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Geological criteria for waste disposal site selection: a case study from Kanichadar, Dhangarhi, Far Western Nepal

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ABSTRACT

Proper management of municipal solid waste in an environmentally friendly way needs first-hand knowledge of site geology. A clay layer (i.e. geological barrier) of sufficient thickness and extension beneath the surface is a suitable condition for a sanitary landfill site. The clay layer acts as a natural barrier against the migrating pollutants originating from leachate into the ground. The leachate generated at the landfill site can pollute the groundwater in absence of such geologic barrier.

The Kanichadar area is underlain by about 3 m thick fine-grained soil. The topmost soil layer is 20-50 cm thick dark brown organic clay. There is a highly compact, dark brown and dry inorganic clayey silt layer of more than 1.5 m thickness below the organic clay layer. Soil samples collected from different Auger holes were subjected to laboratory analysis to determine their physical and chemical properties. The values thus obtained indicated that the soil belongs to 'CL' type, implying that the soil is inorganic clay of low to medium plasticity. However, the hydrometer analysis showed that the samples were of clayey silt.

The cation exchange capacity (CEC) values obtained from the depth of 0.5-2.30 m revealed that the soil had moderate to high barrier potential for attenuation of the migrating pollutants. Therefore, the area close to these auger holes was found to be suitable for sanitary landfill.

INTRODUCTION

Dhangarhi Municipality of Kailali district belonging to the Seti Zone is situated in the Far Western Development Region of Nepal (Fig. 1). The municipality was lacking an environmentally suitable site for proper management of its ever-growing solid waste. The municipal authority was able to select preliminarily five different sites for waste disposal. After geological assessment (Jnawali et al. 2000) of these sites, detailed investigation was carried out at the most potential site at Kanichadar. The main criteria defining its suitability for sanitary landfill were assessed following the standard method of Oeltzschner and Mutz (1994).

The proposed landfill site is located at about 5.5 km east (Fig. 1) of the Dhangarhi town within a forest area. It is an open ground without settlement in the vicinity. The land belongs to the Department of Forest. The Jakhaur Tal and Murphutta Tal are the two natural lakes situated about 2 km away towards west from the site. These lakes are in the same elevation level of the site.

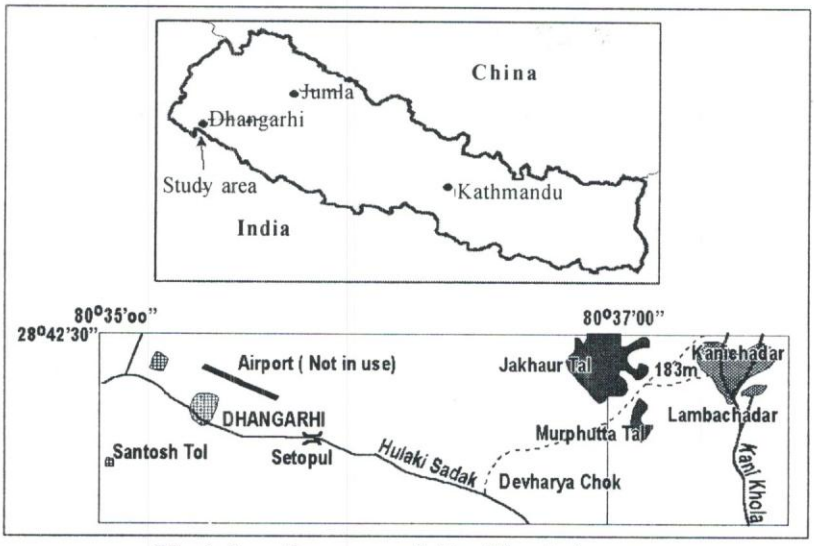

Fig. 1: Location map and site of the study area.

The altitude of the site is 180 m above mean sea level. An intermittent streamlet, the Kani Khola, passes near the site. The site is connected to the Dhangarhi town by a gravel road with last part (about 1 km) requiring improvement.

Surface and subsurface investigation was carried out in the field to acquire information about nature of lithologic units, morphology of soil and to collect necessary soil samples for laboratory analysis. The area was also surveyed to prepare a topographical base map at a scale of 1:500 by Plane Table Method.

Soil sections of up to a depth of 5 m at different locations (Fig. 2) were recorded by boring using a Hand Auger. Altogether 10 Auger holes were made to cover the area for examining the subsurface geology of the site. Four soil sections are shown as litho-logs of Auger holes with respective numbers (Fig. 3).

