Chapter: Spatio-temporal Analysis of Open Waste Dumping Sites Using Google Earth: A Case Study of Kharagpur City, India

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Abstract

Google Earth provides high resolution satellite images over a long period of historical time period which can be used to study land use/land cover (LULC) changes in any area over an extended period of time. In this study, Google Earth Pro was used to identify problems with current locations of solid waste dumping sites and conduct a time-series analysis of the areas occupied by waste dumping sites in Kharagpur city. Five dumping locations were studied of which three are official dumping sites, one is an illegal dumping site and last one is an official dumping site which was cleaned in 2015. Satellite images of the same dumping locations were taken to evaluate changes in the areas of the dumping sites from 2010 to 2017. The results of the study show that most of the sites are situated very close to an airbase runway, railway line, residential area or highway/road which is in contravention of regulations. Time-series analysis show that the sizes of all dumps have varied significantly with respect to time except for the unauthorized dumping site. The reasons behind the fluctuations in area are frequent burning of garbage and partial clean-up of the site due to local complaints. The methodology used in this study can be extended to for an entire city or even several cities to find problems related to the existing illegal or official waste dumping site within a specific time period.

Keywords: Municipal solid waste, Open dumps, Satellite images, Google Earth, Time Series Analysis.

1. Introduction

According to the latest Census of India, the population of India in 2011 was 1.21 billion, which makes India the second most populated nation in the world. The urban population in India in 2011 was 377 million while in 2001 it was 285 million which represents a 2.8% annual exponential increase in urban population in the last Census decade (Census of India 2011). With an increasing population, India is also a growing economy with an annual economic growth rate that is more than 5% (OGD Platform India). Increasing resource consumption and growing population implies that more waste is being generated by the increasing population. Thus, India's one of the biggest challenges today is management of the exponentially increasing quantities of municipal solid waste (MSW) generated.

As population is increasingly exponentially and per capita resource consumption is also increasing, solid waste management (SWM) services are not able to keep up with the increasing quantities of waste being generated (Goel 2008). The current SWM practices are inefficient, require heavy expenditure and are a potential threat to public health and the environment (Biswas et al. 2010). Most countries are still struggling to deal with their problems related to growing waste (Agamuthu et al. 2009). In large India cities, collection efficiency is around 70 - 90% of MSW generated, whereas in smaller cities and towns it is less than 50% of total waste generated (Shaarholy et al. 2008). This uncollected waste is either burned or dumped illegally on open land causing health problems and environmental degradation (Annepu 2012; Sharholy et al. 2008; Kumar 2010). Exposure to pollutants like carbon monoxide (CO), carcinogenic hydrocarbons (HC) (includes dioxins and furans), particulate matter (PM), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) can occur due to uncontrolled burning of garbage as shown in a detailed study in Mumbai (NEERI and CPCB 2010).

The problem of unsanitary landfilling is directly related to the lack of financial resources of the Urban Local Bodies (ULBs). ULBs spend about $10 – $30 (INR 500 – 1,500) per ton on SWM (Department of Economic Affairs 2009). Despite large financial inputs, only about 60-70% of this amount is spent on collection, 20-30% on transportation and no funds are allocated for proper disposal of waste (Kumar 2010; Department of Economic Affairs 2009). India is still creating infrastructure for SWM which is a very heavy financial burden and is often done by borrowing money from international lending agencies like the World Bank or from market and private sources.

Based on annual reports provided by State Pollution Control Boards to the Central Pollution Control Board for the period April 2013 to Dec 2016, the amount of MSW generated in India in urban local bodies (ULBs) was 135,198 tons/day while the amount collected was 111,028 tons/day (82% of generated waste). Only 25572 tons/day was amount treated (18.9% of the generated MSW) while some of the waste was disposed in landfills and is estimated to be 47416 tons/day (35%) (CPCB 2017). The remaining waste remains in the open dumpsites increasing environmental burden in the urban areas (Peter et al., 2019).

