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RESEARCH ARTICLE

INTEGRATED GEOLOGICAL INVESTIGATION FOR SOLID WASTE DISPOSAL SITE SELECTION FOR AKOLA CITY (M.S.) INDIA AND IMPACTS ON RURAL AGRICULTURE AND UNDERGROUND WATER, BY USING HIGH RESOLUTION REMOTE SENSING GIS TECHNIQUES

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ABSTRACT

GIS and remote sensing can be used to analyze the spatial characteristics of the data over various digital layers. Solid waste and their proper disposal t is a global environmental problem in today's world. Solid waste and its disposal site were determined of Akola City, Maharashtra, India, through the integration of geographic information system (GIS) and remote sensing techniques. Geologically the area coves by the Deccan trap basalt and Purna alluvium of the upper Cretaceous to Lower Eocene and Quaternary formation. The rocks from the city are fracture and presences of jointing pattern leading infiltration of the water and in monsoon season the all kind of solid waste mixing with the rain water and causing the ground water pollution in the study area. The solid wastes from the MIDC area are more serious issue in the city which ultimately affects on ground water in near rural area and agriculture. The study area divided in to most suitable moderately suitable and suitable classes.

INTRODUCTION

The increase of population and urbanization and decreases in non renewable resources and disposal of effluent and toxic waste indiscriminately are the major environmental issues posing threats to the existence of human being (Allen et al; 1997). The most common problems associated with improper management of solid waste and their management (Jilani, 2002). The present study intend to find out a suitable site for the disposal of urban solid waste generated from Akola municipality and surrounding areas through the help of Remote sensing and GIS techniques with special emphasis on the geological aspect. Human activities create waste and the ways that waste is handled, stored, collected and disposed of can pose risks to the environment and public health. (Zhu Da et al., 2008). The Geographic Information Systems (GIS) plays vital role in solid waste management and its planning and operations of GIS are highly dependent on spatial data which provides a digital data bank for future monitoring program of the site (Miles et al., 1999). Municipal solid waste management is a costly service that consumes between twenty to fifty percent available operational budgets for municipal services and hence it is very important concern of its proper management (Bartone et.al 1990). Solid waste of different kind may infiltrate in the ground water table and lead to the ground water contamination in the study area.

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Study Area: The Akola city is located at 19°51' and 21°16' latitude north and 76°38' and 77°44' longitude east, covering an area of 150 Km^2 and falls in parts of Survey of India degree sheets 55 D/14 and 55 H/2 at present city Consists of 72 municipal wards in Akola city. The city broadly classified as agricultural, commercial, industrial, residential, transportation, administration etc. This study helps in parallel phenomena, identifying zones of scantiness and inadequacy in the city system of Akola. The elevation in the study area ranges from 261 m to 323 m above sea level. The slope angle ranges from 0 to 4° (Fig.1).

Geomorphology and Geology

Geomorphology: Geomorphologically the study area mainly consist of hilly terrain and covering almost entire north-central part constitutes the alluvial plain**.** In the study area dendritic to sub dendritic drainage pattern is most common pattern is developed on homogeneous rock with control by the underlying geologic structure. The longer the time of formation of a drainage basin is the more easily the dendritic pattern is formed (Fig. 1).

Geology of the Study Area: Geologically the Area Falls under two formation i.e. Deccan trap and Purna alluvium. The Deccan traps occupy an area of about 500,000 km^2 in Central, western and southern part of India. Major part of the district is covered by basaltic lava flows of upper Cretaceous to lower Eocene age (Fig.2 and Table 1).

Below the trap there is vertical thick layer of black cotton soil and red bole.. The thick deposits of alluvium sediments comprising of clay, silt and gravel are found in Purna river valley in the Northern part of the study area.

Lineaments: Lineaments are defined as mappable linear surface features, which differ distinctly from the patterns of adjacent features and presumably reflect subsurface phenomena (O'Leary et al., 1976). The intention of this study is to analyze the spatial distribution of lineaments extracted from satellite images according to their density, intersection density, length and orientation in order to contribute to the understanding of the structural setup of the area and large accept the view that the lineaments are surface expressions of faults, fractures (Sonder, 1947; Wilson, 1948). Satellite images and aerial photographs were used to extract lineaments in the study area and from the study majority of the lineament trending in the area are NE-SW, NW-SE (Fig. 2).

