Technical Committee on Geotechnics of Landfill Engineering
German Geotechnical Society (DGGT)

Technical Committee Sanitary Landfills
German Association for Water, Wastewater and Waste (DWA)
Association of Municipal Waste Management and City Cleaning (VKS in the VKU)

Technical Committee Landfill Technology

Toolkit Landfill Technology

Chapter 2.1

Site Selection

Hansjörg Oeltzschner, Bachern/Wörthsee, Germany

Reviewed by DGGT/DWA-VKS-Technical Committee
“Landfill Technology” and published in the internet
http://www.landfill-technology.info.

June 2009

Table of Contents

1 Principles and Preconditions

The planning of a proper solid waste disposal facility requires answers to the following questions (see also Chapter 1.5 “Principles of Landfill Design”):

- What kind of waste is supposed to go to the landfill?
- What amount of waste will have to be disposed of in the landfill?
- For how long a time must the site be available?
- Which economical criteria have to be respected?
- Which traffic conditions are needed for the transport of the waste to the site?
- How are the existing traffic links?
- What kind of excluding factors have to be respected in the process of site identification and evaluation?
- What kind of restricting factors have to be regarded when the site rating is done?

These questions must be answered, to have a firm foundation for phases 1 to 4 of the planning process. The identification and final selection of a landfill site should be carried out in four main steps, shown in Table 1. Annex 5 gives a short example of a site selection process for a sanitary landfill for the municipality of Kabul, Afghanistan.

Table 1: Flow chart of an area-covering site selection (a focussing process)

Condensation of Information	**Steps and criteria**	**Reduction of areas**
Phase 1: Exclusion criteria	Data collection and exclusion of unsuitable areas (“Negative mapping”)	Total area
Phase 2: Evaluation criteria	Identification of possibly suitable areas (“Positive mapping”)	Reduction to e.g. 4 - 6 sites
Phase 3: Site investigation	Site Investigation: Physical, technical, geological, hydrogeological and geo-technical reconnaissance, environmental assessment, comparative site rating	Reduction to 2 - 3 sites
Phase 4: Final decision	Final proposal and final decision	1 site

2 Identification and Selection of a Site – Scheme of Work

2.1 Phase 1: Data Collection and Exclusion of Unsuitable Areas ("Negative Mapping")

For the areas in question, the concerned municipalities and/or regional authorities, pertinent institutions, national geological services etc. have to be contacted and queried in meetings.

Data and information are collected for a general survey ("desk study") on each area in question with respect to (minimum requirements are underlined):

- Topography / morphology
- Geology, geohydrology, hydrology
- Seismic conditions
- Pedologic, climatic/meteorological conditions
- Geotechnical situation
- Surface water bodies
- Land-use
- Nature protection (national parks, forests, nature monuments etc.)
- Cultural sites (religious, heritage etc.)
- Military areas
- Distance to settlements (existing and planned)
- Distance to airports (existing and planned)

With this information, areas which evidently appear unsuitable are marked accordingly on the drawing, they are thus "mapped negatively" (see section 3).