As mentioned above, a large fraction of the MSW collected in India is disposed on open land or in unsanitary landfills. In most large metropolitans, existing landfill sites are exhausted and the responsible urban local bodies do not have resources to acquire new land (Annepu 2012). As the area provided for landfills is completely occupied, the only remaining option is to increase the height of the dumps. In many cities like Mumbai, Delhi, Ahmedabad and Kolkata, the dumping sites now have man-made mountains of garbage. The dumping site in Dhapa, Kolkata is 17 m high, three open dumping sites in Delhi have heights of more than 40 m and Deonar dumping ground in Mumbai has an area of 144 hectares and height of roughly 55 m (Saldanha and Lukose 2014). Leachate generated from unsanitary landfills contaminates soil, surface and ground water resources (Sharholy et al. 2008; Biswas et al., 2010). Using water contaminated by solid waste for bathing, food processing, irrigation, and drinking exposes individuals to disease organisms and other contaminants (Hoornweg and Bhada-Tata 2012). MSW dumped in landfills also generates greenhouse gases like methane which has 21 times more global warming potential than carbon dioxide. According to International Energy Agency, improper dumping of SWM contributes to 6% of India's methane emissions and is the third largest source of methane in India. This is much higher than the global average of 3% methane emissions from solid waste. Solid waste currently produces 16 million tons of CO_2 equivalents per year and this number is expected to rise to 20 million tons of CO_2 equivalents by 2020 (International Energy Agency 2009).

Geospatial and remote sensing (RS) technologies now become widely available, readily accessible, and more apparent in our daily lives than ever before (Bodzin et.al. 2014). Together, RS and GIS have been widely used in various stages of MSWM like waste collection and transportation, route optimization, calculating size of dumping sites, and identifying landfill fires (Brimicombe 2003; Ghose et.al. 2006; Dutta and Goel 2017; Khan and Samaddar 2016; O'Conner, 2013). However, some preliminary knowledge is required to use RS and GIS tools. Learning to use satellite imagery data and software like ArcGIS, Q-GIS, and ERDAS takes time, experience and effort to use them efficiently and precisely. Simple tools and software like Google Maps, Bing Maps, Google Earth and Google Earth Pro can also be effectively used for climate and environmental studies due to the availability of high-resolution satellite images. Google Earth software is a virtual globe that contains and integrates a wide arrangement of remotely sensed and modelled images created with various satellite and aircraft data at different points in time. In Google Earth, available images can be zoomed in to where the resolution is about 1 meter/pixel to 15 meters /pixel enabling users to identify physical features such as river catchments, canyons, agricultural fields and mountains along with their elevations (Bodzin et.al. 2014). Currently, researchers have been using Google Earth to visualize data for studying various environmental issues and phenomenon including LULC change impacts on river basin, to study flow and dispersion of pollutants, forest conservation, mapping mining areas and its impacts assessment etc. (Gorelick et al. 2018; Kumar and Mutanga 2018; Liu and Kenjeres 2017; Tsai et al. 2018; Zurqani et al. 2018). Google Earth can be a very effective tool to generated data for the areas where good quality RS-GIS data is unavailable. Google Earth can be used to identify various dumping locations in and around cities and to evaluate changes in the shape and size of these dumpsites with respect to time.

The objective of this study was to analyse changes in the shape and size of the open dumping sites over a period of time and to evaluate problems related to unsystematic dumping practices using Google Earth. The area selected for the study was Kharagpur city situated in the state of West Bengal, India. Changes in land use/land cover (LULC) are routinely monitored using Google Earth Pro and the same concept was applied for delineation of open solid waste dumping sites in Kharagpur from 2010 to 2017. The approach used in the study was quite simple and Google Earth is an easily accessible software due to which anyone with a basic idea about online satellite maps (like Google maps, Bing maps) and MSWM can use this approach. Beside the simplicity of the approach, the present study can provide valuable information to planners and decision makers regarding land use/land cover changes over time. This methodology can also be adopted for regular monitoring of solid waste dumping sites in any city or town.

1.1 Study area and Current scenario of MSW management in Kharagpur

Kharagpur is in West Bengal, India and is about 120 km away from Kolkata, one of the largest cities in India. Kharagpur has one of the largest railway workshops in India and the 3rd longest railway platform (1.0725 km long) in the world. Kharagpur is located at Latitude 22.33 °N and Longitude 87.32 °E with an average elevation of 29 meters (95 ft.) above Mean Sea Level.

Kharagpur municipal area has a population of 2,89,129 (according to the 2011 Census) spread over 91 km^2 area and is divided into 35 wards as shown in Fig. 1a (Kharagpur Municipality, 2016). The Indian Air Force has two airbases close to Kharagpur city: Kalaikunda and Salua.