Slope Analysis: Slope is defined as gradient (maximum) of height of the area. Gradient in a defined point is the angle measured from the horizontal lined to the tangent plane in this point. Slope can be calculated as slope in the direction of axis x, slope in the direction of axis y and maximal slope. The slope of relief is a significant natural pattern of the landscape, because it distributes free available energy. SRTM DEM of 30 mt. spatial resolution is a single pass, synthetic aperture radar interferometry (InSAR) campaign conducted in February 2000. For the first time a global high-quality DEM was achieved with a resolution of 1 arc sec (~ 30 m) and 3 arc sec (~90 m, free availability) covering the Earth's area between 60° N and 54° S (Van Zyl, 2001). The maximum slope can be determined by taking the norm of this vector. On a grid DEM, slope calculation is performed using 3x3 moving window to derive finite differential. In this study second order finite difference is being used. Four Closest Neighbors (FCN) algorithms (Guth, P. L., 1995, Raaflaub & Colloins, 2006) have been used for computing the slope. It takes into account two orthogonal components of slope, slope in x direction and slope in y direction. From the slope in the study area ranges from 0^0 t0 4^0 which indicating that the slope in the study area is normal (Fig. 3).

METHODOLOGY AND DATA USE

These criteria are grouped into two main categories including physical and social economical information. In physical criteria the parameters like lithology, geomorphology, slope, drainage, population, lineament/fracture and distance from major roads, distance from major streams and distance from drainage while in social criteria the population, distance are taken (Table 2). The present study Indian Remote Sensing Satellite IRS 1C Linear Imaging Self Scanner (LISS-III) imageries with 23.5 meters spatial resolution and SRTM DEM of 30 mt. spatial resolution which was downloaded from the website USGS (Fig.4 & 5).

SOLID WASTE AND MANAGEMENT

Solid waste refers to any solid or semi-solid substance or object resulting from human or animal activities, discarded as useless or unwanted by human being. It is an extremely heterogeneous mass of wastes, which may originate from household, commercial, industrial or agricultural activities. Solid waste is a broad term, which encompasses all kinds of waste such as municipal solid waste, industrial waste, hazardous waste and bio-medical waste. It consists of organic and inorganic constituents which may or may not be biodegradable. One hand, the recyclable components of solid waste could be useful as secondary resource for production processes. On the other hand, some of its toxic and harmful constituents may pose a danger if not handled properly. Solid waste disposal site is the final stage in the solid waste management process. Several studies have been conducted on different scales to find the optimum locations for solid waste disposal sites (Nas et al., 2010). It must combine social, environmental, technical, and economical parameters (Siddqui et al., 1996, Baban, et al., 1998).Geographic information system (GIS) has the capability to handle and simulate the necessary data gathered from various sources. Topographic aps, aerial photographs, and satellite images) with quantitative, qualitative, and descriptive information databases by supporting wide range of spatial queries. All of these factors have made GIS is essential tool for location studies, especially for disposal site (Church, 2002, Murry, 2010).The integration of GIS has been shown in studies related to site determination in many various subjects including ecological sciences, urban-regional planning, waste management, hydrology and water resource, agriculture, forestry, natural hazards, recreation/tourism, housing/real estate, geological sciences, manufacturing and cartography (Malczewski, 1999).

Solid Wastes in Akola City: Solid waste management in Akola city has been undertaken in the context of an inadequate policy and legislative direction and with insufficient funds. However, there is a lack of solid waste management as well as specific criteria for selecting appropriate locations of disposal sites. The amount of MSW generated in Akola city in 2011 (Table 3). Despite of being the disposal method used in most of the municipalities dumping sites led to less negative environmental impacts, there are still some consequences that require mitigation in performance Benchmarking of Urban Water Supply and Sanitation report (Manjare, 2013) (Table 3).

Akola Municipal Corporation: A GIS based analysis, examines a number of possible choices for a sating problem, taking into consideration multiple criteria and conflicting objectives. In order to use GIS for site selection, data were obtained from different sources and stored in the GIS system (Table 4).

