Remote Sensing and GIS for Waste Disposal Site Selection in the Kathmandu Valley: A Case Study of Taikabu Area

Ganga B. Tuladhar
Department of Mines and Geology
Lainchaur , Kathmandu, Nepal
env@ ntc.net.np

Abstract: Geo-scientifically viable, environmentally suitable, and socially acceptable sanitary landfill sites are very limited in the Kathmandu Valley and is confronted with the burning problem of safe disposal of urban waste. This paper deal with the evaluation and assessment of its interface, following the major criteria defining suitable geological barrier, Cation Exchange Capacity and other necessary physical parameters with the optimum utilization of remotely sense data along with GIS techniques. The study revealed one of the most viable sites at the flat land of natural depression of Taikabu area and has potential to serve all the municipalities of the Kathmandu Valley.
Keywords: Waste disposal, Geologic barrier, Remote Sensing, GIS

1. Introduction

The Kathmandu Valley is one of the large intramontane basin developed in the Lesser Himalayas of Central Nepal with an area of about 660 sq. km, filled with fluvio-lacustrine sediments of Quaternary age. A steadily growing population of around 1.5 million is witnessing an acute problem of safe disposal of urban waste, generated about 500 tons per day after the closure of previously operating Gokarna landfill site. At present, the Kathmandu Metropolitan City is dumping its waste along the Bagmati River directly at the riverbed near Balkhu as a temporary means of crisis management, despite knowing the fact that uncontrolled dumping of waste will become a serious and irresponsible ecological and economical burden for tomorrow. It is a serious problem that increasingly demands the attention of scientists, engineers, policy- makers and the general public. The selection of potential sanitary landfill sites and management of solid waste is a multi-disciplinary task and requires a series of activities with possible options for utilizing the waste as a resource after processing and recycling. One of the first steps is the identification of areas with sufficient geological barrier potential to avoid pollution of subsoil and groundwater by toxic leachate originating from waste disposal. For any scientific planning and management of urban waste, the planners and decision-makers need appropriate information about landuse and soil/rock condition on appropriate map scale. Areas of low-permeable sediments with thickness of at least 5m and high Cation Exchange Capacity (CEC) as potential areas for waste disposal should be clearly indicated on the maps in contrast to non favorable areas of high permeable sediments with low CEC values.

2. Geomorphology and Geologic Condition

The valley has a roughly circular outline having diameters of 30 km in EW and of 25 km in NS direction, surrounded by the Lesser Himalayas and the Mahabharat Mountains ranging from 2,000 to 2,800 meters above mean sea level. The average altitude of the valley floor is about 1,350 meters and terrace landforms are widely developed. The Bagmati River, along with its main tributaries, Manohara, Dhobi Khola, Vishnumati and Nakhu Khola, forms a centripetal drainage system. It was a lake during the Plio-Pleistocene times when the palaeo-Bagmati River was dammed by rapid upheaval of the Mahabharat range. The lake was gradually filled up by lacustrine and deltaic river sediments (Dongol, 1985) eventually draining the water through a Chovar gorge at south.

The north-eastern part of the basin are occupied by coarse micaceous sand and gravel sediments derived from the Sheopuri gneiss, while the central and southern parts are filled with very fine sediments mostly black carbonaceous clay with lignite and diatomaceous earth at places. The maximum thickness of the sediments as revealed by the deepest drill-hole in the valley is about 550 meters at the central part. Borehole data acquired so far of the Kathmandu Valley indicate that 33 drill-holes have reached the basement rock while the others are still in soft sedimentary deposits. This implies that the valley floor has a highly undulating topography with buried ridges of mostly Pre-Cambrian rocks. The basement rocks at the northern parts consists almost exclusively of gneisses and granites while the southern parts is underlain by limestone, marble, phyllite and quartzite of Paleozoic age.

3. Hydrogeology of the Kathmandu Valley

Generally, two main aquifers are known within the sediments of the valley (Jha,. et.al. 1996). The upper one consists of late Quaternary sands up to 20 meters thick, mainly on debris cones and fans in the northern part of the valley, overlying an aquitard of black to gray-green clay with the intercalation of peat and lignite at places. The main occurrences of this aquitard are located in the west, east and center of the valley and are utilized by

brick factories as a resource. A deeper confined aquifer, of great importance for drinking water supply to the population of Kathmandu lies at the base of this thick clay and shows sand and gravel beds with intercalation of clay, peat and lignite.