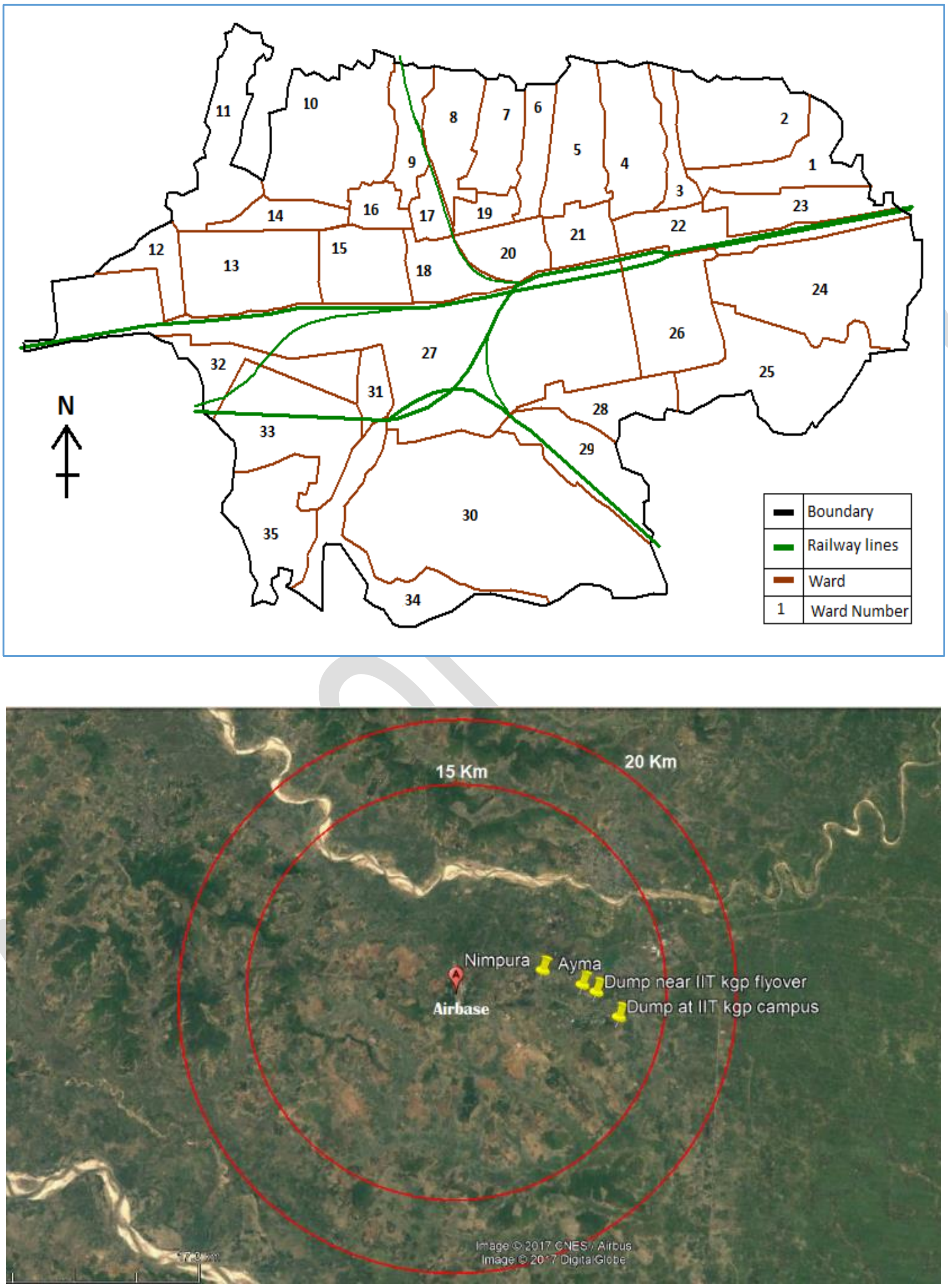

Fig. 1 (a) Cities of Kharagpur and Kolkata (google maps) (b) Location of dumping sites with respect to local air base.

Major sources of MSW in the Kharagpur area are residential areas, commercial/market areas, government offices, hotels/restaurants, and institutions. Kharagpur Municipality is responsible for the collection, treatment, and disposal of solid waste. The estimated population of Kharagpur in 2017 is 314,628 persons and with a per capita waste generation rate of 0.5 kg/capita-day, the total amount of solid waste generated in Kharagpur is estimated to be 158 metric tons (MT)/d. Of this 158 MT of waste, only half of the waste is collected by the municipality, while the rest of the waste is either burned or dumped illegally. Due to poor collection efficiency and lack of proper waste treatment, illegal dumping of waste is common in the city. There are several illegal dumps in city; one of them is situated near the IIT Kharagpur flyover adjacent to a state highway and in between two railway tracks.

Characterization of MSW generated in Kharagpur city was done by Kumar and Goel (2009), which shows 19.6 % of the generated waste was recyclables (plastics, paper, and textiles) and 80.4 % was mixed residue (includes organic material, soil, mud and other inert materials). This mixed residue had an organic carbon content of 8.92 (±5.92) % and fixed solids content of 80.35 (± 9.54) %. Due to hot and humid environmental conditions, organic matter degrades rapidly in the city resulting in foul smell when openly dumped.