Distance from Urban Areas: The urban areas were mapped using the IRS LISS-III false clour composite satellite data of 2009. The disposal site should not be located very close to urban area. It should be situated at a proper distance and away from urban areas for example aesthetic, odor, noise and health as it concerns to public safety (Fig.6).

Distance from Agricultural Lands: It is extremely significant to determine the locations of agricultural lands to avoid placing the disposal sites within these lands. Disposal site should not be near to the agriculture land due to the dangerous effects of odor and insects on the farmers and crops which consequently may affect on the agricultural activities. This is because Akola city absolutely surrounded by the agricultural lands. Because it has a direct effect on the community, which is very important planning for a disposal site. In the study area the disposal site was based on the agricultural land distance (Fig.6).

Age	Group	Formation	Lithology
Recent		Black Cotton soil Thick Layer of Local Alluvium	Black Cotton Soil
Quaternary (Pleistocene to Recent)			Purna Alluvium
Cretaceous to Paleocene	Sahyadri Group (Deccan Trap)	Ajanta Formation	2 Aa and 8-compound Pahoehoe (10-Basaltic Lava flows)

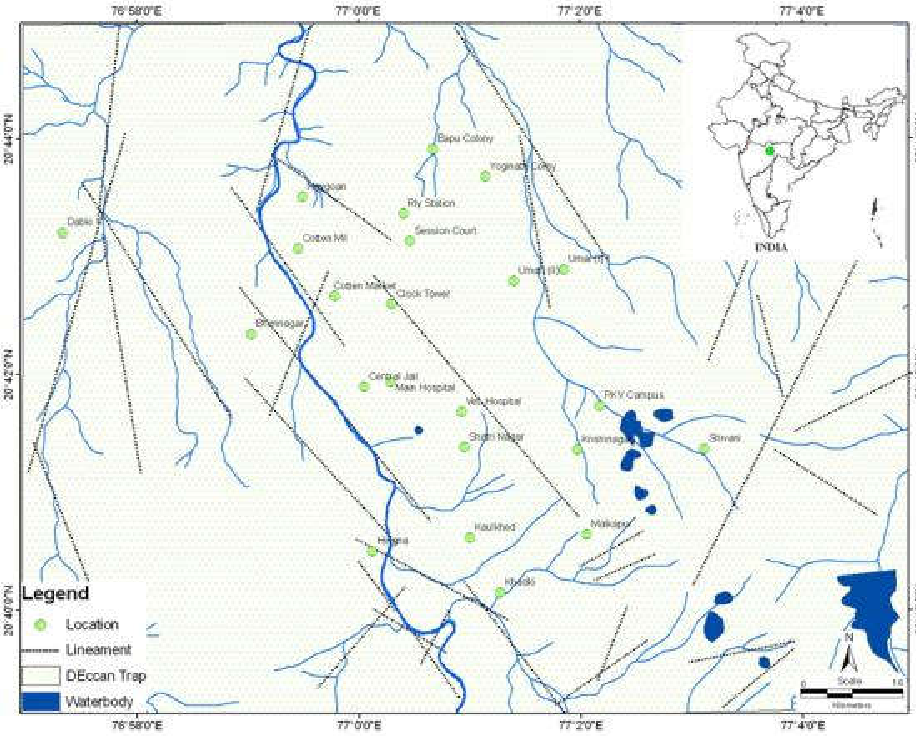

Fig. 2. Location, geological, drainage and lineament map of the study area (Modified after GSI, 2000)

