Geoscientific Investigations for Searching Suitable Solid Waste Disposal Site Using Remote Sensing and GIS

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Abstract. The whole world is facing challenges of geo-environmental disposal of municipal solid waste. Considering the problem, in this paper author has established a methodology for searching the geo-scientifically feasible solid waste disposal site using advent geospatial tools. GIS modeling with overlay operation is most useful to find out geoscientifically feasible areas satisfying criteria decided for site selection. Present disposal system of study area is representing the unawareness about the geo-environmental problems and health hazards. This study provides a selection of environment friendly and geo-scientifically suitable areas for the disposal of solid waste supplying reasonable, convenient and administratively transparent solutions to the waste disposal problems.

Introduction

All over the world, solid waste management and protection of the environment from solid waste hazards is becoming a serious problem and it is major issue facing all the environmental planners, administrators and policy makers. Industrial, domestic, commercial and construction activities of human being and organic waste of animals generate solid waste in various forms (Rokade, 2012). Disposal of this waste is most difficult task and needs to take care of social and geo-environmental factors like lithology, geological structures, landuse/landcover, geomorphology, groundwater conditions, depth of weathering, soil pattern, surface water bodies, drainage density, slope, biodiversity, human health and meteorological conditions of the area. Generation, storing, updation, integration, modeling and display of such enormous geoscientific data encourages to use geospatial technology for the integrated study of solid waste disposal site selection. High resolution remote sensing data helps us to discriminate different thematic features like rock type, land use/land cover, road network, drainage pattern, landforms, lineament and geological structures etc. which can be analyzed and modeled using the GIS. Several case studies have already been reported from different parts of the world, demonstrating the use of Remote Sensing and GIS for management of resources.

GIS has been used to search solid waste disposal sites in Philippines (Cruz 1993), animal waste disposal sites in Australia (Basnet et al., 2001) and landfill sites (Basagaoglu et al., 1997). GIS in urban planning and development has been used by Yaakup et al., (2005); Yaakup et al., (2004); Uy and Nakagoshi (2008). The GIS expert knowledge based decision support systems are used by Kallali et al., (2007) to determine adequate potential soil aquifer treatment sites for groundwater recharge. Chang et al., (2008) identified sites using a single-objective multi-criteria analysis. Ratnapriya and De Silva (2009) determined the most suitable locations for putting up the treatment plants for non-point source pollutants using GIS technology. The allocation of sites for wastewater treatment plant suitability and landfill site selection using Geospatial technology is widely established by many workers (Finn et al. 2006; Gemitzi et al. 2007; Gilliland and Potter 2007; Kallali et al. 2007; Akbari et al. 2008; Zhao et al. 2009; Huffmeyer et al. 2009; Ribeiro et al. 2010).

Present research is focused to give out the best suitable site for municipal solid waste disposal for Jalgaon city using high resolution satellite data and advanced GIS techniques. Criterion of site selection is established as per the availability of the land which can minimize the geo-environmental degradation, pollution of resources and spreading of stinking smell in the surrounding area (Rokade, 2012).

Study area. The study area is Jalgaon city, headquarter of the Jalgaon district, Maharashtra state. The city lies on 21°36’ North latitude and 75°34’15” East longitude on the bank of north flowing river Girna. The city is situated on a flat terrain with small hilly area in southern part along Shirsoli and Mohadi roads having gentle slope towards North and an elevation of 201 m above mean sea level. The total area included in Jalgaon Municipal limits is 68.24 sq. km with population of 5,52,827 (as per 2001 census) and current annual growth rate of population is 5.2% (JMC, 2005). The climate of the area is dry and hot except during the monsoon period and the average annual rainfall of the area is 826.30 mm. About 99% of the annual rainfall is received during the southwest monsoon season during the months of June to September. Average temperature in the area varies from 15°C to 47°C and the air is dry except during monsoon period. The direction of wind is generally southwest to northeast.
Girna water pumping station and Dapora dam are two main sources supplying water to the city. Geologically, Jalgaon city is underlain by basaltic lava flows (central and southern part of the city) and thick alluvial deposits of Quaternary age (northern part of the city). The solid waste generated in the city area mainly consists of domestic refuse, wastes from commercial areas, vegetable and fruit markets, slaughter houses, bio-medical wastes, wastes from hotels and restaurants and industrial solid wastes. Right now solid waste of Jalgaon city is disposed off on alluvium stratum, near Nimkhedi Village which may affect the quality of groundwater and soil of the area. In present study geo-scientific factors considered in evaluating potential sites for the long term disposal of solid waste are: distance from main urban area, restricted locations, available land area, site access facility, soil conditions and topography, surface water hydrology and local environmental conditions.

