Available online at www.sciencedirect.com
ScienceDirect
Environment International 32 (2006) 1010–1020
ENVIRONMENT INTERNATIONAL
www.elsevier.com/locate/envint

Recent developments in the application of risk analysis to waste technologies

S.J.T. Pollard [a,*], R. Smith [a], P.J. Longhurst [a], G.H. Eduljee [b], D. Hall [c]

[a] Integrated Waste Management Centre, School of Industrial and Manufacturing Science, Cranfield University, Cranfield Bedfordshire, MK43 0AL, UK
[b] SITA Limited, Maidenhead, SL6 1ES, UK
[c] Golder Associates (UK) Ltd., Nottingham, NG12 4DG, UK

Available online 24 July 2006

Abstract

The European waste sector is undergoing a period of unprecedented change driven by business consolidation, new legislation and heightened public and government scrutiny. One feature is the transition of the sector towards a process industry with increased pre-treatment of wastes prior to the disposal of residues and the co-location of technologies at single sites, often also for resource recovery and residuals management. Waste technologies such as in-vessel composting, the thermal treatment of clinical waste, the stabilisation of hazardous wastes, biomass gasification, sludge combustion and the use of wastes as fuel, present operators and regulators with new challenges as to their safe and environmentally responsible operation. A second feature of recent change is an increased regulatory emphasis on public and ecosystem health and the need for assessments of risk to and from waste installations. Public confidence in waste management, secured in part through enforcement of the planning and permitting regimes and sound operational performance, is central to establishing the infrastructure of new waste technologies. Well-informed risk management plays a critical role. We discuss recent developments in risk analysis within the sector and the future needs of risk analysis that are required to respond to the new waste and resource management agenda.

Keywords: Risk; Analysis; Waste; Management; Developments; Process; Technology

1. Introduction

Environmental risk assessment is an established feature of modern environmental decisions and has been used successfully to target risk management actions on the key drivers of risk across a range of anthropogenic and natural hazards (European Environment Agency, 1998). The basis of risk assessment (Vose, 2000) is an evaluation of the connectivity between the source of a hazard and an environmental receptor — something one wishes to protect. Without a "dose"— an amount or duration of exposure to a harmful agent, there can be no harm at the receptor and one purpose of risk assessment must, therefore, be to evaluate the likelihood and consequences of determining this harm. Many regulators now promote a tiered approach to risk assessment that allows for an initial screening and prioritisation of risk prior to undertaking more detailed assessments (DETR et al., 2000). This assists in ensuring that problems are well-defined, that potential sources, pathways and receptors are comprehensively considered and that subsequent risk assessment effort and resources are focussed on the key risks identified at a screening stage.

The waste management sector applies risk assessment widely to issues such as the risks to groundwater from landfills (Environment Agency, 1996; Hall et al., 2003), the potential risks to human health from continuous stack emissions (Harrop and Pollard, 1998; Eduljee, 2001) and to the potential health impacts from exposures to landfill gas (Attenborough et al., 2002). The development of conceptual models, site-specific exposure scenarios and application of the source-pathway-receptor approach (DETR et al., 2000; Environment Agency, 2000; WHO, 2000), supported by quantitative analysis (Vose, 2000) where appropriate, is now commonplace. Environmental risk tools are based upon models that characterise pollutant pathways in open environmental systems and assume, or model, the release of the source of a hazard to the environment, be it through mechanisms such as liner failure, the episodic flux of emissions to air, or diffusive flow through a landfill cap. Modern groundwater risk assessments for landfills couple a performance assessment of the liner system (Environment Agency, 2001; Hall

* Corresponding author. Tel.: +44 1234 754101; fax: +44 751671.
E-mail address: s.pollard@cranfield.ac.uk (S.J.T. Pollard).

0160-4120/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envint.2006.06.007

et al., 2003) with a contaminant transport model to assess potential risks to receptors such as downgradient abstraction boreholes (Fig. 1). The numerical approach to characterising pathways of environmental exposure (e.g. groundwater dispersion or air diffusion) and modelling the distribution of contaminants in the environment, has proved powerful for the developers and operators of waste facilities in securing environmental permits (Garrick, 2002).

