y_g / 3600$	m ³ /s
Gas-driven mass source	$\dot{m} = CQ$	g/s
Event averaging	$f = \min(1, t_e/T)$	dimensionless
Residual after containment	$\dot{m}_r = \dot{m}_g(1 - \eta)$	g/s

Calculation	Expression	Output
Plume dimensions	$\sigma_y = \sqrt{[(W/4)^2 + (\alpha y x)^2]}$; $\sigma_z = \sqrt{[(H/2)^2 + (\alpha z x)^2]}$	m
Receptor concentration	$C = [m \times 1000 / (\pi u \sigma_y \sigma_z)] \exp[-z^2 / (2 \sigma_z^2)]$	mg/m ³
Required source reduction	$\eta = \max[0, 1 - C_t / C_0]$	dimensionless

All inputs must use consistent units. The calculation should retain unrounded values internally and round only the reported output. Every comparison must use a benchmark with a compatible averaging period and purpose.