Materials and Methodology. Present investigation of all spatial and non-spatial information of the study area are collected from the source organizations which are generated by using resources like IRS-P6 (L4 MX) satellite data (acquired on 9th January, 2006 and 6th April, 2006), IRS-1C PAN data (acquired on 19th May, 2006), Survey of India’s (SOI) toposheets 460/12, 460/8, 46P/5, and 46P/9 mapped on 1: 50000 scale (Surveyed in 1975), District resource map published by geological survey of India (GSI, 2009), Historic data of the wells and subsurface lithological details available with the Ground water survey and development agency (GSDA), Jalgaon and field work notes (about the geology, geomorphology, landuse/landcover etc.) and socio-economic data collected from Jalgaon municipal corporation and National informatics centre (NIC), Jalgaon. The overall methodology adopted for this research is summarized in Fig. 1. Erdas Imagine 9.1 software is used for image processing, image analysis

![Flowchart](image_url)

**Fig. 1.** Flowchart depicting methodology adopted for searching suitable site of waste disposal.
and for generation and updation of thematic information, GIS integration. GIS analysis and GIS modeling is carried out in arc GIS 9.2. To generate disposal site suitability map, geotechnical approach was employed and suitable geographic areas are shortlisted and combined map layers based on established criteria was prepared (Table. 1).

**Results and Discussions**

**Geology of the area.** On the basis of interpretation of satellite data, field work and existing district resource map of Jalgaon district (1: 2,50000 scale) published by Geological Survey of India, the area has been mapped (Fig. 2). The Tapi alluvium and basaltic flows of Sahyadri group of Deccan trap constitute geology of the Jalgaon and surrounding area. The lava assemblage of Sahyadri group consists of alternating sequence of Pahoehoe and Aa flows with cumulative exposed thickness varying between 90 and 200 m. In study area, Sahyadri group is represented by Aa flows, compound Pahoehoe flows and group of compound Pahoehoe flows and Aa flows of upper Cretaceous to Palaeogene age. These rocks are dark, massive, fine to medium grained and highly jointed (vertical joints and columnar joints) basalt. The Tapi alluvium comprises of beds of clay and silt with lenses of coarse sand, gravels and pebbles. The entire thickness of alluvium is upto to 80 m bgl. major NE-SW, N-S, NNW-SSE and NW-SE trending lineaments, fractures, vertical and columnar joints also occur. Areas having closely spaced lineament and thick deposition of alluvium are not favourable for waste disposal.

**Land use/Land cover.** Information on land use and land cover is necessary for identifying the waste disposal site. For the present investigation land use/land cover map (Fig. 3) of the study area has been prepared using digital image processing techniques and verified and updated by field visits and LU/LC map published by NBSS and LUP, Nagpur. Most of the area is covered by agricultural land (rabi crops, kharip crops, double crops, current fallow land), followed by built up land, waste land and water bodies. Agricultural land, area having water bodies and habitation areas are not preferred for the disposal of solid waste. Waste land available on the southern part of the study area may be used for solid waste disposal.