A number of soil samples from different soil layers were collected from the Auger holes. Samples were selected to represent the identical layers recognised during field observation from different Auger holes. These samples were analysed in the geo-technical laboratory for grain size analysis and determining the Plastic and Liquid limits (Table 1). Furthermore, hydrometer analysis was performed for few samples passed through 0.06 mm sieve to find out the percentage of silt and clay sized particles in the selected soil samples. Cation Exchage Capacity (CEC) as well as pH were determined in the Chemical Laboratory of the Department of Mines and Geology.

Cation Exchange Capacity is the capability of soils to absorb solved substances at their surface (In: Kharel et al. 1998). Sodium acetate method was used to calculate the CEC values. The calculated values together with textural classes of the soil were utilised to compare with the FAO Standard Chart (Kharel et al. 1998) for determining the barrier potential of the soils.

Main Criteria defining a suitable geological barrier

The main criteria defining a suitable geologic barrier (Oeltzschner and Mutz 1994) are as follows:

- Low permeability ground ($K_f \leq 10^{-7}$ m/s) of at least 3 m thickness preferably clay or low permeable bedrocks.
- High Cation Exchange Capacity (CEC) and low percolation rate of the subsoil.
- More than 2 m distance between level of groundwater and bearing surface of the landfill site.

Additional geological and hydro-geological parameters mandatory for a suitable landfill site are:

- Site not located in the drinking water catchment area, well fields main groundwater recharge areas.
- Sufficient distance to the major drainage (approx. 200 m); not located within flood prone areas.
- Availability of cover material in the vicinity of the site.
- No settlements and historical / religious monuments within 200 m distance.

RESULTS

Results obtained from the Grain Size Analysis, Atterberg Limits Tests and CEC Analysis are presented in Table 1 and 2 respectively. A topographical base map (Fig. 2) was

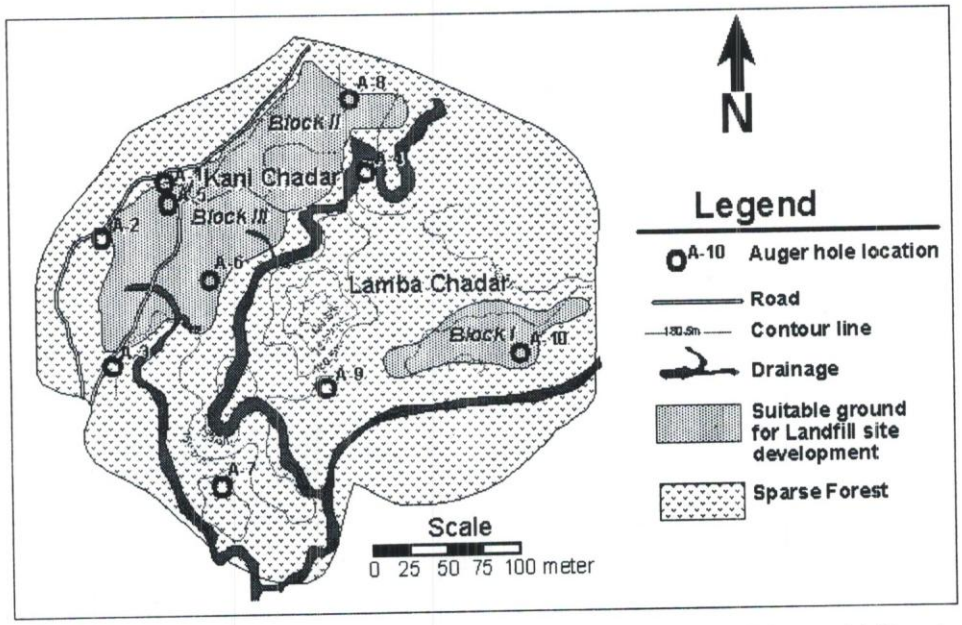

Fig. 2: Topographical map of Landfill Site area of the Kanichadar, Dhangarhi, Nepal.

Table 1: Soil classification of Kanichadar Landfill Site.

