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Significance of baseline study in landfill risk assessment

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Abstract

Environmental awareness and concerns of the public over potential environmental threats posed by anthropogenic activities have grown rapidly worldwide in the last decade. Risk Assessment and Risk Management are very vital to the effective management of the environment against hazards arising from inevitable anthropogenic activities, thereby resulting in a cost-effective compromise between financial and environmental costs and ensuring that the philosophy of 'sustainable development' is adhered to. In parallel with the above, environmental legislation is becoming more and more strict as well as global, and a realisation of the significance and effectiveness of risk assessment in environmental management has kick-started the imposition of risk assessment as a legal requirement.

In our literature review mainly related with landfill risk assessment, no evidence has been found of a holistic risk assessment methodology. In fact, a range of knowledge gaps has been found in the literature reviewed to date. One of these gaps in knowledge is the procedure for carrying out Baseline Study, which covers a range of subject areas, including Geology, Hydrology, Topography and Climate. This paper, with reference to the relevant literature reviewed, discusses the extent to which Baseline Study is missing in landfill risk assessment approaches and the elements that should contribute to the procedure of Baseline Study in order to have a successful landfill risk assessment.

1 Introduction and background

Landfills, via undergoing the process of waste degradation, produce products in all three main states. These are, solid (which is more or less stabilised waste),

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liquid (called leachate) and gas (generally named landfill gas). Further, landfills have very high potential to pollute the three principal environmental media - the atmosphere, the lithosphere and the hydrosphere. Such pollution will be transmitted through these media and will impact, either directly or indirectly, upon the human and natural environment (including aquatic and terrestrial flora and fauna) and built environment. Thus landfills have to be risk assessed and managed to guard the environment against their hazards.

The awareness and concern of the public over the environmental issues have been ever growing not just for the present generation but also the generation to come. On the other hand the UK legislation has been increasingly supporting and guiding sustainable environmental management in all areas, through a series of regulations. Environmental issues and environmental legislation have increasingly followed a global theme. For instance, the Waste Management Licensing Regulations [28] transposed from an EC Directive on Groundwater [6] Environment Agency [8]; EU Directive on IPPC (Integrated Pollution Prevention and Control) [12]; EC Directive on EIA (Environmental Impact Assessment) [11]; Environment Protection Act [9]; Environment Act [7]; etc. In a similar manner to the growing environmental concerns and globalisation process described above, having realised the significance and effectiveness of risk assessment in environmental management, the environmental legislation has started to impose risk assessment as a legal requirement [8]. For instance, for the protection of groundwater from landfill leachate a risk assessment requirement has been legislatively introduced in the UK since 1st May 1994, through Regulation 15 of the Waste Management Licensing Regulations [28].

Furthermore, not withstanding the type of risk assessment and the field / area of application (from environmental issues to any business fields), one of the most common elements is Baseline Study on which any risk assessment process is based. In our literature review it has been found that no landfill risk assessment approach or computer model has a holistic Baseline Study procedure. In the following sections of the paper the extent to which Baseline Study is missing in landfill risk assessment approaches and the relevant computer models, and the elements that should contribute to the procedure of Baseline Study in order to have successful landfill risk assessment are discussed. However, in the context of risk assessment, the authors define Baseline Study as the most preliminary step or the very first step of a risk assessment process in which all basic information and / or data is gathered, organised and analysed on which the rest of the risk assessment process is based. In the case of landfill risk assessment the Baseline Study has to cover a wide range of subjects as described in section 4.0.

2 A holistic risk assessment methodology for landfills and baseline study procedure

Risk Assessment is a recent [19] and growing field of study [27], not just in relation to landfills and other environmental issues but also other business fields including, Finance, Construction Management, Food Industry, Ecology, Epidemiology, Health Physics, Radiation, Building Contract Selection, Insurance, Economics and Oil Industry, [15], [27], [19], [23], [30], [10]. The review of the literature shows clearly that Baseline Study is a common element in a risk assessment process. The requirement of Baseline Study in a risk assessment process is so important that it has to be carried out irrespective of the field of application. However, literature on risk assessment related to environmental issues and mainly regarding landfills has been the main focus of the literature review presented in this paper. This includes [2], [8], [18], [5], [22], [16], [21], [29], [4], and [1].