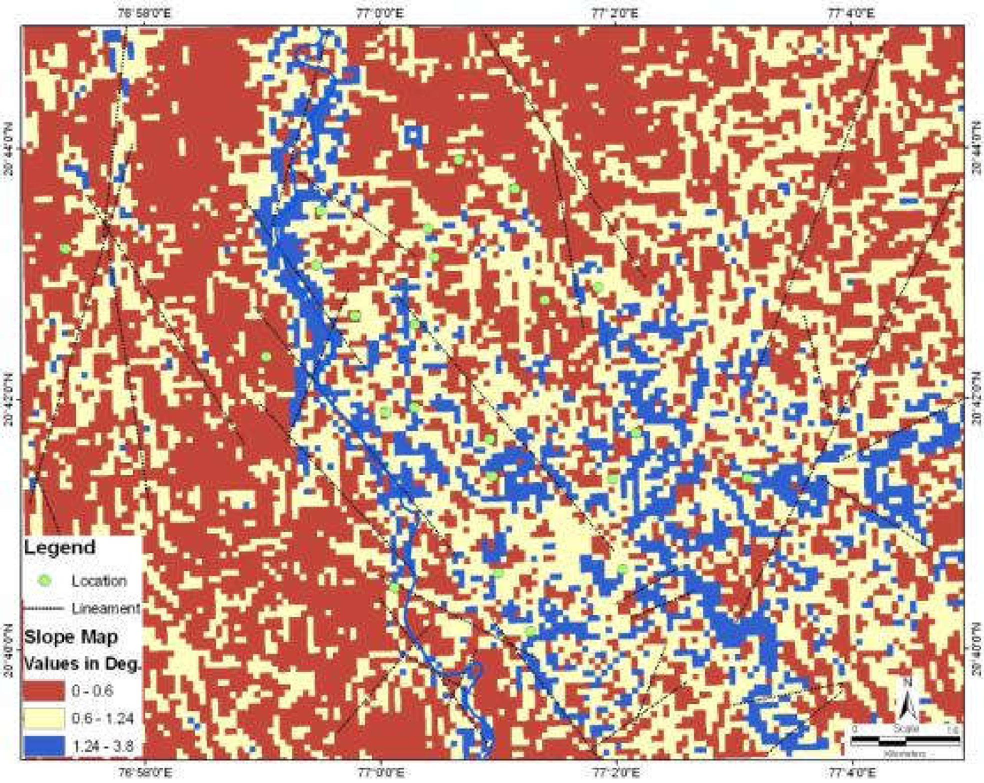

Fig. 3. Slope map of the study area

Table 2.The Criteria used in development of GIS database

Physical Criteria-	Social economical criteria
Lithology	Population
Geomorphology	Distance from major roads
Slope	Distance from streams
Drainage	Distance from drainage

