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Research Article

Waste as A Medium for Agriculture – An Example of Sustainable Waste Management: A Case Study of Titagarh Municipal Dump Site, West Bengal

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Abstract

Urbanization is considered as a core event which accelerate the generation and accumulation of waste materials in a large scale. This waste can be managed by different ways; garbage farming is most environment friendly among them. The aim of the current work is to uncover the present waste management system of Titagarh municipality, waste characterization and valuate this waste management system. As such, review of several official documents from the municipality, waste sample collection and subsequent testing in laboratory, a few interviews were undertaken to approach the objectives. Approximately 60–65-ton waste is being deposited in this dumping ground every day, which are the main source of bio-fertilizer of 70.08 acre of land. By using this organic manure, the chemical properties of the agricultural field are so good that three crops can be cultivated in a year. Therefore, the gross economic value of this landfill site, taking into account the financial value of garbage farming and other sources, is approximately 1.6 million Indian rupees.

Keywords: Solid waste; Garbage farming; Waste characterization; Economic valuation

Introduction

Humans are the ultimate result of biological evolution. From the moment of creation, man has tried to create his own environment, which we call the cultural environment (Scarr and McCartney, 1983). It is needless to say, people have created this environment by sacrificing the nature (Jaiswal, 2018). Over the last four decades, human beings have tripled the consumption of the earth's natural resources, said a recent report from the United Nations Environment Programme (UNEP, 2015).

The world's exponentially growing population generates vast amounts of waste that must be disposed of in a way that is environmental-friendly. Many conventional waste management techniques are no longer sufficient to deal with rising waste production (Aruna et al., 2018). Land filling and incineration are two common methods of dealing with bio-waste (Liu et al., 2017), but all have harmful environmental consequences, such as the use of productive land and the emission of hazardous gases (Ayilara et al., 2020). However, application of non-hazardous wastes to land is an environmentally and economically sound waste management alternative. When it is done with reasonable care, plants benefitted from the return of nutrients and organic matter; soil physical properties are improved; and waste are turned into resources (Khan et al., 2018). Therefore, to meet the need of environmental protection, significant research has been spent in enhancing the quality and efficacy of waste management systems (Smith, 1996). As such, Biotechnology has enabled the development of faster and more effective waste management systems (Ghormade et al., 2011). Moreover, regulations and sustainable management activities are also required to protect soil and water from inappropriate waste materials, and standards are required to ensure environmental protection (Bai et al., 2010).

The impacts of new waste management technologies and the increasing use of recycling and composting will require assessment and monitoring. Although, the structural components of cells, cellulose, and hemicellulose, make bio-waste very susceptible for bio-product development (Mishra and Mohanty, 2018; Ayilara et al., 2020) and needs extra care. Bio-waste is an incentive for biotechnology to help sustain environmental stainability through a variety of bio-conversion technologies (Chan et al., 2017). However, shifting from the conventional definition of "waste treatment" to a culture of "waste utilization" necessitates facing several barriers (Okonko et al., 2009; Herczeg et al., 2018). Environmental concerns and the scarcity of fossil fuels have shifted public attention to the use of sustainable, environmental- friendly energy. In order to lessen the rivalry between fuels and food production, researchers are concentrating their exertions to the utilization of wastes and by-products as raw materials (Nuss et al., 2012). Urbanization is considered as a core event which accelerate the generation and accumulation of waste materials in a large scale. So, the concerned about the waste management is now becoming a major issue of every urban authority. Many researchers have shown the use of kitchen waste, field-based waste, animal waste, sewage water into the agriculture (Alvarez et al.,2000). Many families have used these wastes to grow their kitchen garden. Household food wastes are being produced in great quantities and their handling can be a challenge.