4. Data Inputs

Landfill site selection process involves the generation of multi thematic data and hence, remotely sense data and their integration into GIS environment is being utilized in the present study. All the relevant data were acquired and reviewed together with soil profile assessment along with chemical and grain size analysis. All the coverages are stored in the Modified UTM and analysed using ARC/INFO and ArcView software. The data are compiled in different sub-directories depending upon the coverage and final map on Potential Areas for Waste Disposal of the Kathmandu Valley (Fig. 2) was produced in 1:50,000 scale as a main output.

5. Methodology

The investigation was based on delineating geological barrier units of varying permeability potential and CEC values. In the beginning, areas with low-permeability ground and high CEC that are assessed as positive areas owing to their natural properties were defined. Then the areas covered by sensitive settlements (water well field or site of groundwater abstraction, spring, pond, reservoir, lake, airport, cultural heritage, tourists sites etc.) to landfill proximity and the areas prone to natural hazard that are assessed, as negative areas were determined. Finally, eliminate the negatively identified areas from the positively assessed area, after superimposing for further consideration of detail site investigation.

During the site investigation within the positively assessed area, two steps formed the basis of the evaluation. The first step was based on the grain size evaluation of lithological borehole logs of the top 7 m. In this case, the sediments were grouped into three classes such as high barrier potential with more than 5 m clay, silty-clay or clayey silt as very low to low permeability. Similarly, moderate barrier potential with more than 5 m clay to silt, silty sand, sandy silt or fine sand, and low barrier potential with less than 5 m clay to fine sand and mainly medium to coarse sand with some gravel as high permeability. The second step was based on CEC values of soils in mmol/100g derived from chemical analyses of samples taken down to 2 m depth. The derivative of above two steps is taken as the final barrier potential units that are of interest for selection of favorable waste disposal sites and essentially indicating into the following three classes.

- High barrier potential: Clay, silt loam (CEC>16mmol/100g) – Favorable to waste disposal.
- Moderate barrier potential: Loam, silt (CEC 12-16mmol/100g) – Possible only with special technical measures.
- Low barier potential: Sand, grave, silt (CEC<12mmol/100g)-Unfavourable.

5. Further Investigated Sites

Six sites that appeared to have favorable geological conditions for waste disposal area were investigated by drilling to a maximum depth of 8 m. These include Sanglatar, Bhimdhunga, Satungal, Panga, Bhaktapur, and Taikabu. Examination of soil profiles, chemical analyses of soil samples for CEC determination and grain size analyses revealed sufficient barrier potential at all site except at Sanglatar where underlying sediments were found to have low CEC values indicating low barrier potential.

7. Case Study of Taikabu area

With respect to the infrastructure and other relevant criteria sensitive to waste disposal, Taikabu area (Fig. 1) was found to be the most appropriate site for landfill site development. It is a bowl-shaped natural depression nearly with 500 meters diameters and bound by vertical walls, composed of sandy to silty sediments on the top and silty to clayey towards bottom from three sides. It is located at about 5 km east of Bhaktapur municipality office and about 1.5 km southwest in the vicinity of the Taikabu village. The area has only one outlet towards southeast direction with Hanumante River. Auger drilling to a depth of 5.25 m at the valley-floor revealed an increase of clay content with high CEC values towards depth. However, the area is a cultivated land, there are only a few small houses around and a motorable road has already reached up to the rim of the depression. The depression has a sufficient capacity to develop the sanitary landfill site and manage the urban waste of the whole Kathmandu Valley for at least 50 years with adequate space for establishing composting and recycling facilities.