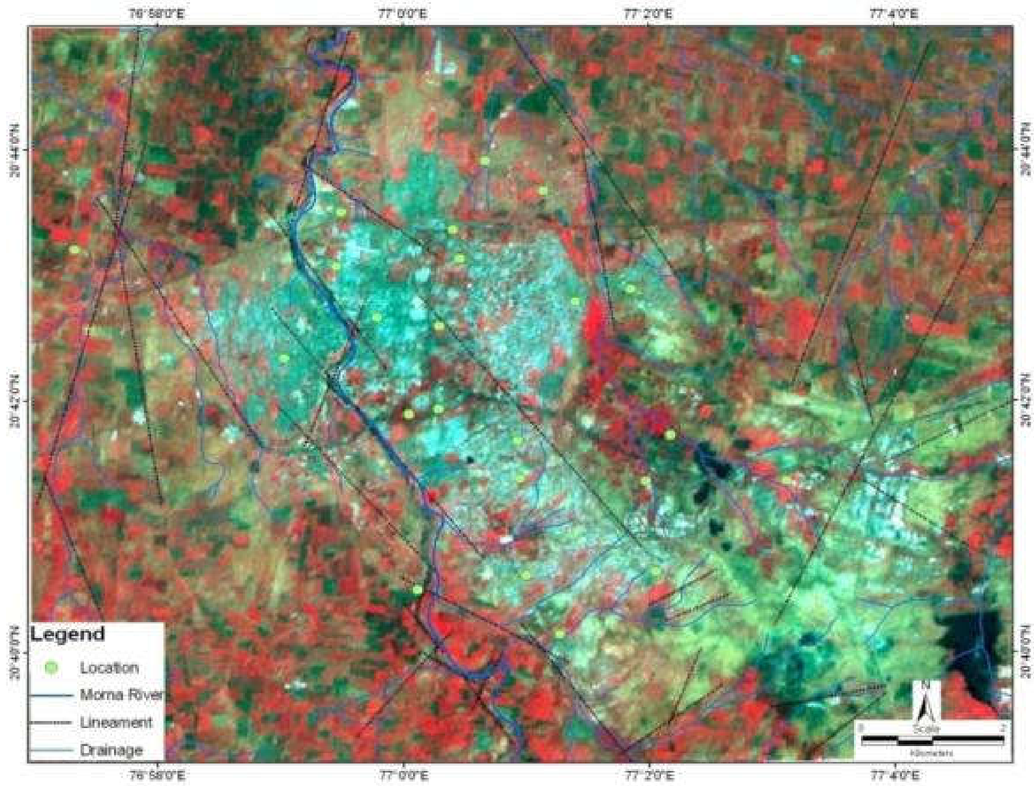

Fig. 4. Representation of study area on IRS LISS III (FCC) satellite data

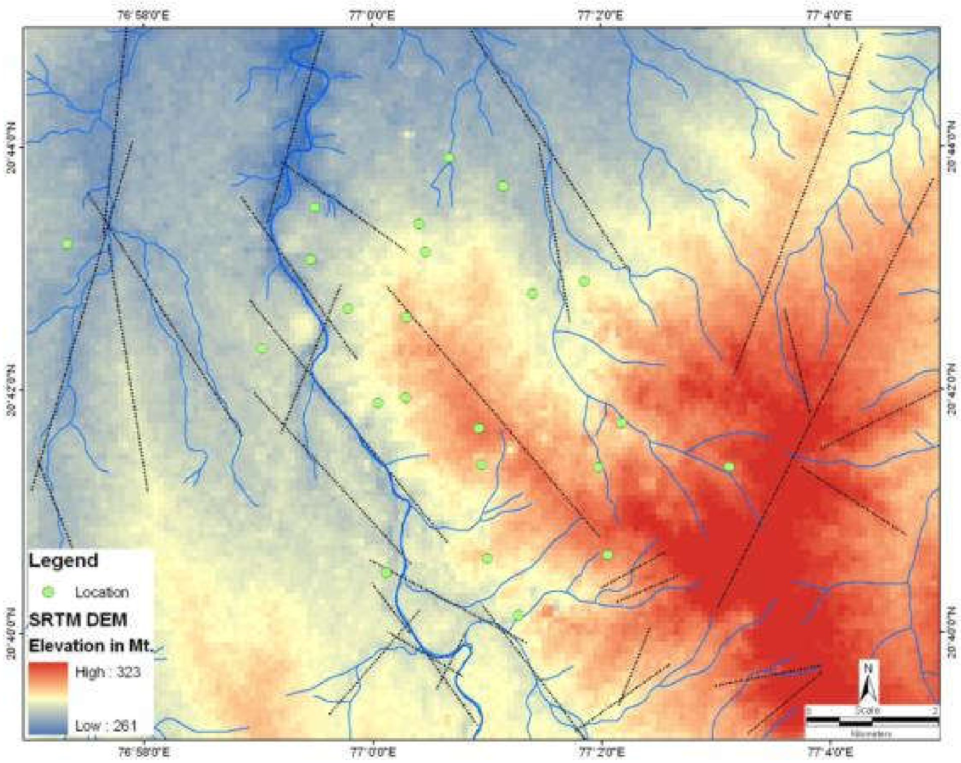

Fig. 5. Digital Elevation map of the study area

Table 3. Basic information of Solid Waste Management of the Akola city

Class	Municipal Corporation
District	Akola
Area (sq. km.)	28
Total city population (Lacks)	449,112
Total households (Lacks)	100,919
Density (persons per sq. km.)	16,040
Total municipal staff	2,071
No. of slum settlements	81
Slum population	147,479
Slum households	29,495
Total annual city capital receipts (Rs.)	120,321,111
Total annual city capital expenditure (Rs.)	196,985,801
Total annual city revenue receipts (Rs.)	561,857,404
Total annual city revenue expenditure (Rs.)	465,741,346
Waste generated (TPD)	130.0
Waste collected (TPD)	130.0
Quantity of waste treated (TPD)	22.0
Waste received at scientific disposal (TPD)	0.0
Door to door colln.(no. of households and establishments)	18,250.0
Waste segregation at source (Y/N)	N
Annual revenue receipts from SW (Rs.)	0.0
Annual revenue expenditure on SW (Rs.)	0.0
Annual capital expenditure on SW (Rs.)	0.0