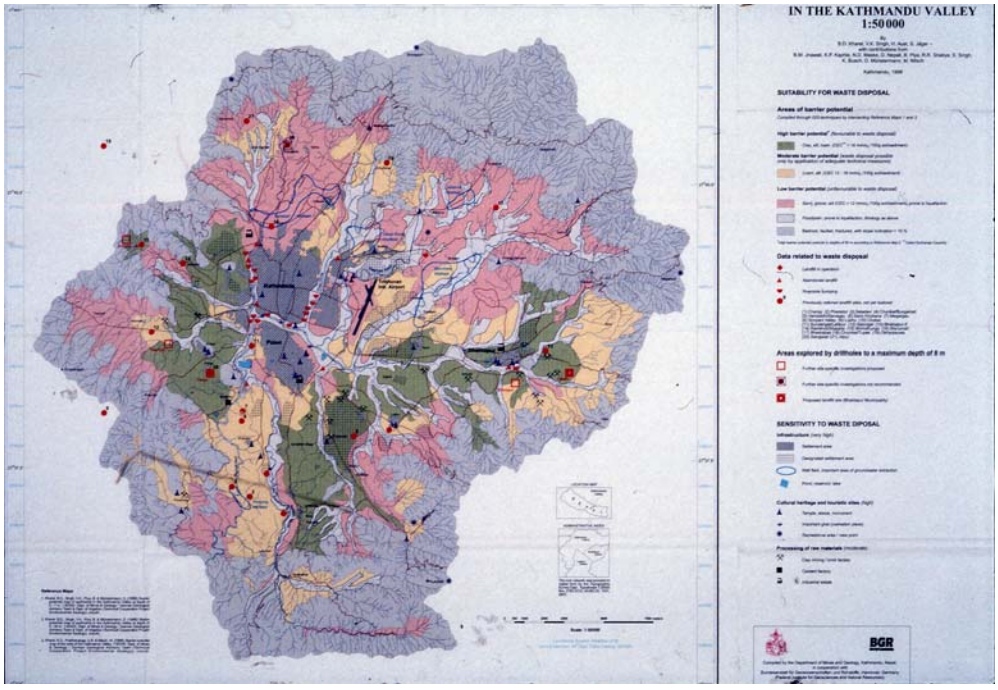


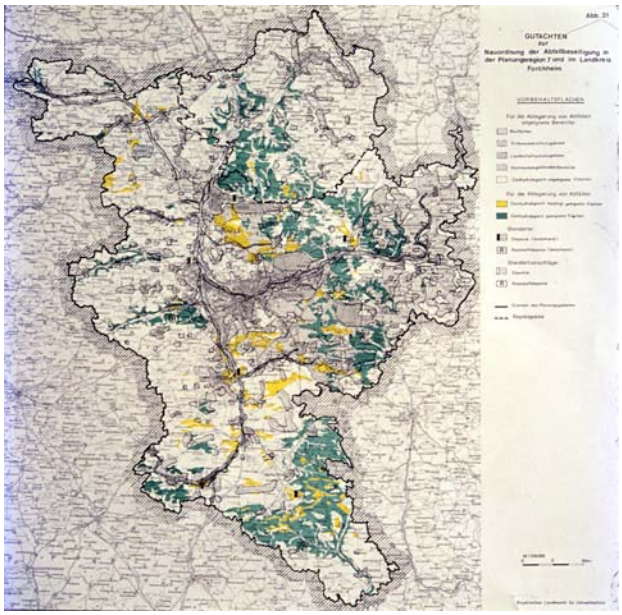
Figure 1: Kathmandu Valley, Nepal: Example of a positive/negative mapping for the identification of areas suitable for a sanitary landfill (BGR, Hannover)

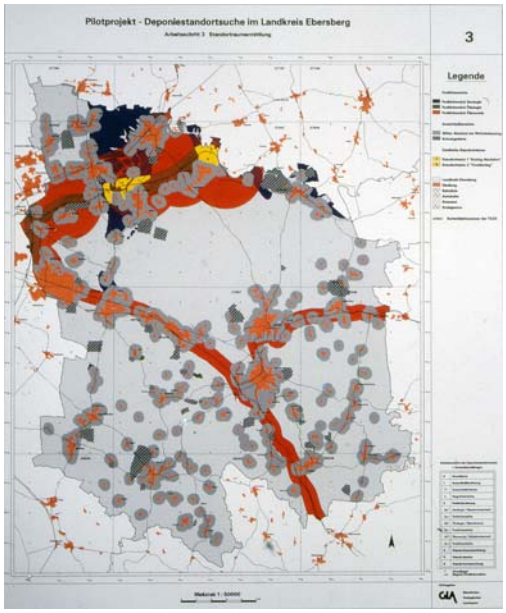
2.2 Phase 2: Identification of Possibly Suitable Areas ("Positive Mapping")

Areas of interest which pass phase 1 successfully are investigated with respect to:

- Availability of land
- Minimum size and geometry of site
- Traffic links
- Access to selected sites
- Investment budget
- Acceptability by the public

Areas which pass these tests successfully are regarded as possibly suitable areas. They are marked accordingly on the drawing; they are thus "mapped positively".





Figures 2 and 3: Example of a negative/positive mapping for the selection of a site for a sanitary landfill in Germany
Figure 2 (left): Green areas positive, yellow areas potentially positive
Figure 3 (right): Only orange areas positive

2.3 Phase 3: Site Investigation: Physical, Technical, Geological, Hydrogeological and Geotechnical Reconnaissance

Phase 3 comprises visits of the areas of interest and investigations of the geologic, hydrogeologic, and geotechnical conditions at the potential sites (see section 6).

2.4 Phase 4: Final Proposal and Final Decision

After comparison of the results of the site investigations at the areas of interest, one site may turn out to be most favourable. The properties of this site will be presented in a report with the recommendation to select this site among the candidates, which were examined and compared.

3 Criteria of Site Rating

The survey for a potential landfill starts with a careful desk study leading to the production of a program for field investigations and laboratory testing. The final scope of the overall investigation program will often not be decided until the field surveys are in progress. The finding and selection of a suitable site for a sanitary landfill depend on certain criteria. Some of the criteria exclude the possibility to establish a landfill in a certain area. Some criteria have to be regarded in detail as indicative of potentially negative factors when the site situation is evaluated. And finally, some of the criteria clearly distinguish suitable sites from unsuitable sites.

In the process of site rating, especially the geological and hydrogeological conditions of a potential site have to be regarded as basic elements to be studied in the investigation. The best “safety feature” for a sanitary landfill will be a competent natural barrier that keeps contaminants away from the groundwater. This important function of a “geological barrier” can be fulfilled by geological strata with a very low permeability and a very low transmissivity, and if possible with a good contaminant retention capacity (essentially high ion-exchange capacity). Therefore, the identification of areas with a “suitable” geology is one of the most important preconditions for site identification.

For the site selection and evaluation the criteria listed below have to be respected. Criteria excluding an area from the site selection process are (minimum requirements are underlined):

- Existing or planned (i. e. already officially registered) drinking water-protection- and catchment-areas
- High-flood-areas
- Karst and similar areas with soil conditions, which allow a fast permeation of contaminated water or leachate to the nearest aquifer
- Areas with unstable ground like swamps, moors and/or marshes
- Areas with an extreme morphology (steep slopes, danger of landslides/avalanches etc.)
- Areas endangered by sink holes, collapsible sites, deep excavations
- Areas nearer than 300 m (minimum distance) to inhabited sites
- National parks, nature protection areas and nature monuments, areas with precious biotopes
- Military areas
- Civil aviation buffer zones (bird strike hazard)

According to the “Ford Act” (see EPA, 2003) areas closer than 6 miles (9.66 km) to an airport must be avoided. The local situation, in particular flight and landing routes, bird population, and special legal regulations have to be checked.