The review of the environmental related literature led to the conclusion that a holistic, detailed and sound risk assessment methodology which encompasses the various types of landfill systems and their surroundings, and takes into account all possible characteristics of landfills in terms of risks and quantification of risks posed by landfills does not exist. A range of knowledge gaps has been found in the literature reviewed to date and the most common gap has been that of a procedure for carrying out Baseline Study. For instance, ICE [16], describes risk assessment from the contaminated land's point of view rather than from landfill's perspective. In other words this publication is not specifically about landfills. Furthermore, although this publication outlines the main contents of a Baseline Study for risk assessing any types of contaminated land, but does not describe a robust and objective procedure of carrying out Baseline Study for landfills or any contaminated land. Similarly, Asante-Duah [1], describes all important aspects of risk assessment and risk management (including Baseline Study) but not in the form of a methodology rather independent of each other in different chapters. Moreover, like ICE [16], this publication is also from the contaminated land perspective rather than specific to landfills, thus does not cover a range of landfill aspects including leachate formation, migration and attenuation. Blight and Fourie [2] although focusing on landfills only but still very briefly outlines the requirements of Baseline Study for landfill risk assessment. Environment Agency [8], more focused on landfills in risk assessment terms than the literature described above and outlines very clearly what should be the main contents of a Baseline Study. However, no description was given on the procedure for carrying a Baseline Study out.

In summary, in the reported literature to date no evidence has been found on how to perform a Baseline Study for risk assessment of landfills. The current practices for Baseline Study, particularly in the UK, have no organised approach to carrying it out since a holistic procedure does not exist in the first place. Different risk assessors carry out Baseline Study in different ways, depending upon a number of factors including the characteristics of a given landfill scenario, which also includes the degree of availability of the information. There is no such thing as a checklist of methods for all the modules and sub-modules (section 4.0) against which they can streamline a Baseline Study process for risk assessment process for a given landfill.

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3 A holistic computer model of risk assessment for landfills and baseline study procedure

As a part of the literature review different relevant computer models were also studied. Three models were identified closely related to landfill risk assessment issue. These are LandSim [14], HELP [26] and RIP [13]. LandSim and HELP are the only computer models found to be specifically designed for landfills, although RIP was also later on added with the features, which could take into account landfills on a comparatively large scale. While other software types studied are not landfill related. They could be used to cover some of the aspects of landfill risk assessment methodology. For instance, the software Drill Guide [25] is useful and can be included in the geology module of a Baseline Study procedure which consequently will help in a risk assessment process for a given landfill. As far as the landfill related software are concerned they do not cover all elements of the risk assessment methodology for landfills, which includes Baseline Study. Some models cover aspects of Baseline Study in parts. For example, LandSim uses various input data to prepare site conceptual model. However, LandSim does not describe how to find and process this data, all of which forms part of what has been referred to as 'Baseline Study' in this paper. In other words, the LandSim is a part of the whole risk assessment process for a landfill [24]. Similarly, HELP model does contain some aspects of Hydrology including precipitation and surface runoff but does not cover many other aspects of hydrology including evaporation, transpiration, interception and liquid wastes. It also does not involve some other important modules of Baseline Study, including geology, hydrogeology, landfill site history and wastes types. In summary, there exists no computer model, which has a holistic Baseline Study procedure for landfill risk assessment.

4 The development of the baseline study procedure

The explanation in sections 2.0 and 3.0 firmly establishes the need for the development of a procedure for the Baseline Study, which is holistic. The authors are designing keeping this in view, a Baseline Study (BS) procedure by having it divided into eight modules (Figure 1) namely, Geology, Hydrology, Hydrogeology, Topography, Climate, Geography, Site Management and Human Influences. The main approaches to collect information on them in connection to a given landfill is via either Desk Study or Site Inspection or Ground Investigation or any combination of these three, as shown in Figure 1. The sub-modules of these eight modules are also shown in Figure 1 to give an idea of what main relevant areas of these eight modules are to cover. For instance, the sub-module Human Influences includes past, present and future potentials of human influence in terms of quarrying / mining, water abstractions, developments, etc. Further details and features of the procedure are discussed in the following section 5.0 in connection with the computer model being designed.