Currently Kharagpur Municipality has two official dumping grounds where waste is dumped without any treatment: Nimpura and Ayma. At present there is no sanitary landfill in Kharagpur and location of all the present dumpsites are also not according to Indian regulations. According to Indian regulations, a landfill should be located at least 500 m away from any residential settlement and State/National Highway, and at least 20 km away from the airbase runway (SWM Rules 2016). Both, Nimpura and Ayma are in contravention of these rules. The disposal site at Nimpura is less than 5 km away, whereas the site in Ayma is around 8 km away from the Kalaikunda Airbase (Fig. 1b).

2. Material and Methodology

A time-series analysis was done by comparing satellite images of the same dumpsite location at different times. Historical satellite images were obtained by using historical imagery in Google Earth Pro software (version 7.3.1.4507(64-bit)). Total 5 dumpsites were studied in the present study. Location of 5 dumpsites and study period of the time series analysis is shown in table 1. Area and perimeter of each dump was calculated by drawing the outline of the dumps in the mapping software. Time-based comparison of dumps was done on the basis of the area rather than perimeter. Since, area and perimeter were not always directly proportionate to each other, area was found to be a better estimate of the size of a dump rather than the perimeter. Satellite images before 2010 are not used for time series analysis due to their poor resolution which may lead to false conclusion. Also, many satellite images after 2010 were also not very clear due to cloud cover or poor resolution or darkness, so only clear and good resolution satellite images were used in the study for accurate results.

Table 1. Location of dumpsites studied and time period of time series analysis study

Dumpsite	Latitude	Longitude	Time Series Analysis period
OT road	22°21'43.38"N	87°20'17.26"E	Jan-2010 to Nov-2015
Ayma	22°19'56.22"N	87°17'58.42"E	Jan-2011 to Oct-2016
Nimpura	22°20'30.17"N	87°16'18.89"E	Jan-2011 to Oct-2016
Near IIT Kgp flyover	22°19'38.40"N	87°18'34.36"E	Nov-2014 to Oct-2016
Inside IIT Kharagpur	22°18'42.45"N	87°19'30.12"E	May-2012 to Jan-2017

After completing the time-series analysis, possible reasons were sought for change in size of dumps by visiting the sites and conducting a ground survey. Personal interviews and meetings with authorities responsible for waste management (Kharagpur municipality and IIT Kharagpur Sanitation department), nearby residents and rag pickers also provided some reasons for changes in dump areas. Further, to check locations of the dumpsite as per Indian regulations, distance of dumpsites was calculated from the airbase runway, nearby railway line and nearby roads using the ruler tool in Google Earth Pro.

3. Results and discussion

3.1 Site near OT road (Dump Site - 1)

Kharagpur municipality was using the site on Orissa Trunk (OT) road from 2007 to 2015 for dumping solid waste. This dump site was cleaned in 2015 for widening of OT road and now there are several big business establishments along this road and others are planned as well. Prior to 2015, it was one of the major dumping grounds for municipal waste and flyash from a neighbouring thermal power plant (Kharagpur Municipality, Kumar and Goel 2009). Comparison of satellite images from 20-January-2010 to 22-November-2015 is shown in Table 2. The size of the dump increased from 20-January-2010 to 30-March-2014 and started declining after that because municipality cleaned the site and transferred waste to another site (Fig. 2 shows result of time series study of OT road dumpsite). By the end of 2015, the site was cleaned up completely and currently, there is a residential complex at the dumping site.

Table 2. Results of time series analysis on all 5 dumpsites

Dates	OT Road dumpsite		Ayma dumpsite		Nimpura dumpsite		Kgp-Flyover dump		IIT Kgp dumpsite	
	Area (in m^2)	Perimeter (in m)	Area (in m^2)	Perimeter (in m)	Area (in m^2)	Perimeter (in m)	Area (in m^2)	Perimeter (in m)	Area (in m^2)	Perimeter (in m)
20 Jan 2010	472	90	-	-	-	-	-	-	-	-
18 Dec 2010	1201	133	-	-	-	-	-	-	-	-
13 Jan 2011	-	-	4937	586	3137	345	-	-	-	-
20 May 2012	2718	222	9135	1168	-	-	-	-	0	0