Additional criteria for consideration exist for areas where the conditions do not seem to be very favourable for a landfill site and further investigations might not make much sense:

- An unfavourable local hydrogeological situation, e.g., high permeability of the soil (no “geological barrier”), springs or drinking water wells within a very near vicinity of the chosen area
- Extremely bad access, i.e. no existing access roads to the selected area, which may involve long distances (> 5 km) from main roads to the surroundings of the site and to the site itself
- Access roads of very poor quality and/or access roads passing densely populated areas
- Great differences in altitude (extreme morphological differences) between the area of waste collection and the selected site, often in combination with an extremely exposed position, e.g., on a ridge
- An active population, e.g. farmhouses etc. at or very close to the site (< 300 m) often going together with:
- Very intense agricultural use, mainly small-scale farming
- Too small available volume
- Difficult geological situation: danger of mass movements, too steep slopes, strata-bound groundwater etc.

There are other criteria, which may lead to the exclusion of a site, especially concerning unacceptable impacts on groundwater, surface water, and particularly on drinking water catchment areas. Comprehensive knowledge of the groundwater regime is therefore required including the following detailed information (see also section 4):

- Groundwater regime, direction, gradient and rate of flow including long-term and seasonal fluctuations
- Permeability (horizontal and vertical) or transmissivity of the outcropping strata, maximum and minimum values
- Distribution, thickness and depth of aquifers, aquicludes and aquitards, including the locations of springs
- Groundwater levels, indicating hydraulic gradients and effective flow velocity in the individual strata components, if appropriate
- Groundwater chemistry, including determination of naturally occurring aggressive substances and groundwater quality
- Possible background contamination of the subsoil and groundwater
- Influence of short-term or long-term lowering of the water table, restoration and extraction or augmentation of groundwater in the future
- Influence of nearby open waters and their interaction with the groundwater system
- Situation in respect to receiving streams, influences of flooding and tides
- Effective rainfall, surface runoff, percolation rate, evaporation, groundwater recharge

If no suitable site is found, the applied set of criteria/additional criteria should be reconsidered. An alternatively identified site might require additional technical measures to mitigate the undesirable aspect of the site.

4 Site Evaluation Methodology

An “evaluation-sheet” or checklist is a useful tool for the detailed technical and ecological evaluation of site areas. It can be used during the field reconnaissance and may also help to make the evaluation more easily understandable to third parties. Such an evaluation sheet is attached as Annex 1 at the end of this chapter. The site-evaluation checklist focuses on 6 groups of data and parameters:

- General data, e.g., volume, traffic links, distances from main waste sources, morphological situation
- Hydrogeology and water management
- Geotechnical and constructional aspects
- Meteorological aspects
- Aspects of emissions and immissions
- Nature protection and land-use

The checklist in Annex 1 can be used in the field. It shall help the investigator to gain insight on the general situation at the site area. After a field visit to the identified area, based on the data recorded on the checklist, the investigator should be able to make a first evaluation of the site. He should be able to understand, if there are favourable or less favourable conditions for the establishment of a landfill site or if the situation is positive because there will be no important (= indifferent) environmental impact on the respective parameters.

At the end of the field visit the investigator should be able to decide, whether further research on the site area should be done, or if the site seems unsuitable, so detailed investigations would not be justified. Another option could be to postpone more detailed investigations at this site area until results of alternative sites are available, which might indicate that no better site could be found. In many cases a combination of various negative factors leads to the exclusion of sites from further investigation. In some cases, even if there are a lot of positive factors, an area may eventually have to be rated as „less suitable“ or „not suitable“, because of only a few, but important (decisive) negative factors, e. g. hydrological risks, no competent geological barrier, etc. The results of the field visits and of the detailed review of background information concerning the geological, hydrogeological, pedological, and land-use situation at the proposed sites have to be documented in a detailed report. At last, a comparative site rating process has to be carried out in order to demonstrate which of the investigated sites is the best suitable for the construction of a sanitary landfill.

5 Methodology of Environmental Impact Assessment and Comparative Site Rating of Potential Landfill Sites

In comparison with the virgin, undisturbed natural condition, a sanitary landfill will always have an impact on the environment at the site location, even if designed, constructed and operated according to the state of the art. Therefore, an evaluation of the ecological/environmental impact has to be integrated in the evaluation of a site which will be proposed for a sanitary landfill. At an early stage of the project, this can be done by a simplified method based on the results of the field visits of the sites, regarding especially the ecological factors. If the site is located in a very sensitive area a detailed investigation of the proposed area has to be carried out. A good general help is the World Bank's Operational Manual BP/OP 4.01 concerning environmental impact assessment.

Annex B of this manual, dealing with the "Environmental Assessment Report", EA defines a Category A project as follows:

> *"A proposed project is classified as Category A, if it is likely to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. These impacts may affect an area broader than the sites or facilities subject to physical works. EA for a Category A project examines the project's potential negative and positive environmental impacts, compares them with those of feasible alternatives (including the "without project" situation), and recommends any measures needed to prevent, minimize, mitigate, or compensate for adverse impacts and improve environmental performance, focuses on the significant environmental issues of a project. The report's scope and level of detail should be commensurate with the project's potential impacts".*

According to the referenced source, an "Environmental Assessment Report" (EA) for a sanitary landfill shall include the following items:

(a) Executive summary. Concisely discusses significant findings and recommended actions.