Sample No.	Depth (m)	Fines (%)	Liquid limit (%)	Plastic Limit (%)	Soil Name
A4	0.2 – 1.55	67.94	32	27.53	clayey silt with
A5	0.35 – 0.90	83.2	39	23	clayey silt
A6	0.35 – 1.25	66.8	31	22	clayey silt
A8	0.5 – 2.30	94.69	37	21	clayey silt
A10	0.5 – 2.75	84.78	45	20	Clayey Silt

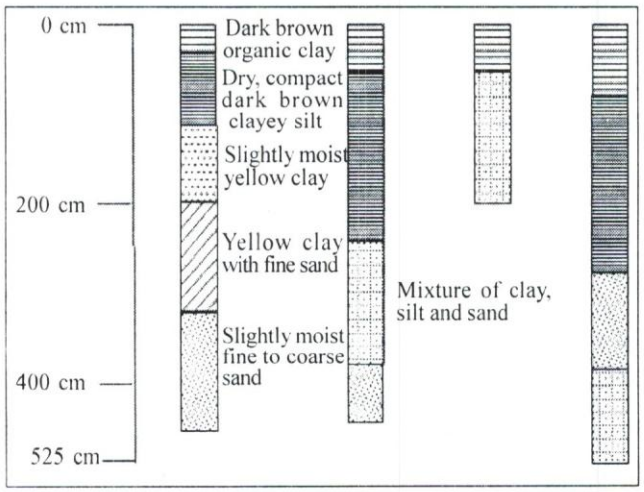

Fig. 3: Litholog of some Augar holes.

prepared at a scale of 1:500. Grain size distributions in some soil horizons are shown on the Distribution Curve (Fig. 4) as an example. The soil sections observed during auger boring are compiled as lithologs of Auger holes (Fig. 3). According to the type of soil and their CEC values the ground is divided into suitable area and not suitable area for waste disposal purpose. The suitable areas are separated into three different blocks. Each block is indicated with their respective numbers I, II, and III (Fig. 2).

DISCUSSION

The proposed waste disposal site is an open ground located in the middle of the forest. The ground is flat and small depression most probably occupied by a shallow lake in the past. There are small lakes such as Jakhaur Tal and Murphutta Tal situated about 1-2 km away from the site.

Auger boring carried out in the area revealed that the topmost soil layer (i.e., first layer) is a dark brown organic clay. The layer is 20–50 cm thick and is developed within the demarcated blocks (Fig. 2, blocks: I, II, and III) indicating a lacustrine environment of the past. There is a highly compact, dark brown and dry inorganic clayey silt horizon (second layer) of more than 1.5 m thick in the areas closer to Auger borings no. A5, A6, A7, A8, and A10 below the organic clay

Table 2: Chemical Analysis of the Soil Sample.

Sample No.	Depth (m)	pH Value	CEC Value meq/100g
A4	0.2 – 1.55	6.53	7.8 low
A5	0.35 – 0.90	7.08	14.3 high
A6	0.35 – 1.25	7.73	12.2 high
A8	0.5 – 2.30	7.57	19.1 high
A10	0.5 – 2.75	7.30	10.0 moderate

layer. The third layer is a mixture of clay, silt, and fine sand of 1.5–2.0m thick. The grain size analysis of the samples collected from this horizon revealed about 16% clay, 70% silt and 14% sand.

The Liquid Limit and the Plasticity values of the second layer were plotted in the 'Plasticity chart for fine grained soils'. The values indicated the soil lies in the range of 'CL' implying that the soil is inorganic clays of low to medium plasticity. However, the hydrometer analysis showed the sample of being clayey silt. From the computer analysis of the disturbed soil samples the permeability values are estimated in the range of 3.5 to 3.7 X 10^{-7} meter per second. This implies that permeability of the soil is low enough to be within acceptable limit for intended purpose.

The CEC value determined from the samples collected by Auger borings A4, A5, A6, A8 and A10 were used to evaluate the barrier potential of the soils. Except for A4 the CEC values obtained from the clayey silt samples are in the range between 10-19 (Table 2). These values were utilised for comparison with the Standard Charts of FAO (Kharel et al. 1998). This procedure was previously adopted for calculating the barrier potential of soils in the Kathmandu valley to select potential areas for waste disposal. The values derived from comparison revealed that the soil is having moderate to high barrier potential.

Due to the presence of dry and compact organic clay (first layer) and inorganic clayey silt layers with sufficient