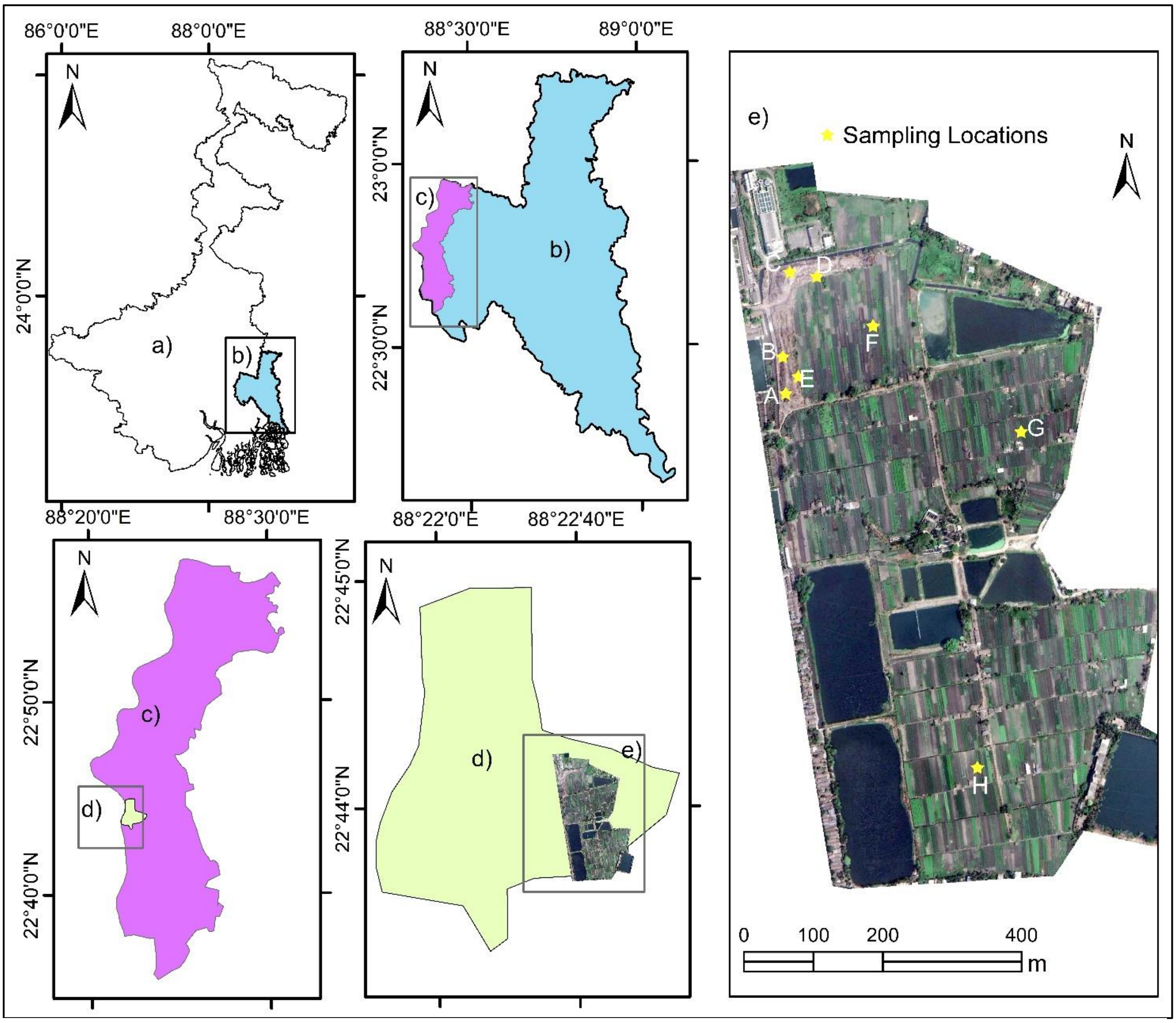

Fig. 1. Location of the study area. In e) the yellow stars denote the sampling sites. *Source*: c) Google Earth image (DoA:12.04.2021)

Moreover, their disposal can cause severe environmental issues (for example emission of greenhouse gasses). On the other hand, they contain significant amounts of sugars (both soluble and insoluble) and they can also be used as raw material (Lin et al., 2013). The method now includes a distinct liquefaction/saccharification stage (Braden, 2018), which reduced the viscosity of the high solid content substrate quickly, allowing the fermenting microorganism to combine easier. using non-hazardous wastes as processing inputs improves the environment by eliminating recycling costs, reducing manufacturing costs, and conserving virgin resources (Schulz and Roheld, 1997). Although, the energy supply and waste management are among the most significant challenges in human spacecraft. In the recent time, great attempts have recently been made to manage solid waste, recycle grey water and urine, clean the environment, remove CO2, generate and save energy, and make better use of components and products (Baykal, 2019).

Garbage farming is one of the most scientific ways of economic activity where we can produce food by utilizing non-profitable waste material. Organic waste component also helps to maintain the agronomic productivity, increase the bio-chemical efficiency of soil which acted as a beneficial fertilizer replacement (Hait and Tare, 2012).