(b) Policy, legal, and administrative framework. Discusses the policy, legal, and administrative framework within which the EA is carried out. Explains the environmental requirements of any co-financiers. Identifies relevant international environmental agreements to which the country is a party.

(c) Project description. Concisely describes the proposed project and its geographic, ecological, social, and temporal context, including any offsite investments that may be required (e. g., dedicated pipelines, access roads, power plants, water supply, housing, and raw material and product storage facilities). Indicates the need for any resettlement plan or indigenous peoples development plan.

(d) Baseline data. Assesses the dimensions of the study area and describes relevant physical, biological, and socio-economic conditions, including any changes anticipated before the project commences. Also takes into account current and proposed development activities within the project area but not directly connected to the project. Data should be relevant to decisions about project location, design, operation, or mitigatory measures. The section indicates the accuracy, reliability, and sources of the data.

(e) Environmental impacts. Predicts and assesses the project's likely positive and negative impacts, in quantitative terms to the extent possible. Identifies mitigation measures and any residual negative impacts that cannot be mitigated. Explores opportunities for environmental enhancement. Identifies and estimates the extent and quality of available data, key data gaps, and uncertainties associated with predictions, and specifies topics that do not require further attention.

(f) Analysis of alternatives. Systematically compares feasible alternatives to the proposed project site, technology, design, and operation — including the "without project" situation — in terms of their potential environmental impacts; the feasibility of mitigating these impacts; their capital and recurrent costs; their suitability under local conditions; and their institutional, training, and monitoring requirements. For each of the alternatives, quantifies the environmental impacts to the extent possible, and attaches economic values where feasible. States the basis for selecting the particular project design proposed and justifies recommended emission levels and approaches to pollution prevention and abatement.

(g) Environmental management plan (EMP). Covers mitigation measures, monitoring, and institutional strengthening.

Most of the information can be obtained by a desk study (section 2), which includes a compilation of all available information from archives, geological and topographical maps, meteorological data, aerial photographs (black and white, colour, infra-red). The configuration and previous use of the land, data relating to water supply and distribution and analysis of available borehole data should also be reviewed. In addition to geological and hydrogeological maps, pedological atlases and maps of mineral deposits can also yield valuable information on the subsoil, as can regional geological publications.

Furthermore it is necessary to check the range of the environmental impact i.e., if after the closure of the site there is only a short term, or a long term influence, if the influence is only local, or wide-range, reversible, or irreversible, if it will be significant, or negligible. The degree of the environmental impact should be evaluated as: very high, high or minor. Positive results also have to be addressed in the EA. In Annex 2 the range of possible environmental impacts is described.

The results of the investigations lead to a comparative site rating. Annex 3 presents a simplified method of a comparative site rating concerning the environmental impact.

As the „output“ of these investigations a map of „positive“, „possibly positive“ or „negative“ areas should be produced. Combined with a related report a documentation of areas, which may be suitable for a landfill site, can be presented. This can serve as a good basis for the discussion with the responsible authorities as well as with the public. It is recommended to make all planning stages transparent to the concerned public. The identification and siting of a new landfill must be unbiased and impartial.

6 Overview of On-Site Ground Exploration

After having executed a comparative evaluation of pre-selected sites a certain number of sites (normally only one or two) may be rated favourably for further investigations. At such locations special investigations have to be carried out “on-site”. To explore the ground of a site it is recommended to use “indirect” and “direct” methods: Indirect methods are geophysical techniques, like geo-electrical survey methods, ground-penetrating radar and seismic refraction. The selection of the proper geophysical techniques depends on the geological setting. The application of these methods does not require drilling or excavation. However, the geophysical investigations should always be combined with direct methods of exploration. While geophysical procedures can provide large amounts of data at relatively low cost, they require careful interpretation by qualified experts. Therefore, geophysical data must be verified by results from direct exploratory procedures such as borings or test pits.

Direct investigation methods include the excavation of pits and trenches, the drilling of boreholes and monitoring wells. Direct methods allow observation of the geological conditions on the site to take samples and to obtain direct measurements. Boring logs provide descriptions of the soil strata and rock formations, discontinuities (rock joints, faults, ancient slip surfaces) encountered, as well as the depth at which they occur. In addition, boring logs should provide standard penetration test results and rock quality designation for runs in rock. The boring logs should record the intervals for, and the results of any field hydraulic conductivity testing conducted in the boring. Direct methods allow the investigator to obtain samples of subsurface material for laboratory testing of engineering properties. Laboratory data should be set out in summary tables.

It is particularly important that the investigation borings, test pits and trenches, and other procedures be performed as near as possible to the site, if not within the boundaries.