19 Apr 2013	-	-	13256	1318	-	-	-	-	-	-
20 May 2013	-	-	-	-	6363	355	-	-	34998	1154
30 Mar 2014	3673	491	11259	1461	5815	344	-	-	52022	1807
17 Jun 2014	3439	501	-	-	-	-	-	-	-	-
6 Nov 2014	-	-	-	-	-	-	0	0	-	-
22 Nov 2015	0	0	9065	1319	5244	389	3582	350	48015	2165
29 Mar 2016	-	-	10394	1464	6184	380	3999	393	68034	1883
30 Oct 2016	-	-	6438	1187	6578	375	4488	415	13653	1706
05 Jan 2017	-	-	-	-	-	-	-	-	33978	1813

Fig. 2 Time Series analysis of OT road site from 20-Jan-2010 to 22-Nov-2014 [Colour code: Red 20-Jan-2010; White 18-Dec-2010; Green 20-May-2012; Blue 30-Mar-2014; Cyan 17-Jun-2014].

3.2 Site near Railway workshop in Ayma (Dump Site -2)

Kharagpur Municipality has been using the site in Ayma since 2006. This site is situated near the railway workshop and waste is dumped near the workshop building and the railway lines. There is a huge vacant area at the back of the workshop where waste is dumped at three different locations around 160 - 170 m apart from each other (Fig. 3). Ayma is located 8 km away from the Kalaikunda Airbase of the Indian Air Force which is not in accordance with Indian regulations.

Comparison of satellite images from 13-January-2011 to 30-Oct-2016 is shown in Table 2. The size of this dump increased from 2011 to 2013, but after 2013, the size of the dump started fluctuating. Comparing images from 2013 and 2016, it is clear that the size of the dump has reduced significantly (Fig. 3). Reasons behind the reduction in the dump size is frequent burning of the waste at the dumping site. Waste is burned frequently at the other dumping sites in the city by the municipality or local people to reduce size of the garbage pile. Currently, Ayma dumping site occupies an area of 0.65 hectares of the land and its leachate flows directly to an open drain. The soil in Ayma is laterite morum soil which is highly permeable due to which chances of groundwater contamination are very high in the area.

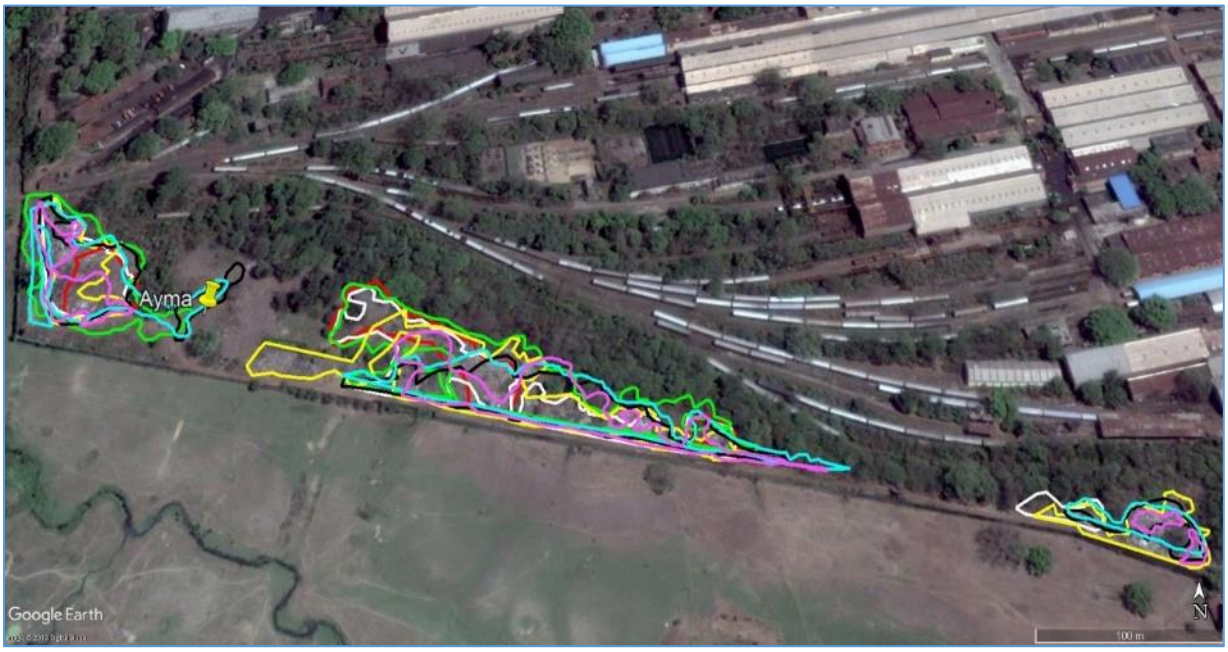

Fig 3. Time series analysis of Ayma dumpsite [Colour code: Red 13-Jan-2011; White 20-May-2012; Green 19-Apr-2013; Yellow 30-Mar-2014; Black 22-Nov-2015; Cyan 29-Mar-2016; Pink 30-Oct-2016)