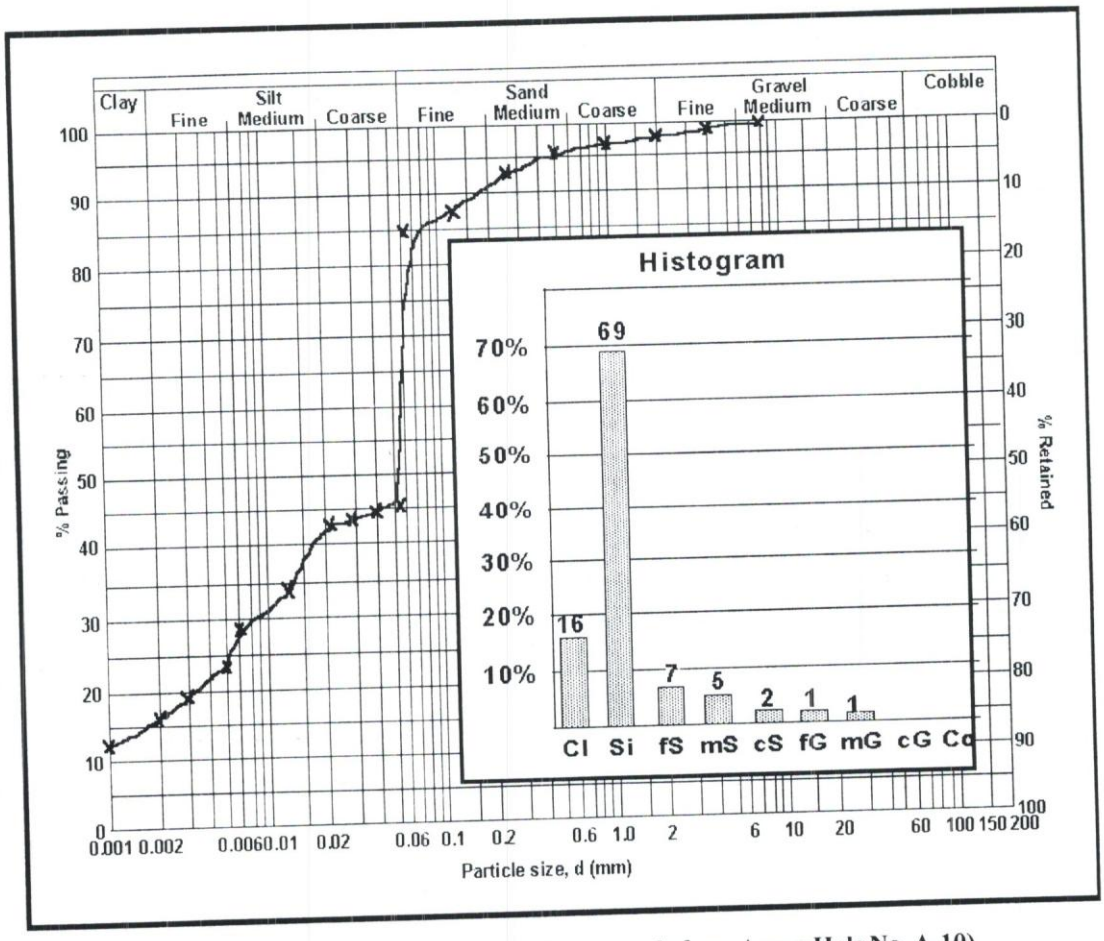

Fig. 4: Grain size distribution-curve (an example from Auger Hole No. A-10).

thickness and extension just beneath the surface, the proposed site is considered to have a sound geological barrier.

About 1-2 m thick yellowish clay or clay with fine sand occurs below the compact clayey silt layer. Water level is encountered only below 4 m depth (Fig. 3, A6). The water level is within the fine to coarse-grained sand layer.

CONCLUSION

The site being located within a forest is obviously not useable for agriculture and residential purpose. The investigated subsoil layer up to a depth of 50 cm is organic clay followed by 2-3 m clayey silt with little sand. The calculated CEC of the collected samples indicated a moderate to high barrier potential of the soil. The fine-grained soil with low permeability should allow sufficient time for attenuation of the migrating pollutants by absorbing the cations from the leachate. The water level exists only below 4 m from the surface. The cover material is available in the vicinity. The ground conditions with all these favorable parameters permit this area to develop a sanitary landfill for management of urban waste of the Dhangarhi municipality.

RECOMMENDATION FOR SITE DEVELOPMENT

The site can be developed for solid waste management in consultation with technical expert/engineer considering the following points:

- Out of the three potential blocks, Block No. I can be developed first to use up to its full capacity and then develop Block No. II and III subsequently.
- Construction of suitable fence around the identified blocks to prevent the dumped garbage from scattering around as well as barring the wild and domestic animals from entering the site.
- Arrangement of leachate collection and treatment plant.
- Treatment of the leachate before it is drained into the stream.
- Separation of biodegradable and non-degradable waste before dumping.
- Composting of biodegradable waste could be considered as a viable option for producing organic fertilizer, whereas materials like plastics and metals

can be recycled and the rest real dumping material could be reduced to 25-30% only.

- Regular covering of the dumped waste by fine-grained soil and subsequent compaction should be strictly carried out.
- Vegetation plantation (rehabilitation of the site) over the dumped material after it has gained certain stable height.
- Proper management of the drainage system.

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