7 Assessment of the Geotechnical Suitability of the Site

The results of the site investigation should be subject to an overall analysis and evaluation, taking account of the particular design stage and specific requirements of the general safety plan. This assessment should be set out in a geotechnical report considering the following (GDA E 1-1, Sections 5 and 6 [1.8]):

Documentation on site plans indicating:

- Location of boreholes, test pits etc.
- Geological contour plots
- Groundwater level, flow direction and effective flow velocity
- Surface water and hydrological features
- Water resources, drinking water catchment areas, water protection areas
- Geochemical zones for groundwater and soil
- Groundwater recharge (rainfall distribution, fluctuations in groundwater level)
- Groundwater regime and permeability of the subsoil in the area of the proposed landfill and its environs (a groundwater model may be appropriate)
- Flood (and tidal) influence

Geological – geotechnical evaluation:

- Description and representation of the geological structure (especially discontinuities)
- Presence and suitability of natural low permeability strata (thickness, depth, horizontal continuity, permeability, adsorption capacity)
- Overall evaluation of the subsoil as a natural geological barrier for the site. (The subsoil of a landfill site has to fulfil the following conditions: The subsoil or bearing surface of a landfill has to be of natural origin and shall have a low permeability ($k <= 10^{-7}$ m/s). If the encountered strata do not meet these conditions, the geological barrier may be built up artificially by suitable soil layers e.g. compacted clay as an “artificial geological barrier“). The natural or artificial geological barrier should have a high adsorption capacity (essentially a high content of active clay minerals). The minimum thickness of the natural geological stratum with low permeability should be 3 m.
- The level of groundwater should be more than 2 m, but at least 1 m below the bearing surface of the landfill.
- Assessment of stability of natural and/or artificial slopes
- Bearing capacity and deformation behaviour of the subsoil
- Faults, possible subsidence, risk of collapse, earthquake risk and other hazardous situations
- Notes on geotechnical measures required to improve the quality of the subsoil as a natural geological barrier (e.g. grouting)
- Assessment of site soils regarding their possible use as mineral sealing materials

Beside the detailed survey and evaluation of the hydrogeological, geological and geotechnical situation (see Annex 4), non-geological aspects should also be integrated into the final assessment as demonstrated in sections 3 and 4, as there are:

- Local situation with respect to populated areas (possible problems of noise, odours, “airborne” waste)
- Access roads or other traffic links like railways
- Local meteorological situation
- Possibilities for the treatment of leachate and the treatment and possible use of methane gas
- Impacts on the local ecological situation, the local landscape in general
- Impacts on existing water bodies
- Evaluation of costs and of cost benefit ratio

For a very detailed critical and careful review 5 investigation checklists with basic and advanced parameters (see Annex 4) may be used as a helpful means to demonstrate the geo-scientifically relevant results of the field investigations (AUST et al. 1996).

8 Bibliography

AUST, H. et al., 1997: Geowissenschaftliche Rahmenkriterien zur Standorterkundung für Deponien. Geologisches Jahrbuch, Reihe G, E. Schweizerbarth'sche Verlagsbuchhandlung, Stuttgart

EPA, 2003: Federal Register Environmental Documents: Municipal Solid Waste Landfill Location Restrictions for Airport Safety. www.epa.gov/cgi-bin/epalink?logname=allsearch&referrer=Municipal%20Solid%20Waste%20Landfill%20Location%20Restrictions%20for%20Airport%20Safety|4|Fed&target=http://www.epa.gov/EPA-WASTE/2003/October/Day-15/f25934.htm

EPA, 2003: Location Criteria Standards. www.epa.gov

GAUFF, ICON, IBU, 2005: Environmental Report, Part I: Solid Waste (Emergency Infrastructure Reconstruction Project (EIRP), Sanitation Improvements in Kabul City),

OELTZSCHNER, H.; MUTZ, D.,1996: Guidelines for an Appropriate Management of Sanitary Landfill Sites (2nd ed.). Ed. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn

OELTZSCHNER, H., 2000: Special Aspects of Identification, Construction & Operation of Sanitary Landfills under Tropical Conditions. ISWA Hong Kong 2000, International Symposium & Exhibition on Waste Management in Asian Countries, Hong Kong

GERMAN GEOTECHNICAL SOCIETY (ed.), 1993: Geotechnics of Landfill Design and Remedial Works – Technical Recommendations, E 1.1 (Chapter 5 & 6). Ernst, Berlin

RUSHBROOK, PH.; PUGH, M., 1999: Solid Waste Landfills in Middle- and Lower-Income Countries.- World Bank Technical Paper no. 429, Washington, DC, USA

WORLD BANK, 2004: The World Banks Operational Manual "Environmental Assessment" Operational Policies BP/OP 4.01, Washington DC, USA

Annex 1: Site Evaluation Checklist

Checklist for Site Evaluation (Data Collection Sheet - First Survey):

of a(n)	existing	☐	Dump site	☐
	planned	☐	Sanitary landfill	☐
			Compost plant	☐
			Transfer station	☐

Id.-Nr.		Locality	
Village/City		District	
Map		Altitude	m a.s.l.
UTM-Coordinates: X:		Y:	

Date: **Name(s) of investigator(s):**

		Conditions*		
		Positive	Indiffe-rent	Nega-tive
1.	**General data**	**+**	**0**	**-**
1.1	Distance from main waste source (< 5 / 5 - 15 / > 15 km)			
1.2	Possible volume / capacity			
1.3	Traffic links / existing access roads			
1.4	Morphological situation (e.g. steep slopes, ravine etc.)			
1.5	Access to site			
1.6	Availability of land			
1.7	Other:			
2.	**Hydrogeology, hydrology, water protection**	**+**	**0**	**-**
2.1	Drinking water protection areas nearby			
2.2	Drinking water catchment areas nearby			
2.3	Distance to groundwater table (< 1 m / 1 – 5 m / > 5 m)			
2.4	Distance to next surface water (river, creek, lake)			
2.5	Danger of high flooding			
2.6	Existing wells nearby			
2.7	Surface water ingress			

* Conditions on site: + favourable / no negative conditions
0 indifferent conditions
- unfavourable / negative conditions