3.3 Dumping site in Nimpura (Dump Site - 3)

The waste dumping site at Nimpura is amidst to a densely populated area, and the nearest settlement is not more than 10 m away from the site. Problems of foul smell and pests (especially mosquito and flies) are quite common in the area and in the rainy season it gets worse. Nimpura is also located in the proximity of the Kalaikunda Airbase of the Indian Air Force just like the disposal site at Ayma. The disposal site at Nimpura is less than 5 km away from the airbase due to which risks of scavenger bird hits is greater at Nimpura compared to all other sites.

Currently, the Nimpura dumping site covers 0.66 hectares of land. Comparison of satellite images from 13-January-2011 to 30-Oct-2016 is shown in Table 2. The size of this dumping site increased from 2011 to 2013, but after 2013 the size of the dump start decreasing till 2015 after which it has been increasing continuously. Reasons for size reduction include cleaning of a part of the site when garbage is dumped too close to the adjacent road. Reported by the local residents and rag-pickers, the dumpsite is partially cleaned many times but never cleaned completely.

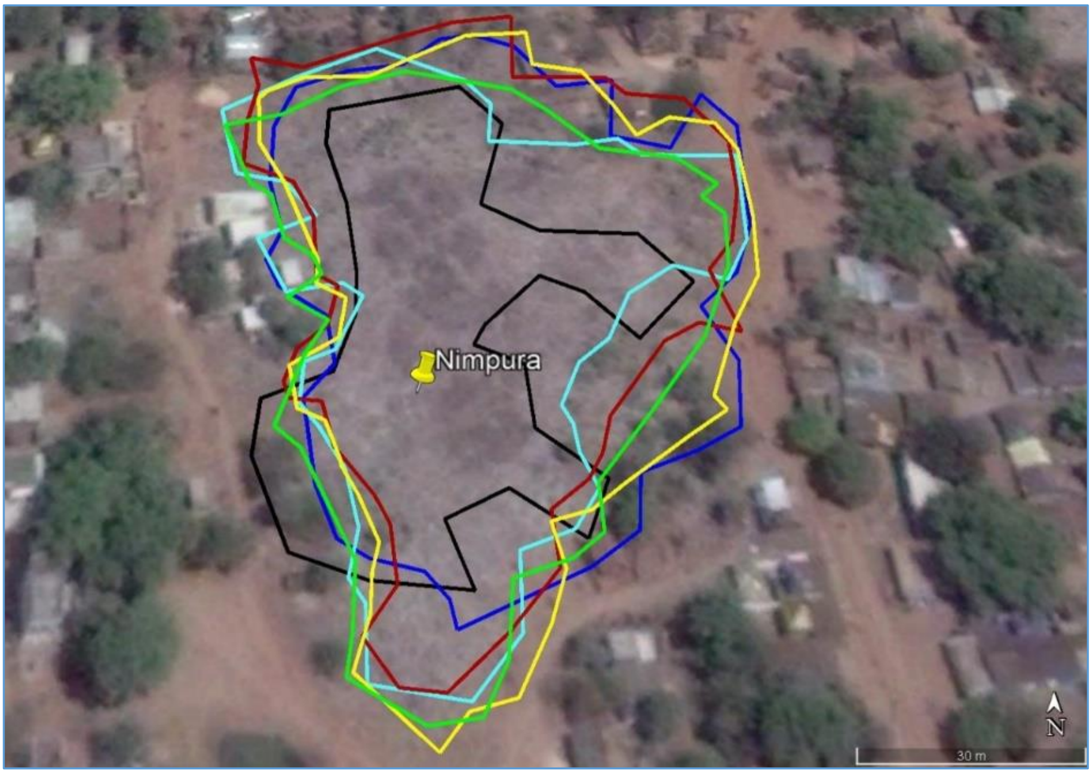

Fig 4. Time series analysis of Nimpura dumpsite [Colour Code: Black 13-Jan-2011; Blue 20-May-2013; Green 17-Mar-2014; Cyan 22-Nov-2015; Red 29-Mar-2016; Yellow 30-Oct-2016]

3.4 Illegal dumping site near IIT Kharagpur flyover (Dump Site - 4)

Another major waste dumping site is close to IIT Kharagpur campus and on State Highway-5 (SH-5) just at the end of the IIT Kharagpur flyover. It is an illegal dumping site used by the residents of Ward 27. This dumping site is located between two railway lines as shown in Fig. 5. This dumpsite is also located in the proximity of the Kalaikunda Airbase just like Ayma and Nimpura dumpsites (9.5 km away from the runway).