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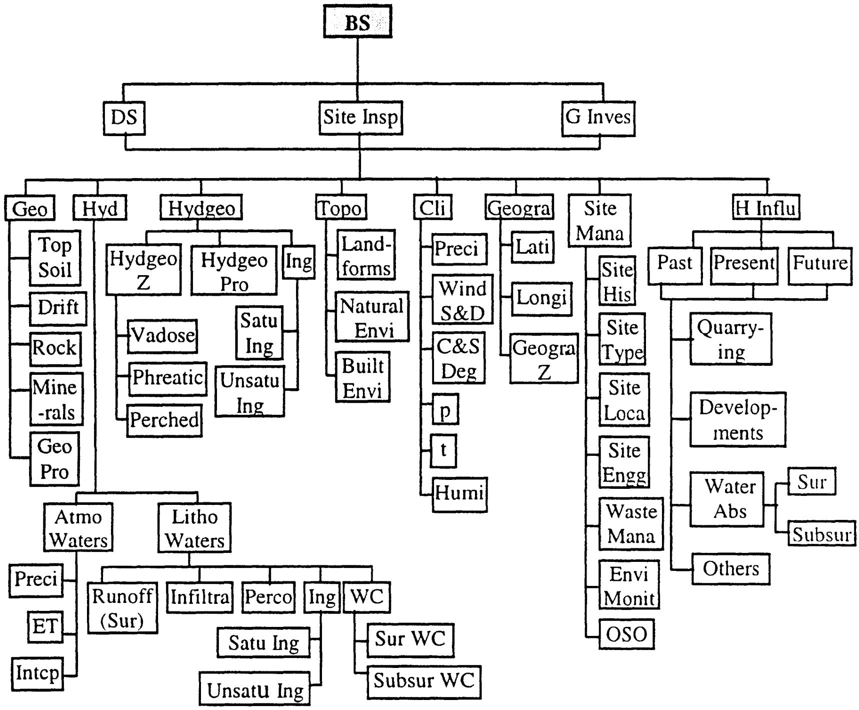
Figure 1: The structure of the Baseline Study procedure (For 'Notation' see the following page)



5 The development of the knowledge-based computer model

The issues raised in the previous sections of the report do not only firmly establish the need for a holistic Baseline Study procedure for landfills' risk assessment process but also the requirement for an electronic presentation of this procedure. The underlying context of model development was decided based upon the needs of a risk assessment process for landfills. It also covers wide range of relevant users and subjects such as, legislation, engineers, risk assessors, risk managers, lenders, funders, contractors, etc. Using information derived from literature sources, anecdotal exchanges with experts / end users and personal intuition, awareness of possible avenues for model development was cultivated.

After considering a range of computer languages / master programmes to use as a computer platform for developing the computer model, in the light of discussions with computer experts Microsoft Access was selected. This was decided on the basis of a number of features of MS Access including; being comparatively easy and quick to learn, specially good for beginners and non-technical users, having Visual Basic for Applications (VBA) embedded in it and being a relational database product [31], [20], [3]. However, having established a basic development of template the issues of input and output data were

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addressed. Typically, a knowledge-based model requires and generates a significant amount of data. Given that the input data sets for this type of model are often complex, incomplete and / or difficult to obtain then a decision was taken to adopt a policy of alternative provision of data. The objective was to enable risk assessors to make use of 'general' type of data from literature, database or from other alternative means for instance, relevant professional experts. This provision has been embedded while attempting to maximize model usability, retaining a high accuracy, and imparting information rich output.

Notation:

Abs	Abstraction(s)	Intcp	Interception
Atmo	Atmosphere / Atmospheric	Inves	Investigation
B	Baseline / preliminary	Lati	Latitude(s)
C&S Degree	Degree of Cloudiness and Sunlight	Litho	Lithosphere / Lithospheric
Cli	Climate	Loca	Location
D	Desk	Longi	Longitude(s)
Engg	Engineering	Mana	Management
Envi	Environment	Monit	Monitoring
ET	Evapotranspiration	OSO	Other Site Operations e.g. documentation
G	Ground	p	Pressure
Geo	Geology / Geological	Perco	Percolation
Geo Pro	Geological Properties e.g. porosity	Preci	Precipitation
Geogra	Geography / Geographical	Pro	Properties
Geogra Z	Geographical Zone(s), e.g. tropical	S	Study
H	Human	Satu	Saturated
His	History	Subsur	Subsurface
Humi	Humidity and / or Relative Humidity	Sur	Surface
Hyd	Hydrology / Hydrological	t	Temperature (wet & dry bulb)
Hydgeo	Hydrogeology / Hydrogeological	Topo	Topography
Infiltra	Infiltration	Unsatu	Unsaturated
Influ	Influence(s)	WC	Watercourse(s)
Ing	Ingress	Wind S&D	Wind Speed & Direction
Insp	Inspection	Z	Zone(s)

5.1 Six categories of methods

The computer version of the Baseline Study procedure being developed, is a template [17]. This template is such that it will not only be a structured knowledge or knowledge-based but it will also accommodate database to a reasonably high extent. For instance, in the interception sub-module, a number of interception loss measurement methods that are presently available have been described.