3.	**Geotechnical matters, aspects of site construction**	**+**	**0**	**-**
3.1	Overall stability of the site (bearing capacity, slope stability, danger of mass movements)			
3.2	Drainage possibilities of surface water			
3.3	Drainage possibilities of leachate			
3.4	Treatment and discharge of leachate			
3.5	Geological barrier (thickness < 2m / 2 - 5m / > 5m)			
3.6	Geological lineaments (faults etc.)			
3.7	Availability of material for a mineral bottom liner			
3.8	Availability of drainage material			
3.9	Availability of material for final capping			
3.10	Mining activities / Excavations (on site / nearby)			
3.11	Soil mechanical aspects (e.g. settling, land slides, seismic activity)			
4.	**Meteorology**	**+**	**0**	**-**
4.1	Precipitation (average per year) (> 800 mm / 300 – 800 mm / < 300 mm)			
4.2	Atmospheric conditions (e. g. direction of winds)			
4.3	Temperatures (minima, monthly average, maxima)			
4.4	Exposition to winds			
5.	**Existing immissions / pollution sources**	**+**	**0**	**-**
5.1	Existing dumpsites nearby (closed / still operating)			
5.2	Industrial area with possibly polluted areas nearby			
6.	**Possible immissions by new treatment facility**	**+**	**0**	**-**
6.1	Access roads traversing settlements			
6.2	Road quality in settlements to be passed			
6.3	Effects of noise emissions at the site			
6.4	Distance of site to next settlements (< 300 m = negative)			
6.5	Effects of odour emissions at site			
6.6	Effluents from site			
7.	**Nature protection and land-use**	**+**	**0**	**-**
7.1	General degradation of the landscape / exposition			
7.2	Nature protection area / National park			
7.3	(Important) biotopes/vegetation			
7.4	Land use / agriculture			
7.5	Important forest areas			
7.6	Tourism areas nearby			
7.7	Cultural places nearby			

8. Others	**+**	**0**	**-**
8.1 Civil Aviation buffer zone, distance to airport (< 5 / 5 - 10 / > 10 km)			
8.2 Military areas			

9. **Remarks**: Each evaluation sheet should be accompanied by a short report, („remarks“), and an explanation of the decision, why the evaluation has been negative or positive.

10. **First evaluation of site:**
Negative, not suitable……
Rehabilitation / upgrading possible……
Suitable …….

11. **Proposed further investigations**: e.g., geodetical survey, detailed geological / geotechnical investigations, property situation, etc.

Annex 2: Environmental Impact (Range of Impact)

Range of Impact

of a(n)				
	Existing		Dump site	
	Planned		Sanitary landfill site	
			Compost plant	
			Transfer station	

Name of site:	Identification No.	Nature of possible impacts									
		Negative impact						Beneficial influence			
		ST	LT	R	IR	L	W	ST	LT	St	N
Waste management in general											
Neighbourhood / settlements											
Forests / parks											
Wildlife / biotopes											
Surface water quality											
Groundwater quality											
Soil quality											
Air quality											
Noise											
Traffic conditions (Access roads)											
Agriculture / farming											
Socio-economic aspects (e.g. scavengers)											
Aesthetic aspects											
Cultural / religious											

ST Short-term
L Local influence
LT Long-term
W Wide-range
R Reversible
St Significant
IR Irreversible
N Normal
* after closure - negligible

General evaluation of environmental impact:		negative	positive
	very high		
	High		
	Minor		

Annex 3: Environmental Impact (Comparative Evaluation)

Comparative Evaluation

Regarded components – environmental impact on:	**Effects of environmental impacts (EI)**			
	Sites			
Location/name of the site (or identification no.)	**#1**	**#2**	**#3**	**#4**
Neighbourhood / settlements	EI	EI	EI	EI
Forests / parks	EI	EI	EI	EI
Wildlife / biotopes / vegetation	EI	EI	EI	EI
Access to site / passing through settlements	EI	EI	EI	EI
Surface water quality	EI	EI	EI	EI
Groundwater quality	EI	EI	EI	EI
Soil quality	EI	EI	EI	EI
Air quality	EI	EI	EI	EI
Noise	EI	EI	EI	EI
Agriculture / farming	EI	EI	EI	EI
Aesthetic aspects / landscape	EI	EI	EI	EI
Others	EI	EI	EI	EI
Summary assessment				

Degree of environmental impact:

EI 0 negligible / indifferent
EI 1 minor impact; no special measures necessary
EI 2 medium impact, but low environmental risks, measures and/or monitoring necessary
EI 3 stronger impacts (possible), measures for protection and/or monitoring necessary
EI 4 very negative impact, high pollution risks, ecologically not tolerable

If a regarded component of a proposed landfill site is evaluated with a “4” the site normally should be excluded from further planning (depending on the importance of the component).