Fig. 5 (a) Time series analysis of illegal dumpsite near Kgp flyover [Colour Code: Blue 22-Nov-2015; Yellow 23-Mar-2016; Black 30-Oct-2016] **(b)** Picture of the illegal dump where waste is scattered along the road.

Initially, the site was created for dumping waste construction material from the construction of the adjacent flyover. Residents in the area started dumping their garbage illegally at this location mainly due to the absence of community bins in the ward at that time. Slowly this illegal dumping site started expanding and currently, it occupies an area of 0.45 hectare with a height varying from 0 to 2.5 m. In terms of topography, the dumping site is situated at higher ground level compared to nearby areas including the road. Due to this, leachate generated goes directly into the storm water drains and during heavy rains, leachate enters houses adjacent to the waste dumping site (housed are <100m away). Many street animals move over the site and scatter waste alongside the road (Fig. 5b). Many accidents have also occurred on the highway and railway line due to stray animals.

The earliest satellite image in which dumping is apparent is from Nov 2015; no dumping is apparent in the image from 06-Nov-2014. Therefore, dumping at the site is likely to have started in late 2014 or in early 2015. On comparing images of 22-Nov-2015 and later, it is clearly visible that within a year, the size of the dump increased significantly and continues to grow. Even though garbage at the site is burned on continuous basis but size of the dumpsite still keeps on increasing. On 30-Oct-2016, size of this illegal dump was about 0.45 hectare.

3.5 Dumping site in IIT Kharagpur campus (Dump Site - 5)

The campus of Indian Institute of Technology Kharagpur is at the southern end of the city, i.e., Ward 30 of Kharagpur city. Another waste dumping site is located inside the campus boundary near the south-west corner of the campus. Currently, the site is used for dumping of institutional waste (waste generated from hostels, campus markets, departments and laboratories) and construction and demolition (C&D) waste. The nearest settlement is within the institute boundary and 400 meters away from the dump site. Further, the site is hardly 50 m away from the road and 55-60 m away from the railway line (Fig. 6a). The distance of this site from Kalaikunda airbase runway is 11.5 km which is again not in accordance with regulations. During the rainy season, leachate generated from the dump accumulates in a nearby pit having an area of approximately 500 m^2. This accumulated leachate is a suitable environment for breeding mosquitoes and other harmful pests resulting in health hazards for sanitary workers, rag pickers and others working in the area. Also, this accumulation of leachate increases the chances of groundwater contamination due to shallow ground water table depth (5-10 m) and highly permeable laterite morum soil.

The Institute sanitation department started using this site for dumping waste in late 2012. In a time-series analysis of this site, it was seen that the size of the dump increased significantly from 20-May-2013 to 30-March-2014. Most of the waste from the site was cleaned after March-2014 and the rest of the waste was burned at the site due to which the size of the dump decreased considerably. After Mar-2014, the size of the dump increased again until 29-March-2016. In April-2016, there was a fire accident in the campus, near the dumping site. The fire spread rapidly in nearby areas because of dry vegetation. A large part of the waste dump also caught fire due to which the size of the dump was reduced drastically. After 30 October-2016, the area of the dump site has been increasing again. Based on the 05-Jan-2017 satellite image, the dumping site occupies an area of 3.4 hectares.

Garbage is burned on a weekly basis to reduce the size of the dump (Fig. 6b) despite regulations against it. The smoke resulted from open burning is a health hazard for those exposed to it due to the presence of high concentrations of dioxins, sulphur oxides, nitrogen oxides, carbon oxides, arsenic, and lead. In the daytime, there are many rag pickers at the site, collecting plastics, metal and other recyclables while children often play nearby. So, these rag pickers and their children are directly exposed to this hazardous smoke on a daily basis. Beside regular institutional waste, hazardous waste generated from chemical and biological labs which was also dumped at the site (Fig. 6b). This could be a greater threat to the rag-pickers, sanitary workers and nearby by environment compares to regular MSW. Burning of this hazardous waste will many times increase the toxicity and exposure of the toxic smoke.

Soil near the dumping site is highly permeable laterite morum and the average ground water table depth is just 5-10 m below the ground surface. Therefore, the chances of ground water contamination are extremely high and due to hazardous waste at the site it could lead to a catastrophe. In the Prembazar area, which is hardly 500-700 m away from the dumping location, many people still use groundwater via hand pumps or open dug wells. So, if the groundwater gets contaminated it will directly affect the population in this area.