For the modules and sub-modules of the Baseline Study procedure which can come up with objective / mathematical value, methods to find values have been

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grouped in six categories, namely; Organization, Field Experimental Method(s), Laboratory Experimental Method(s), Empirical Method(s), Typical Values and Judgement. Each category can have more than one method of finding values and in some cases a category may not be having any method depending upon factors such as practicality, reported knowledge to date, etc. For instance, it is not practicable for precipitation to be measured in a laboratory therefore in the category of Laboratory Experimental Method(s) there would be none. For a quick reference on the six categories of methods readers are directed to see Figure 2 on interception loss measurement, quoted from the MS Access work carried out to date.

5.2 Query features of the MS access work

With reference to Figure 2, the initials HAL stand for Highest, Average and Lowest. The idea behind this approach is that whatever number of methods are applied and whatever number of times they are applied they all will not be giving the same Maximum, Mean and Minimum values. So one has to find out Highest and Lowest Maximum and Minimum values, and Average of Mean values. Thus, in the case of each module and sub-module for which mathematical / objective values are being worked out, there will be altogether five values. Figure 2 shows a front page of interception loss measurement designed by the authors. The Access programme will pick up the five aforesaid values when a risk assessor clicks the button called 'Workout (HAL)'. To pick these values up the computer programme will search its relevant Union Query table, for instance see Figure 3 where all the values from all the applied methods were saved. Due to time constraints in the research project, the term 'Most Likely' in the model has been deemed equal to Mean, although strictly it may not be so, at least not every time. The Average of the mean values is to be used by a risk assessor for the Most Likely scenario. However, depending upon the nature of the module or sub-module being evaluated, Highest or Lowest Maximum value or, Highest or Lowest Minimum value can be selected for Worst case scenario. As an example see the text box explanation just above the 'Workout' button in the bottom of Figure 2.

5.3 Mutual interconnections or mutual information transport between modules and sub-modules in the computer model

Modules and Sub-modules of the Baseline Study procedure, which consist of objective / mathematical values, need to be interconnected with other modules and sub-modules where these values are required for subsequent analysis. These interconnections, which were first developed on big sheets of papers (to ascertain the logical order of information requirement), have partially been extended to the computer version of this project. That is, the interconnections have been partially implemented in the Microsoft Access Programme. The following example quoted from the work done so far is described to explain this.

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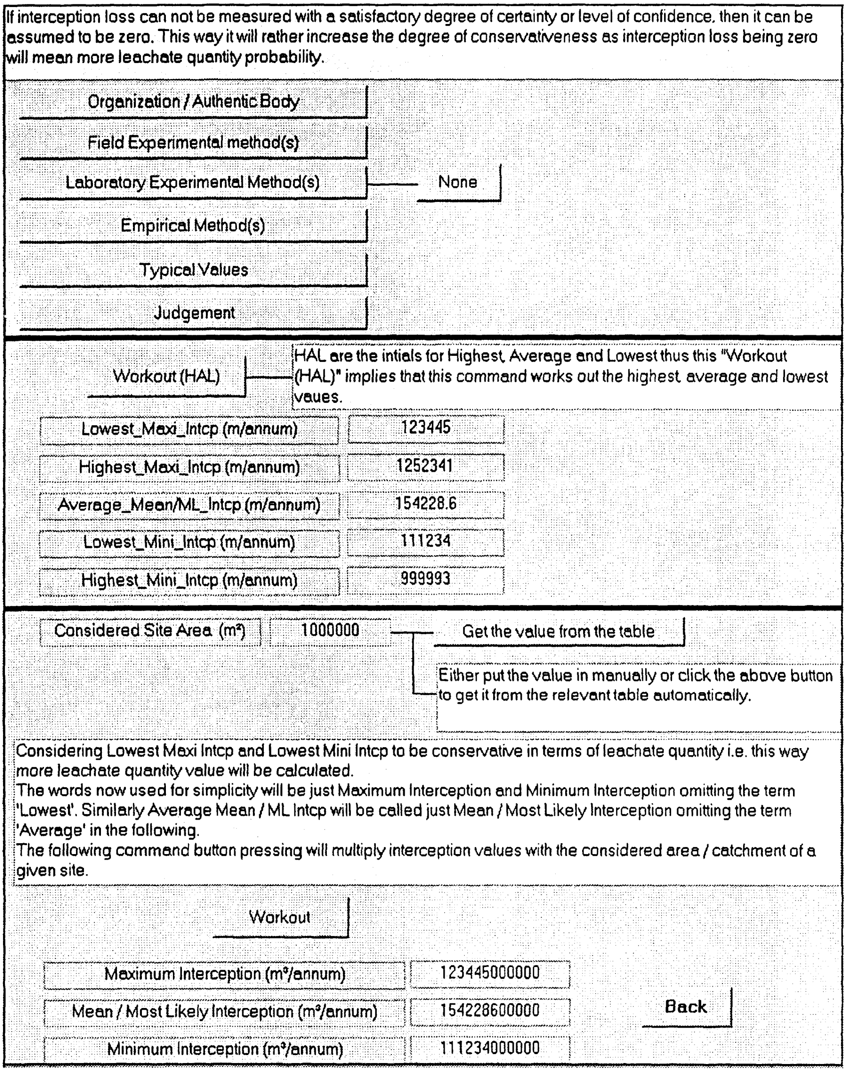
Figure 2: Interception (Loss) Measurement Dialogue Box in the Computer Model