The development of agricultural production system with the use of urban degradable waste is being practiced for a long period in the Titagarh Municipality under Kolkata agglomeration zone. Municipalities have used degradable waste material in the agriculture sector, which is near the dumping ground, where they are the nodal authority that controls or regulates the distribution and segregation of waste to manage quality concerns. Separation at source is the best way to use the waste material effectively in different recycling activities. However, in most of the cases, cent percent source segregation not been achieved (WBPCB, 2019). In that case, the role of waste pickers at the dumping ground is very important. This waste pickers collects different types of non-degradable waste (like plastic, cloth, wood, glass, metal etc.) from the dumping ground and also sell them to the buyers of some recycling units and then the left-over materials are settled there for 15 to 20 days under the newly dumped substances. By this way, the underneath materials are breaking down and their physical and chemical properties improve significantly, and then it is used by agricultural workers in the production field. This method is used for last 40 years in this area under the assistance of municipal authority. This type of farming system has been introduced abroad, although, it has not been developed enormously in developing countries like India. So, if this farming system can be introduced to the people, it will be possible to manage and minimize the municipal solid waste in both developing and under-developed countries with a minimum effort (Sharma et al., 2019).

This paper is, therefore, basically structured to convey the current condition of municipal solid waste generation, their management strategy, characterization of decomposed and partially decomposed waste materials, waste-based agriculture production system, and their economic valuation in respect to sustainable development.

Materials and Methods

Study area

Titagarh is a municipal town under Barrackpore subdivision of North 24 parganas district in West Bengal, situated between 22°43'21.98"N to 22°44'57.03"N and 88°21'42.43"E to 88°23'8.25"E, having a total population of 1.17 lakh (Census of India, 2011), covering a total area of 3.24 km^2. It is close to Kolkata and covered by Kolkata Metropolitan Development Authority (KMDA). Daily, roughly 60-65 tons of waste was dumped in this municipality's dumping ground, which is in Ward-23 on the eastern side of the Barrackpore-Sealdah Train Corridor (Figure. 1). The total area of this dumping ground is about 18025.3 m^2, with an average height of around 7 m and an estimated dumped waste volume of 44558.28 ton.

A farming system has been developed along the side of this dumping ground with the help of degradable waste and wastewater. This traditional sustainable farming in this region is about 50 years old (since 1970s). Here, garbage farming is practiced on a total of 90.7 acres of land separated into 140 plots. It delivers fresh vegetables, purifies sewage water, and creates employment opportunities to the local community. This kind of multipurpose land use scheme is extremely rare in Kolkata's outskirts, where it has enlisted around 600 farmers.

Much of the time, the land is leased to the farmers for 2 to 10 years, and they employ labor to work on it. This type of land use is conservative and protective by nature, since human-caused waste is used to produce food, and recycling bio-degradable waste is one of the system's basic principles.

Sampling design and preprocessing for physio-chemical analysis

Physical and chemical analysis is necessary to know the nature of the initial state of the garbage and the organic soil generated from it. In that case, a total of eight garbage and organic soil samples were randomly collected (Figure. 1) with the help of hand operated grab sampler from the dumping ground and the adjacent agricultural field and reported by GPS (Garmin eTrex 10) for future reference purposes during October 2020. After sampling, various nitrogenous shells, and undesirable items such as glass, tree roots and barks, pebbles, etc. were discarded by hand-picking at the site. During the shipment to the laboratory, the samples were stored in a heat resistant icebox. The samples were then dried in the laboratory at a temperature of 80°C for 24 hours in an electrical hot air oven, and then the large lumps holding the samples were broken down by hand and shook to well analyzed by a 45-phi sized mechanical sieve. A total of eleven physio-chemical characters have been considered viz. temperature, bulk density, moisture content, pH, Electrical Conductivity (EC), total alkalinity, Nitrogen, Phosphorus, potassium, organic matter, and sodium.

Estimation of physio-chemical properties of garbage and garbage-based soil

Initial garbage and organic soil temperature were recorded specifically in situ using a soil thermometer. Side by side pH and EC were also measured onsite using electrical pH and EC meter. The rest measurements were sampled and processed in the laboratory.

To know the bulk density, a metallic cube (15cm×15cm) was used through the formula

$$\rho = \frac{w2-w1}{v} \quad (1)$$

Where, ρ is the bulk density of the sample, $w2$ is the weight of unfilled cube in gm, $w1$ is the weight of cube with sample in gm, and v is the cube volume.