Annex 4: Detailed Investigation Checklists

Table 1: Site Investigation

Type of site:			
Name / Description of site:			
Investigation phase: First check? Detailed investigation?			
Investigation parameter, method	**Rock/Soil type: Application + / - (Quantity)**	**Investigation method**	**Remarks / Results**
Occurrence / Thickness			
Geological maps			
Remote sensing			
Mapping / Outcrops			
Digging, Small-scale drilling, Exploration well(s)			
Surface geophysics			
Others: Helicopter survey?			
Rock / Soil Properties: ***Texture, Homogeneity, Petrography***			
Mapping / Surface geophysics			
Inventory of rock/soil sections Bore-hole geophysics			
Soil sampling			
Investigation of samples • Grain size • Soil analyses • Mineralogical check • Palaeontol. check			
Soil gas measurements			
Others:			

Table 2: Hydraulics

Type of site:			
Name / Description of site:			
Investigation phase: First check? Detailed investigation?			
Investigation parameter, method	**Rock/Soil type:** **Application + / - (Quantity)**	**Investigation method**	**Remarks / Results**
Permeability (in-situ) *k [m/s]*			
Permeability (laboratory) *k [m/s]*			
Transmissivity *(k_x, k_z)* *T [m^2/s]*			
Effective porosity *n [dimensionless]*			
Storage coefficient *S [dimensionless]*			
Hydraulic gradient / Dip of groundwater table *I [dimensionless]*			
Distance to depth of groundwater *[m]*			
Groundwater flow velocity *v [m/s]*			
Groundwater flow direction *[°]*			
Potentiometric status of groundwater table			
Specific groundwater flow *Q [m^3/s]*			
Others:			
Installation of monitoring wells			

Table 3: Hydrochemistry

Type of site:			
Name / Description of site:			
Investigation phase:	First check?	Detailed investigation?	
Investigation parameter, method	**Rock/Soil type: Application + / - (Quantity)**	**Investigation method**	**Remarks / Results**
Water sampling			
Organoleptic indication			
Physical and physico-chemical indications *(pH, conductivity)*			
Anions			
Cat-ions			
Trace elements			
Compounds collectively analysed			
Gaseous components			
Advanced parameters:			
Isotopes			
Radioactive constituents			
Groundwater inventory			
Transport models			
Others:			

Table 4: Pollutant retention

Type of site:			
Name / Description of site:			
Investigation phase: First check? Detailed investigation?			
Investigation parameter, Method	**Rock/Soil type: Application + / - (Quantity)**	**Investigation method**	**Remarks / Results**
Soil sampling			
Clay minerals / percentage of swelling clay minerals			
Specific clay mineral surface			
Cat-ion exchange capacity *CEC [$cmol_c$ / kg dry unit weight]*			
Total porosity *n [dimensionless]*			
Water content *w [dimensionless]*			
Carbonate *[dimensionless]*			
Organic carbon *C_{org} [dimensionless]*			
Distribution coefficient *k_d*			
Others:			

Table 5: Geo-techniques

Type of site:			
Name / Description of site:			
Investigation phase: First check? Detailed investigation?			
Investigation parameter, method	**Rock/Soil type: Application + / - (Quantity)**	**Investigation method**	**Remarks / Results**
Soil sampling			
Grain size *d [mm]*			
Water content *w*			
Water-storage capacity w_s			
Consistency limits			
Content of organic components			
Soil density ρ *resp.* ρ_D *[g/cm³]*			
Grain density ρ_s *[g/cm³]*			
Compactibility			
Proctor density ρ_{Pr} *[g/cm³]*			
Permeability *k [m/s]*			
Process of settlement E_S *Stiffness [MPa/m²]* *E Young's modulus [MPa/m²]*			
Shear strength ϕ' *Angle of friction* *c' Cohesion [MPa/m²]*			
Others:			

Annex 5: Example of a Site Selection Process

Selection of a suitable site for a sanitary landfill for the municipality of Kabul / Afghanistan (2004 – 2007)

The investigations had been part of an overall assessment of the Kabul Sanitation improvement, a project of World Bank carried out by Gauff Engineers, Frankfurt and ICON-Institute Cologne. One task of the expert had been (beside others) the:

- Technical and environmental evaluation of the existing dumpsites of Kabul Municipality
- Identification, technical and environmental evaluation of potential sites for a sanitary landfill (see Figure 1)

For the identification of a site suitable for a sanitary landfill the following “road map” had been followed:

1. Description of the actual situation – general facts about Kabul
   - Geographic, topographic and demographic situation of Kabul
   - Climatic conditions
   - Hydro-geological and geological situation in the Kabul Basin
   - Groundwater
   - Soil quality and land use
2. Generation and disposal of solid municipal waste (SMW) in Kabul
   - Quantity and quality of SMW
   - Collection and transport of SMW
   - Current sites for waste disposal in Kabul
3. Identification of a new sanitary landfill site
   - Identification of site areas
   - Environmental impact assessment of landfill sites and comparative site rating

Figure 1 is showing the planning region with 6 proposals for a sanitary landfill.