'Get the value from the Table' button is used after 'Workout (HAL)' button (See Figure 2). This button, when pressed, will retrieve the value of 'Considered Site Area' of site from 'Site Engineering' form, which is another part of the Access programme. To keep the programme flexible a risk assessor has been provided with a facility to feed the value of his / her choice if he / she does not want to use exactly the same value as the one lying in the 'Site Engineering' part of the programme.

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Figure 3: Union Query Table for Interception (Loss) Measurement in the Computer Model

Category Title	Method Title / Source Ref	Maxi Intcp (m/annum	Mean/ML Intcp (m/annum	Mini Intcp (m/annum)
Empirical Method	Horton Method	1000000	513245	999993
Empirical Method	XYZ	125000	123456	124000
Field Expe Method	Approximation Method	1234411	114322	118765
Field Expe Method	Corbett and Crouse Method	1252341	111167	111323
Field Expe Method	Horton Method	1234456	111111	111235
Field Expe Method	XYZ			
Judgement	XYZ	145233	123456	133323
Lab Expe Method	XYZ	123456	112322	112345
Organization	Climate Centre			
Organization	Hydrology Centre	199345	187654	177456
Organization	Meterology Centre	123445	15677	111234
Organization	XYZ			
Typical Values	XYZ	143267	129876	134454

6 Discussion and conclusion

As stated earlier in section 1.0 on 'Introduction' that landfills, even though being of very high potentials to pollute the environment, are inevitable and highly required. So risk assessment and management are very vital to the effective management of the environment against landfills' hazards. On the other hand, in our literature review on landfill risk assessment approaches and computer models, no evidence has been found of a holistic landfill risk assessment methodology and nor that of a holistic knowledge-based computer model which could perform the process of risk assessment for landfills from start (i.e. baseline study) to end (i.e. risk quantification). A range of knowledge gaps has been found in the review among which a holistic Baseline Study procedure is the most common. On the other hand the Baseline Study is a most important factor of an effective risk assessment as the success of latter is based on the former. In this paper an attempt has been made to outline a holistic procedure of Baseline Study from the point of view of landfill risk assessment. The electronic translation or representation of the procedure (i.e. the computer model) has also been presented. Once this model is complete it is anticipated to be very useful in a number of ways which includes the following benefits. The Baseline Study model will provide useful input information for LandSim and, may also be useful for other risk assessment models such as HELP and RIP. This model of Baseline Study will provide a much stronger base to carry out hazard assessment (by helping in identifying landfill hazards in terms of quantity and quality), risk assessment and consequently risk management, where risk assessment is a legal requirement to protect groundwater resources against leachate hazards. This model can also be used for a more solid Environmental Impact Assessment and Statement, which is a legal requirement for landfills. And thus it can also play indirectly an effective role in landfill planning permission and also in design, construction and hazards mitigation measures.

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