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A mini review on application of GIS and remote sensing in Municipal Solid Waste Management

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ABSTRACT

The municipal solid waste and remarkable increase in waste production because of increased population and urbanization is a vital issue at the global level. The inadequate infrastructure for disposal and management is a serious concern across the world. The present article gives a comprehensive review of the role of remote sensing and GIS in municipal solid waste disposal. Various studies have suggested that these techniques can be widely utilized in potential landfill site identification as well as for assessment of pollutant emission. The GIS based model has been utilized in assessment of groundwater pollution. It is well established that the remote sensing and GIS techniques can be integrated with field and laboratory based studies for a consistent spatio-temporal monitoring of the landfill sites.

Key words: *Municipal Solid Waste, GIS, Remote Sensing, Landfill, Site identification*

Introduction

The current state of population and urbanization at the global level has led to the fate of solid waste disposal and more specifically municipal solid waste (MSW). With the gradual advancement of population and elevated standard of living, the characteristics of MSW has become diversified. The major challenges encountered in context of MSW are the collection, transport, landfill site selection and treatment (El Maguiri *et al*., 2016). The generation of enormous waste and its management has been a crucial with respect to environment and human health both in developed and developing nations. A lack of infrastructure inhibits/hampers the quality of data and small scale studies do not give reliable information, because they are confined to point sources only (Singh, 2019). The sites of solid waste disposal have elevated concentrations of toxic gases, leachate, heavy metals and nitrate contamination. Hence, an updated information and evaluation about these landfills becomes critically important.

Role of GIS and Remote Sensing

The identification and monitoring through manual conventional techniques are difficult because of the inaccessible location of the landfills and associated health hazards. The open sanitary landfills consist of substantial toxic wastes and emissions causing serious environment hazards. The large pollutant load (Methane, Dioxins, Carbon dioxide) as well as pathogens pose a serious threat in conducting a regular and consistent site verification or ground verification. The other issues include portability, logistics for consistent monitoring and complexity of the whole process. The advancements in RSGIS have been significant in identification of potential landfill site selection, primarily in urban areas due to the synoptic coverage, spatial and temporal database and ability to integrate various thematic maps

at a common platform. The present article is an attempt to highlight the multiple aspects of landfill sites which can be addressed through Remote Sensing and GIS (RSGIS).

Landfill Site Identification and Monitoring through RSGIS

RSGIS has been significant for the preparation and assessment of a suitability index and based on land and environment based indices viz. surface water, groundwater, atmosphere, soil and human health. The Solid Waste Rules, 2016 as notified by MoEFCC prescribes criteria for site selection which include certain specifications with respect to its location and distance from water bodies, critical habitat areas and important zones (Parks, Highway, Airports) in built up areas. RSGIS techniques have been instrumental in site identification of landfills and subsequent assessment of potential landfill sites as per the prescribed norms and regulations. A number of studies have highlighted these methods as an efficient and prospective tool as detailed herein.

Analytical Hierarchy method was conducted for MSW landfill site selection using various base layer maps of groundwater parameters and water quality, DEM, relative distance from settlements/generation sites/roads and other environmental factors at Giroft, Iran (Javaheriet *et al*., 2006). An overlay of the maps leads to a suitability map and a zone classification districts viz. appropriate, fairly appropriate and inappropriate were selected and prioritized for identification and selection of sanitary landfill sites.

A GIS based analysis using Multi criteria and overlay approach for landfill site identification was carried out at Pondicherry region, India (Sumathi *et al*., 2007). Relevant thematic layers like water reserves and ground water quality, geological map, land use alongwith other associated maps were examined and given weightage as per their respective significance. The method laid out 17 potential sites for landfills based on further verification which were later optimized to shortlist 3 sites.

A pioneer study exploring an area of about 1969 km^2 to identify possible illegal landfill sites at Venice, NE Italy (part of the Venice lagoon watershed) using IKONOS satellite (July 2001) data (Silvestri, 2008) has been conducted. The soil contamination reflected through stressed vegetation was used as a reliable indicator for landfill identification. The known illegal landfill sites were calibrated from the 52 sites and subsequently used in identification of potential sites prone for waste landfill. A prior database for road network with precise street information, population density and historical aerial photographs was also incorporated.