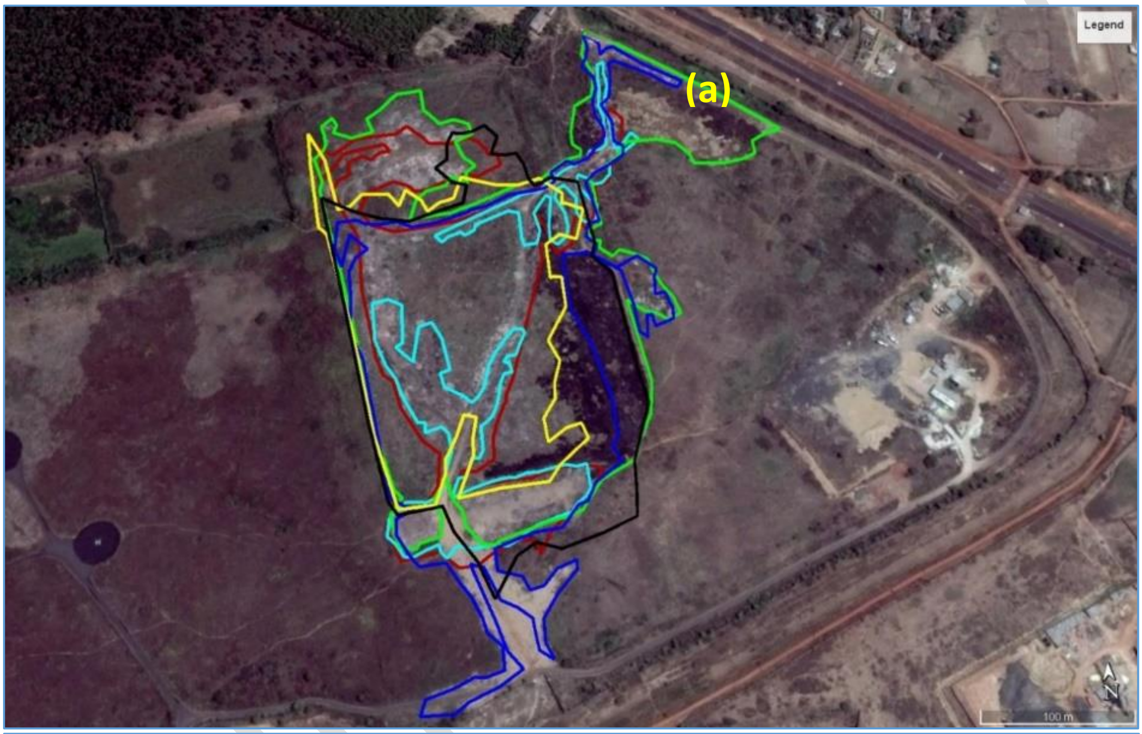

Fig. 6 [a] Time series analysis of dumpsite at IIT Kharagpur [Colour Code: Yellow 20-May-2013; Black 30-Mar-2014; Blue 22-Nov-2015; Green 29-Mar-2016; Cyan 30-Oct-2016; Red 05-Jan-2017] **[b]** Current photo of the dumping site at IIT Kharagpur **[c]** open burning of garbage and empty chemical bottles/containers at the site.

4. Conclusions

A time-series analysis of five municipal solid waste dumping sites in Kharagpur, including one that was closed in 2015, has been completed using historical satellite images from Google Earth Pro. These images along with information collected from municipality officials, and local people were used to determine changes in the sizes of these dumping sites and the reasons for these changes. The results of the study show that except unofficial waste dumpsite, the area of all the dumping site is varying significantly with the passing years. There are two major reason behind these fluctuations in the area of the dumpsites. First, is the frequent open burning of the garbage to reduce the size of the dump piles. Second, is the partial cleaning of the dumpsites to reduce the dump size or due to large number of complaints by local residents. The unofficial waste dumpsite is continuously increasing from 2015. Locations of all the 5 dumpsites are not in accordance with the Indian regulation, all of them are located in the proximity of the nearby airbase (<12 km) and two of the sites are located around a densely populated area (<100m). Currently all the 5 dumpsites are degrading nearby environmental quality, especially IIT Kharagpur dumpsite which is a much greater threat due to frequent dumping and open burning of the hazardous waste. This work shows that it is possible to use Google Earth in conjunction with ground-based information to rapidly evaluate changes in land use/ land cover and quantify areas covered by waste dumping sites. The methodology used in this study can be extended to cover an entire city or even several cities within a specific time period. Cleanliness drives and other programs initiated by the government can be monitored and quantified using these tools.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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