**Geomorphology.** Geomorphic landforms may responsible to spread the pollutants in surface and sub-surface geo-

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>1.</td>
<td>Site should be at least 3 km away from the cities/village AND</td>
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<td>2.</td>
<td>Site should be at least 8 km or more away from airport AND</td>
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<td>3.</td>
<td>Area should be underlain by Deccan Trap NOT Alluvium AND</td>
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<td>4.</td>
<td>Geomorphologically Area should be Plateau NOT Alluvial Plain AND</td>
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<td>5.</td>
<td>Area should be 500 mtr away from lineament AND</td>
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<td>6.</td>
<td>Area should be away 100 mtr away from Crop Land AND</td>
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<tr>
<td>7.</td>
<td>Area should be having low Depth of Weathering (Less than 5 mtr) AND</td>
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<td>8.</td>
<td>Slope should be gentle OR flat OR less than 4 degree AND</td>
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<td>9.</td>
<td>Land use/Land cover must be Waste Land OR Fallow land AND</td>
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<td>10.</td>
<td>Site should be at least 500 mtr away from National highways OR State highways OR Rail ways AND</td>
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<td>11.</td>
<td>Site should be at least 100 m away from public roads, AND</td>
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<td>12.</td>
<td>Site should be at least 200 m away from industrial developments, AND</td>
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<tr>
<td>13.</td>
<td>Site should be close to tar road for easy access. AND</td>
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<td>14.</td>
<td>Depth to Water table should be more than 20 mtr. AND</td>
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<td>15.</td>
<td>The site should be 500 mtr away from groundwater recharge structures OR Irrigation canals. AND</td>
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<td>16.</td>
<td>Soil having low permeability is preferable AND</td>
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<td>17.</td>
<td>The disposal site should be at least 200 meters away from streams and streams OR tanks OR River OR surface water resources AND</td>
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<td>18.</td>
<td>The site should be at least 500 mtr away from the nearest Ground water well OR water supply Scheme. AND</td>
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<td>P19.</td>
<td>Disposal site is to be located in an area where local drainage is running away from the site AND</td>
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<td>20.</td>
<td>The site should be located at least 1 kilometer away from protected forest. AND</td>
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environment. On the basis of interpretation of satellite image, SOI Toposheets, field visits, well data and by considering the relief, slope, depth and type of weathered material, geomorphologically area is classified as Moderately dissected plateau (MDP), Slightly dissected plateau (SDP), Residual hills and alluvial plain (Fig. 4). Jalgaon city is situated on flat terrain. A gentle slope occurs towards the south, as hilly areas are present along the Shirsoli and Mohadi roads and northern part of the study area covered by thick deposition of alluvium. For solid waste disposal, area with shallow depth of weathering and less infiltrative zone is preferable, so the alluvial

Fig. 2. Geological map of the study area

Sources:
1. Satellite Data
2. Field Notes
3. SOI Toposheets
4. District Resource Map
Prepared by GSI
plain and highly weathered area is not suitable for solid waste disposal.

**Drainage.** Waste disposal areas must not be sited near surface water bodies (streams, rivers, lakes or any recharge structure) or near drinking water sources. Such sites are located in an area where local drainage is running away from site and it should not be located in flooding zone. The study area falls in the Girna and Waghur-Sur watershed comprising a part of Tapi basin. All the nals and their tributaries constitute dendritic, trellis and combination of dendritic and parallel drainage patterns.
The fine drainage density in southern part confirms to physiography of the area, which has the lower infiltration levels. The central and northern portion of the area with nearly level sloping condition depicts the medium to high infiltration revealed by low drainage density (Fig. 5). Five nullhas (Lendi, Khedi, Pimprala, Gujar and Harivittal) and two water tanks (Mehrun and Manyarked) are in the periphery of study area and site of the disposal must be atleast 500 mts away from these water bodies.

**Slope.** Slope has a dominant influence on the contribution of pollutant derived from solid waste disposal through
infiltration or runoff in the area. Kao and Lin (1996) and Pande et al. (2012) have suggested that the appropriate slope for constructing a landfill is about 8 – 12% because too steep a slope would make it difficult to construct and maintain and too flat of a slope would affect the runoff drainage. In the study area, the average height of the plateau is 270 m and height of the highest peak is 360 m. The major part of the area is nearly level slopes occupies the central and northern part of the area. The strong slopes occupying in the southern and south-eastern parts of the area in association with foot slopes of the hills. Steep slope gradients (15-30%) are characterised with mounds in the southern part of the area. Areas with 8 - 12 % of slope is preferred in the area to avoid high runoff rate and percolation leachate in the ground.