A shift within the sector towards waste process technologies, and the attending concerns raised about the potential environmental harm (Dolk, 2002; Defra, 2004) that may result from routine, unmanaged or accidental releases to the environment however, is forcing a widening of the portfolio of risk tools required (National Research Council, 2000; Environment Agency, 2000). Furthermore, we are witnessing a more joined up approach to the assessment of risks from waste facilities (Environment Agency, 2004a), with a growing need to assess a larger set of causal events and subsequent exposures that might result in detrimental impacts — including issues of odour nuisance, exposure to trace components in landfill gas and to airborne microorganisms from biological waste treatment, losses in slope stability at landfills and risks from process failures in engineered systems. This paper discusses these developments and attempts a synthesis of the role of risk assessment in the modern waste and resource management sector.

1.1. Risk analysis tools

Risk assessment tools can be categorised by reference to the nature of the risk problem they are used to assess. Generally, risk analysts are concerned with three categories of risk problem that can be considered as part of a causal chain of events (Pollard and Guy, 2001; Fig. 2):

(i) *source term* risks associated with the risk of an *initiating event* or combination of events that deviate from normal operating conditions and may result in a *release* to the environment (e.g. fire risk; the loss of flame at a pumped landfill gas flare unit; the catastrophic release of fire wash down from an on-site collection tank; the risk of mixing incompatible wastes; a catastrophic landfill liner failure; inventory loss of treatment reagents or stored wastes; inappropriate mixing of hazardous wastes during treatment; CIRIA, 1997);

(ii) *pathway* risks that address the likelihood of a certain *exposure* of an environmental receptor to a hazard following an initial release (e.g. grounding of a plume downwind of an incinerator stack; movement of a leachate plume towards and abstraction point; off-site bioaerosol exposure from the turning of windrows at a composting facility; Pollard et al., 1999); and

(iii) the risks of harm to *receptors* that might occur as a result of the exposure (e.g. adverse human or ecological health effects as a result of exposure to toxic/asphyxiant gases; a toxic overload to biological wastewater treatment plant as a result of a shock load of hazardous waste illegally disposed to foul sewer; occupational health effects experienced by workers at enclosed composting facilities; needlestick injuries and their consequences to medical waste management operatives).

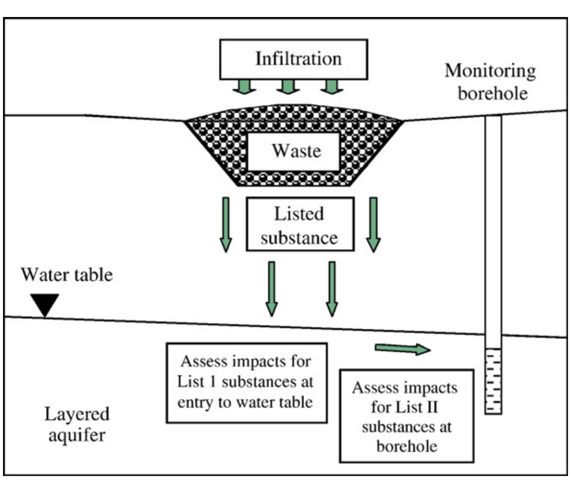

Fig. 1. Basis for the combined performance and risk assessment of landfills and their potential impact on downgradient abstraction points, here by reference to listed substances in the EC Groundwater Directive (Environment Agency, 2000).

Each of these types of problem has associated with it certain categories of risk analysis tools (Fig. 2) that tend to dominate for the analysis in each case. In part, because of the regulatory separation between health and safety and environmental concerns, these tools have historically developed in isolation of one another with little connection between the outputs of one analysis and the input requirements of another. In the future, the integrated pollution and prevention control will ensure that these aspects are more integrated.

Risk analysis tools are also available at a range of tiers of technical sophistication (qualitative, semi-quantitative, quantitative-deterministic, quantitative-probabilistic; DETR et al., 2000; Pollard et al., 2002) and, in deciding on the application of techniques, risk analysts need to consider both (i) the appropriate tool by reference to the type of risk problem being studied (Fig. 2); and (ii) an appropriate level of sophistication selected as needs, complexities, priorities and data allow (Pollard et al., 1995). Changes occurring within the sector are likely to remove the historic barriers between these types of risk problem and their analysis. New guidance for landfill operators in the UK, for example (Environment Agency, 2004a), promotes assessing and presenting the risks for a site as a whole, rather than considering the significance of risks from individual hazards in isolation of one another. This will allow operators and regulators to focus on the priority risks to health and the environment and identify common research needs for the improved understanding of landfill process, for example. Integrated pollution prevention and control is also forcing consideration of risk management at source (pollution prevention) as well as a comparative analysis of risks to the multimedia environment. Under these developments, a broader set of risks (other than just to the aquatic and atmospheric environment) require analysis and comparison.