In the case of moisture measurement, about 150 gm of samples were collected and brought to the laboratory. The samples were transferred into petri dices and initial weight were measured and then placed in a hot air oven for 8 hours at 80°C. The formula for obtaining the moisture content is as follows:

$$MC = \frac{(w1-w2)}{w2} \times 100 \quad (2)$$

Where, MC is the moisture content in percentage, $w1$ is the initial weight of the sample, and $w2$ is the final weight of the dried sample.

The essential nutrients of the soil viz. nitrogen (N), Phosphorus (P), Potassium (K) present in the sample has been measured using Kjeldahl method, Colorimetric method, and Flame photometric method respectively. Besides, the Sodium content was also measured through the Flame photometric method. On the other hand, the modified Walkely and Black method was applied to find out the Organic matter content. Total alkalinity has also been checked using titration method using the HCL.

Economic valuation

The correct value of garbage is calculated using the total financial approach, which describes the use value and non-use value of solid waste. However, determination of non-use value of any system is very difficult. Therefore, a descriptive cross-section study was used in this evaluation to determine the economic use value of the garbage at Titagarh dumping site. A total of 35 direct users out of 52 who used the dumping site were selected as sample population, and an open and close-ended questionnaire survey was performed during period August 2020 – October 2020 to gather data on their direct gain from the dump site.

This dump site is used for two main economic activities, including waste farming, and compost fertilizer extraction using a mechanical hub. Current prices of all these good and services are available via a questionnaire but were further checked by a consumer survey during fieldwork to determine the maximum price that consumers are prepared to pay. Thus, after collection of data through site investigation and questionnaires on goods and their quantities and prices, the Market Price Method (MPM), which is measured by multiplying the quantity of goods produced by the price at which goods are sold on the market, was used to evaluate the value of the goods identified.

Result and Discussion

Present scenario of garbage collection and management

Effective waste management is now becoming a major issue to all the municipalities of West Bengal. Therefore, a sound strategic plan for the effective management of waste is necessary. As a part of Kolkata urban agglomeration, Titagarh Municipality is also experiencing a high growth rate in waste generation as stated in Table 1. Therefore, this municipality has enhanced their waste management sector by two different mechanisms–

a. Proper segregation of waste at source especially for households has been run from 2015. As such, the local governing body has provided two different color bins to all the families (green bin: bio-degradable waste/wet waste; and blue bin: non-degradable waste/dry waste). The deposited waste materials have been collected by municipality workers at every day or alternative day morning. Although, Municipality have achieved 83% efficiency in this respect, since local vegetable markets, hotels, domestic animal husbandry, authorities are not able to impose any kind of mechanisms to segregate the waste properly. Also, wastes that used to throw in the street bins without considering their properties cannot be segregated. Accordingly, at a broad classification, municipality has provided doorstep waste collection services in 6 wards, whereas remaining 17 wards depends on street side bins or from local dump yards. However, house-hold waste management in terms of proper segregation differs in different income groups, stated in Table 2. Segregated non-degradable waste materials are directly sent to some selected recycling units and degradable waste materials are sent to the dumping ground. As such, about 2–3 trucks waste materials are being transferred to the nearby dumping ground.
b. In the dumping ground, some unsegregated waste materials (Table 3) which are collected from un-organized sources are being segregated by the rag-pickers. About 20 to 30 rag-pickers are working there to collect the different non-degradable products, like glass, plastic bottles, plastic, rubber, metals, electric parts etc. They used to sell these products to the different recycling units. The whole process of waste management in the studied area, therefore, is described in figure. 2.

Table 1. Present scenario of population growth and waste generation in Titagarh municipality.

Year	Population	Growth Rate	Waste Generation (MSW/day/Mton)	Growth Rate
2001	124,213	+ 8.9%	64	+10.2%
2011	116,541	-6.2%	60	-6.25%
2021	118,785	+1.93%	72	+20%

Table 2. Income wise Household Waste Management System

Family Income (Monthly)	Used separate bin to segregate the waste materials	Dumped personally at street bins	Dumped at local site
Higher Income group (≥ 50,000)	81%	13.5%	6.5%
Middle Income Group (25,000 – 49,999)	74.5%	10.5%	15%
Lower income group (< 25000)	39%	32.5%	28.5%