**Depth of weathering and soil.** Examination of sections of dug wells observed in the field and litholog data collected from Groundwater Survey and Development Agency (GSDA, Jalgaon) have been used to assess the
depth of weathering. The depth of weathering in the study area varies from place to place. Maximum thickness of weathering has been recorded in the central and northern part of the area. Thickness of alluvium in northern part of the area is recorded in the range of 10 to 20 m bgl. The depth of groundwater table is a significant parameter in determining the contamination risk of groundwater. Ground water in Deccan trap basalt occurs mostly in the upper weathered and fractured parts down to 20-25 m depth.

The soils of the area are generally derived from the underlying Basalt and the Alluvium has a deep cover all along the Tapi valley. The medium black soil, deep black soil, forest soil, loamy soil, and sandy soil were observed in the area. The deep black soils and loamy soils are found in Jalgaon taluka. The study area is famous as banana producing area in Maharashtra. Bananas are grown mainly in loamy soils occurring in the area. Shallow soil cover is observed in the southern, southeastern and southwestern part of the Jalgaon city.

**Proximity analysis.** Proximity of a solid waste disposal site to a water supply schemes is an important environmental criterion in the site selection so that wells may be protected from the runoff and leaching of the disposal site. Buffer zones of specified distances are produced for spatial information like residential area, rail, road, water supply source, water bodies, lineament, drainage network, agricultural areas etc. for making binary maps specifying two classes (0 – non-suitable and 1- suitable). These buffers were created by caring the accessibility, transportation cost, environmental concern, wind direction and distance from rural/ urban habitation. Buffer zones of specific distances are created for avoiding environmental botherations eg. Buffer of 3 km from city/village areas, 500 mts from lineament, 100 mts from agricultural land, 500 mtrs from national highways, 100 mtrs from public road, 200 mtrs from industrial developments, 500 mtrs from groundwater recharge structures, 200 mtrs from stream/drainage and 500 mtrs from water supply source.

**GIS modelling for site selection.** A high population growth rate and increasing per capita income have resulted in the generation of enormous municipal solid waste, posing serious threat to environmental quality and human health (Pande et al., 2012). Traditional way of solid waste disposal site selection is complicated and challenging. In doing so, we have to take care of geological, environmental, social and economical factors, aesthetic, transportation and health. In addition, the disposal site should have sufficient capacity to meet the current and projected waste to be deposited within at least 10 years. GIS technology is useful to generate, store, update, analyse, integrate and model for providing solution to any problem. In proposed study, area specific GIS modeling is carried out by combining a set of input maps with Boolean functions (AND, OR, NOT and XOR) to produce final output map (Fig. 5). Solid waste disposal site selection criteria established for the present study is given in Table 1.

Statements given in Table 1 converts each of the input coverages into temporary binary coverage, where class ‘1’ indicates areas that satisfy established criteria and class ‘0’ indicates not satisfying. For twenty statements of this procedure, twenty binary temporary coverages are created whose values are either ‘1’ or ‘0’ depending upon whether the respective condition is true or false. In the final stage, all the temporary coverages are combined by applying Boolean logical operator (AND, OR, XOR, NOT) and the areas suitable for disposal of solid wastes are demarcated. In study area, southern part of the Jalgaon city is having shallow cover of soil, low depth of weathering, minimum agricultural practices, availability of waste lands, lack of major lineaments, absence of major roads, irrigation structures and water supply schemes, areas are suitable for the disposal of municipal solid waste.

**Conclusion**

The study has demonstrated an integrated remote sensing and GIS based methodology for searching geoscientifically feasible site for the disposal of solid waste. It shows the importance of integrated GIS in for managing waste resources in the area as well as an establishing a relationship of geological factors for the management of solid waste. Northern part of the study area having thick deposition of Quaternary sediments and highly weathered basalt is not suitable for locating disposal site. Study area is dominated by geomorphic unit like alluvium plain and dissected plateau. Southern part of the area having dissected plateau may be used for the disposal excluding highly fractured area. Landuse/landcover of the study area is mainly agricultural, which cannot be used for disposal of solid waste. Some patches of the waste land are observed in the southern part of the study area, which are useful for disposal of the waste after development of the slope. On the basis of GIS modeling, it is concluded that, areas suitable for waste disposal site are near Sirsoli, Kusumba, Chincholi, Bhagpur and Manyarkhed villages.

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