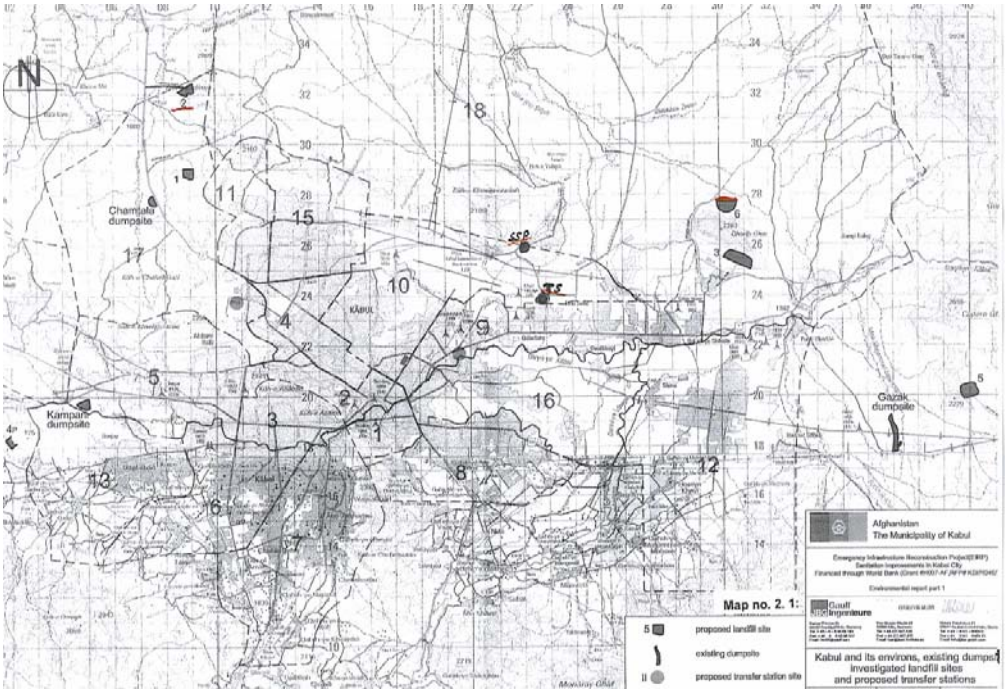


Figure 1: Map of the city of Kabul with existing dumpsites, potential sites for a sanitary landfill

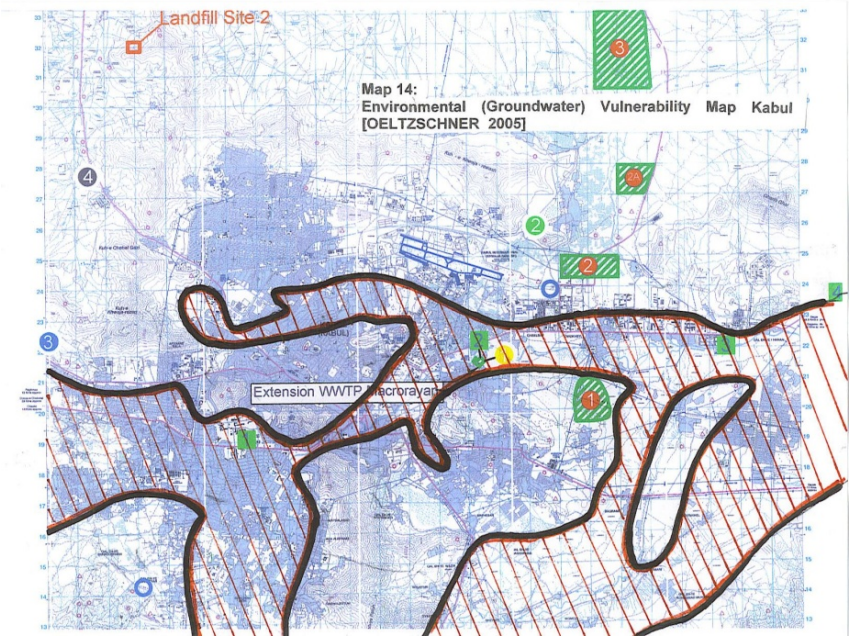


Figure 2: Groundwater vulnerability in the Kabul basin

By an investigation of the hydrogeological situation in the Kabul Basin it was possible to exclude areas with high groundwater vulnerability (high soil permeability and high groundwater table; see Figure 2).

By a comparative environmental assessment of the 6 identified sites it was possible to reduce the number of potential sites from six to one (see Table 1).

Table 1: Comparative environmental assessment of the 6 proposed sites

Regarded Components	**Effects of environmental impacts (EI)**					
	Identified sites					
Location / name (or id. no. of site)	**1**	**2**	**3**	**4**	**5**	**6**
Neighbourhood / settlements	EI 1	EI 0	EI 0	EI 2	EI 0	EI 0
Forests / parks	EI 0	EI 0	EI 0	EI 0	EI 0	EI 0
Wildlife / biotopes / vegetation	EI 1	EI 0	EI 0	EI 1	EI 0	EI 0
Waste handling staff	EI 0	EI 0	EI 0	EI 0	EI 0	EI 0
Access to site / roads passing through settlements	EI 2	EI 0	EI 2	EI 1	EI 3	EI 2
Surface water quality	EI 1	EI 1	EI 1	EI 3	EI 1	EI 1
Groundwater quality	EI 2	EI 1	EI 1	EI 3	EI 1	EI 1
Soil quality	EI 2	EI 1	EI 1	EI 2	EI 1	EI 1
Air quality	EI 1	EI 1	EI 1	EI 1	EI 1	EI 1
Noise	EI 1	EI 1	EI 1	EI 1	EI 0	EI 0
Agriculture / farming	EI 2	EI 0	EI 0	EI 3	EI 1	EI 1
Aesthetic aspects / landscape	EI 2	EI 1	EI 1	EI 2	EI 1	EI 1
Summary assessment	15	6	8	19	9	8

Degree of environmental impact:

EI 0 negligible/indifferent

EI 1 minor impact; no special measures necessary

EI 2 medium impact but low environmental risks, measures and/or monitoring necessary

EI 3 stronger impacts (possible), measures for protection and/or monitoring necessary

EI 4 very negative impact, high pollution risks, ecologically not tolerable

Photo 1:
Proposed site # 2 for a sanitary landfill for the city of Kabul. View from the south to the identified site (left side of the road)

Photo 2: View from the hillside across the area of the proposed landfill in the foreground