Table 3. Composition of Waste Materials. *

Component	G	P	R	M	PB	EM	OW
Share	3.2%	17.6%	1.2%	4.8%	12.2%	4%	57%

** G= Glass; P= Plastic; R= Rubber; M= Metals; PB= Paper or Board; EM= Electronic Materials; OW= Organic Waste*

Estimation of physio-chemical properties of garbage and garbage-based soil

This paper also states the physical and chemical properties of initially decomposed garbage (Surface of the dumpsite), garbage-induced highly fertile organic manures (Bottom of the garbage heap), and garbage-based agricultural lands where entirely decomposed garbage are used as manures (Figure. 3). Result shows that the bulk density of the initial decomposed garbage varies from 0.14 g/m^3 to 0.21 g/m^3, while it ranges from 0.39 g/m^3 to 0.68 g/m^3 in samples obtained from the bottom of the dumping area, since the density of any substrate increases a little due to the pressure, decomposition, and increased cohesion character of substances. The pH values of all the checked samples, on the other hand, do

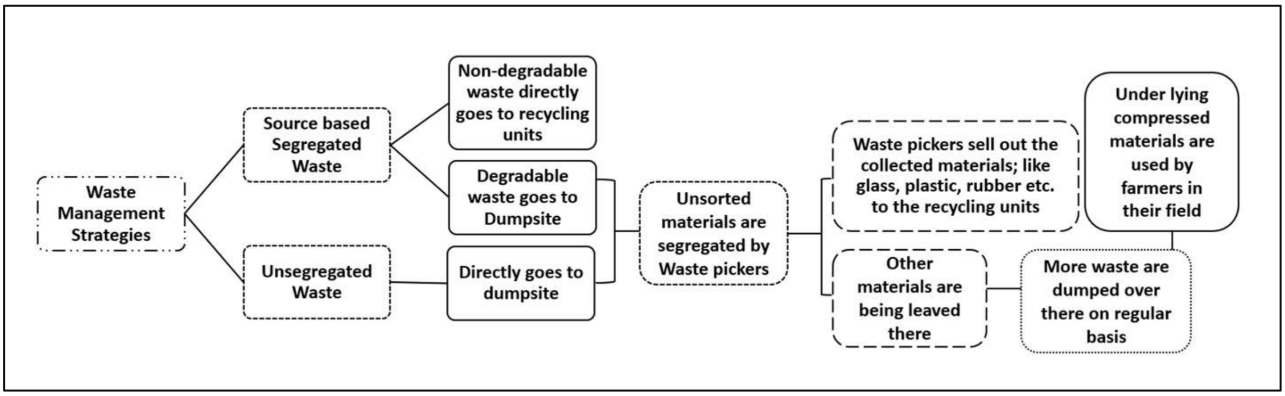

Fig. 2. Overview methodology of waste management in Titagarh municipality

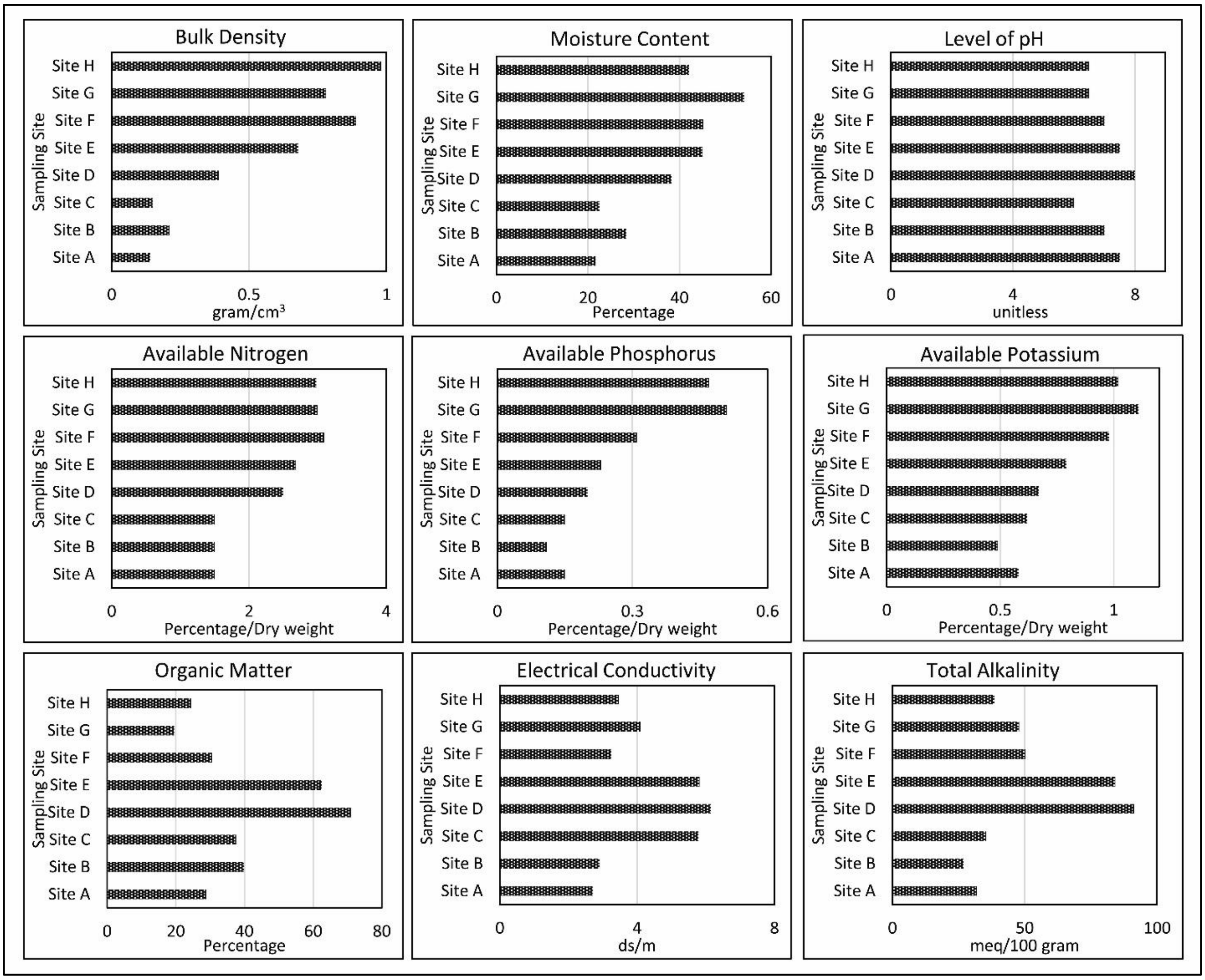

Fig. 3. Physical and chemical characterization of partially decomposed waste (site A, B, and C), fully decomposed waste (site D and E), and wasted based agricultural lands (site F, G and H). Position of sites are mentioned in Figure. 1

not show a strong acidic or alkaline character except the slightly acidic, since farmers used nearby canal water to irrigate, which is always prone to mixed with the generated very acidic leachate (Umar et al., 2010) from this dump site. However, government has not taken any initiative to solve this leachate problem. The NPK content of this agricultural field is optimum due to the use of more organic manure rather than chemical fertilizers. It is to mention that there is a big difference in NPK content between initial garbage and decomposed garbage materials as the increased temperature toward the interior of agricultural fields where some samples were tested the garbage heap speeds up the rate of decomposition, nutrient cycling process and nutrient fixation (Rajaie and Tavakoly, 2016). Accordingly, all the parameters are graphically represented in Figure. 3.