(Source -CEPT University, April 2011)

Table 4: The geospatial data used in this study

Factor	Description	Format	Source
Urban area	Construction material, e.g. asphalt and concrete, road metal typical commercial and industrial buildings, dams residential development (including single/multiple houses)	Raster	Based on Interpretation of IRS-LISS-III(FCC)Satellite data of 2009
Agriculture land	Agricultural areas such vegetable fields, and annual crop fields, cultivated areas (irrigated and non-irrigated vegetation)	Raster	Based on Interpretation of IRS-LISS-III(FCC)Satellite data of 2009
Road network	Any transportation facilities, e.g. highways and local roads and local road	Vector, Shapefile	SOI toposheets
Surface aquifer	Refers to the saturated zone material properties, which control the groundwater movement	----------------	Obtained from CGWB/GSDA
Depth to water	Represents the depth from the ground surface to the water table	----------------	Obtained from CGWB/GSDA
Lineament/fracture	Any planar fracture or discontinuity or linear feature	Vector, Shapefile	DRM of Akola district (GSI)
Well	Observation wells available within the study area	Vector, Shapefile	Obtained from CGWB
Stream network	Refers to the Drainage systems occur in the study area	Vector, Shapefile	SOI toposheets
Slope	Refers to the slope of the land surface	Raster	Interpretation of Digital elevation model (DEM) of SRTM data available at the Consultative Group on International Agricultural Research Consortium for Spatial Information (CGIAR-CSI - http://srtm.csi.cgiar.org)

Table 5: The depth to water table for the stud area (CGWB, 2007)

Sl. No.	Area	Formation	Wells	Depth (mbgl)	SWL (mbgl	Discharge (lps)	Draw-Down (m)	Zones (mbgl)
1	Akola	Alluvium	09	11.30 -231.00	13.82->100	0.14 -10.00	5.69 – 44.90	28.00 – 231.00
		Basalt	06	20.00 –200.00	3.38 – 14.70	0.78 – 15.00	2.78-11.37	-----

Table 6: Statistical analysis for the Disposal site suitability map

Class	Area (km^2)	Area (%)
Most suitable	9.04	5.88
Moderately suitable	4.24	2.76
suitable	12.70	8.26
Not suitable	127.59	83.08
Total 153.57		

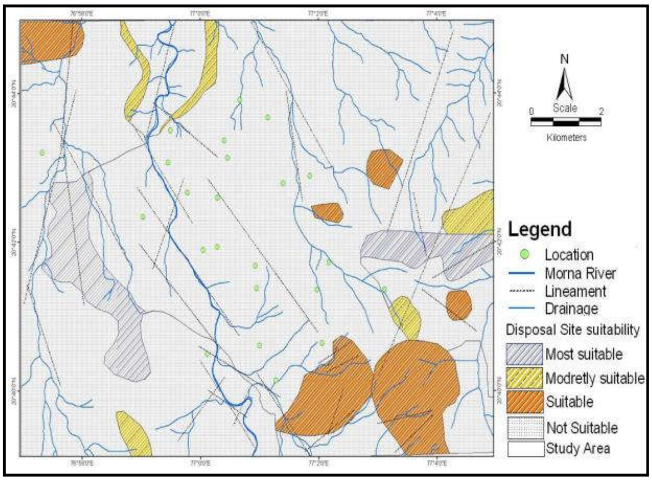

Fig. 6: Suitability map of the study area

Distance from Road network: Disposal site of solid waste should not be near to the road most of the studies suggested that the disposal site should be located within a 1 km buffer from the roads(Baban et al., 1998, Chang et al., 2008, Delgado et al., 2008). However disposal sites should not be too far from the roads because it increases the cost of transportations.

Surface and subsurface Aquifers: The water resources in Akola are in very critical situation. Therefore, it is very important to give the surface aquifers more attention when selecting suitable sites. There are two type of surface aquifer are found i.e. phreatic aquifer in alluvium and basaltic and non phreatic aquifer in basaltic rock. Phreatic aquifer behaves as a, where precipitation enters directly through the fractured outcrops. There are some minor aquifer which occurs in Basalt rock and disposal site selection has not near to the aquifer because of its importance towards the environment specially towards groundwater.