Fig. 1 Proposed landfill site at Taikabu of Bhaktapur

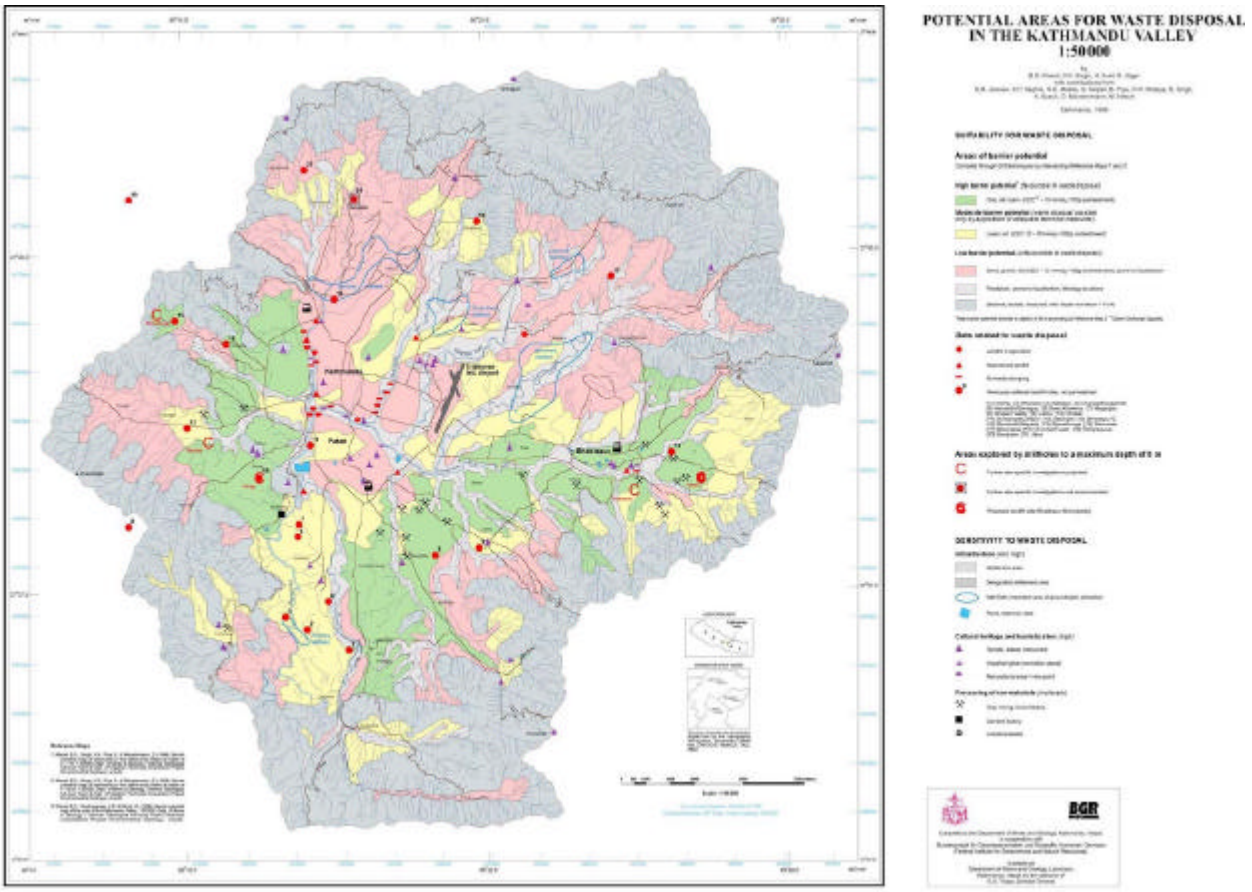

Fig. 2 Potential areas for Waste Disposal in the Kathmandu Valley

8. Conclusions and Recommendations

Remote sensing data with GIS technique was found to be one of the important tools that are well suited to be of use in landfill site selection studies. GIS provide effective and efficient storage and manipulation of remotely sensed data and other spatial and non-spatial data types for scientific, management and policy oriented information. The output, resulting from assessment of barrier potential of sediments in conjunction with other relevant criteria serve as a good basis for selection of suitable sites for urban waste management in the Kathmandu Valley. The flat land of natural depression of Taikabu site came out as the best suitable site from all aspects for developing a sanitary landfill for long-term management of urban waste in the valley.

In want of viable landfill site, still there exists lacking of awareness at the planning and decision-making levels about the actual utility of this scientific information for burgeoning problem of safe disposal of municipal waste. Prudent planning and action in coordination with the related municipalities towards the materialization of landfill development is warranted before it is too late as it often happens due to overlapping interest for competing use of land. Transparency to the concerned public during all stages of planning is recommended in performing the best out of waste.

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