Another study associated with urban solid wastes at Dharmanagar, Tripura, India used geomorphological and land utilization criteria and due weightage (Choudhary and Das, 2012). The analysis for the suitability map shows classified areas as Very less suitable 55.08 Km^2, Less suitable 76.45 Km^2, Moderately suitable 49.49 Km^2, Highly suitable 16.72 Km^2 and Very highly suitable 6.22 Km^2area for dumping waste.

An extensive approach using landsat thermal images on a temporal scale was utilized for identification of landfills by estimating the temperature difference for various waste disposal regions at Glina landfill, Romania (Iacoboaea and Petrescu, 2013). The study was compared for two regions, (i) within the landfill and (ii) surrounding area with no anthropogenic influence and having similar atmospheric conditions as compared to landfill. The active decay and decomposition leads to generation of landfill gases, revealing a considerable thermal difference of 2 °C to 8 °C between these regions.

The identification of existing contaminated sites and multi-factor evaluation (MFE) methods to find out about the probable occurrence of illegal landfills using GIS with multi criteria evaluation (Biotto *et al.,* 2014) is reported as the pioneer work wherein site identification and an analysis of various criteria causing illicit operations have been looked into. The existing spatial information on known illegal landfills within the training area was used to compute the suitability index, which can be designated as a vital tool for environmental management and potential illegal dumps.

A multi criteria decision analysis approach was used on an area coverage of 277 km^2 at Mohammedia, Morocco (Maguiri *et al*., 2016) to identify the potential sites for landfill alongwith the consideration of rehabilitation of the existing one. Six criteria viz. waste generation, surface water, land use, slope of land, transport network and geology were generated vis a vis GIS database related to each criteria leading to provisional selection of three potential sites and the final validation was made based on the land tenure.

Potential dumping sites were demarcated with the help of multi criteria decision analysis and GIS

through multi spectral images and thematic maps to assign weights for different criteria at Coimbatore district, India (Kapilan and Elangovan, 2018). The dataset validation by consistency ratio was used to justify the criteria giving 17 potential zones and subsequent short listing of four suitable sites with supplementary observations through field investigation and therein a suitability index.

Another study based on analytical Hierarchy Process was employed on various thematic maps characterizing land use to prepare an indexed map for suitability regarding solid waste dumping at Logia, Afar region, Ethiopia (Mussa and Suryabhagavan , 2019). The study identified various classes and their suitability in the region, viz. Highly suitable 5.93%, suitable 6.5% moderately suitable 3.23% less suitable 1.02% and Unsuitable 83.32%.

A spatial distribution and characterization study was conducted for disposal sites to assess specific issues like quality and quantity of waste generation, bin location alongwith the probable site identification at the Lagos Mainland area of Lagos State (Jimoh *et al*., 2019). About 79 waste disposal units were analysed through a questionnaire and buffering operations for better decision making.

Conclusion

A consistent monitoring of the landfill sites through the traditional field methods is cumbersome and can be made less complex by integrating the laboratory and ground measurements alongwith satellite based techniques. The recent advances in GIS have enabled an effective identification and regular examination of the potential landfill sites. Moreover, a continuous monitoring of various pollutants and their characteristics has intricate linkages with the ambient air quality and micro-environment of a region. The satellite based surveillance can be used for the quantitative and qualitative monitoring of various parameters relevant to landfills which are otherwise inaccessible and potentially hazardous. Also, the illegal waste disposal can be accessed from time to time reducing the logistics and labour intensive procedure. An integrated approach can give a wider scope for their regular monitoring and source apportionment, thus giving a holistic picture of municipal waste management. A robust method can be devised to see if there are opportunities for future research in this emerging field. These methods can be coupled with primary surface based data so that the field based validation can be made easier.

Conflict of Interest: The authors declare that there is no conflict of interest.

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