Depth to Water Table: It represents the depth from the ground surface to the water table. Discharge from exploratory wells ranged from 1.31 to 30.00 lps for draw downs ranging from 0.67 to 44.90 m. (CGWB, 2007).The solid waste should not come in contact with wells to avoiding water contamination (Table 5).

Distance from Lineaments/Fracture Zone: It is safer if the disposal sites can be located away from the lineaments/fracture system. This can prevent the leachate from finding a way to percolate into the groundwater. In this study, the lineaments/fracture system was extracted from the geologic maps and IRS LISS-III satellite data through a digitizing process. Based on the disposal site shall not be located within 60 meters of a f lineaments/fracture**.** To be more careful regarding the distance from the fault and fracture system, a buffer of 100 m distance was created around the lineaments/fracture (Fig.6).

Distance to Streams: Solid waste disposal sites must not be located into surface water (streams, rivers, lakes, sea). Most of the surface water in the study area is in the form of streams that occurred during heavy rains in winter season because of its influence on the environment. In this study he stream map have been prepared from the toposheet map (Fig.6).

Land Slope: A slope map was created through the interpretation of DEM that covers the study area. Lin and Kao, (1999) stated that neither too steep nor too flat land slopes are appropriate for placing a disposal site, and a slope of less than 12% would suitable, because of its importance toward the environment to have a stable location for the solid wastes. The Elevation maps of the study area have been prepared by the SRTM 90 m resolution and also for the slope map in degree (Fig.6).

Disposal Site Selection: Land suitability map for selecting the best possible solid waste disposal sites within the study area gives the idea about the disposal site. The land suitability map is divided into four classes: most suitable, suitable, moderately suitable and not suitable. From the analysis it shows that 2.76% of the study area has a "moderately suitable" class of disposal site selection, whereas a total of 5.88% of the study area has most suitable and suitable classes shows the 8.26% area and not suitable gives the 83.08% area (Fig.7 & table 6). Based on the land suitability map, the existing solid waste disposal site is located within "moderately suitable" class. This gives an indication that the location of the existing disposal site is in critical situation. The presence of the existing disposal site very close to the nearby villages is not recommended, since it can increase the health risks to the people who are living in these villages. In this study three locations were suggested to alternate the existing disposal site. Site moderately suitable and most suitable on either sides of the nearby existing road is highly recommended among the other sites. This site is not located too close to any village or residential area, which can open the chance to operate this site for a long period. In the same time, there is a wide area of most suitable class for disposal site, which can help to choose the best location for disposal site (Fig.6). A field survey was conducted to check the conditions of the suggested alternative sites. It was found that all the suggested sites, from environmental point of view, can be suitable for a new disposal site. But it might need further investigations, taking into consideration more detailed engineering, geotechnical, and hydrogeological studies.

Conclusion

GIS and remote sensing is widely used for finding, selection and proper mangment of solid waste. The Morna River is major drainage passing through the Akola city on the western side of the study area. The solid waste from the Khadki and Koulkhed area are also deposited near to the small drainage passing near from the Khadki and Koulkhed area of the city which also leads to the ground water contamination in the area. Lithologically most of the area under study is covered by Deccan trap and which also makes the barrier to the infiltration of the contaminated water in to the ground water table below, despite this the ground water below the trap are being contaminated by the improper disposal of the solid waste in the city. The fractured /lineament from the satellite data clearly indicates that in the city there are many fracture zone and causing the more infiltration in the study area which contaminate the dinking dig well and bore well through ground water contamination in the area. Based on the land suitability map for selecting the best possible solid waste disposal sites within the study area gives the idea about the disposal site. The land suitability map is divided into four classes: most suitable, suitable, moderately suitable and not suitable. From the analysis it shows that 2.76% of the study area has a "moderately suitable" class of disposal site selection, whereas a total of 5.88% of the study area has most suitable and suitable classes shows the 8.26% area and not suitable gives the 83.08% area (Fig.7 & table 6) Based on the above study if the solid wastes are not dispose at proper place then it ultimately affects on rural agriculture and rural ground water.

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