Status of agricultural practice in the garbage field

Decreasing productive content in the soil has turned out as a major concern of food production system in all over the world. Rapid production by using chemical substances and non-diversity in crop production gradually turned the productive field into marginal field. Therefore, to support the increasing demand of food, use of degradable waste substances in the agricultural field can be considered as a sustainable way to manage the waste problem by transforming large volume of degradable solid waste into organic manure substrata (Sharma et al., 2017).

Fig. 4. Different scenario of Titagarh dump site, (a) existing dumpsite (b)–(C) agricultural practices using the dumping materials, (d)–(e) application of decomposed organic material on the agricultural lands, (f) waste-pickers who used to segregate the mixed materials.

Titagarh municipality has been effectively run this system 70.08 acre of land out of 90 acre of total dump site for the last 50 years (Figure. 4). The municipality used to dump both the segregated and unsegregated solid waste on selected portions in-between this total area. When the waste in the lower level became disintegrate, cultivators used that material in their field as manure. They spread this material on their land and leave it for an-other 7 to 10 days and water the land every day. After then, they mixed up that material with underlined soil and started the process of plantation. Moreover, in addition to the garbage, the wastewater is also used for the food production since this is the only source of water to this farming system along with rainwater. As such, about 84.51 acres of land gets sewage water via canal system out of total landfill area, and the remaining use the irrigation water from the local ponds. Our observation reveals that there are about 140 plots area in this region with different sizes, ranging from less than 120 m^2 to more than 700 m^2. In this agricultural system, therefore, most of land practices double crop production throughout the year since the use of organic waste-based manure can maintain nutrient level in optimum condition. Not only that, about 31.82% of total agricultural land is experiencing triple cropping in a single plot. Although, intensity of triple and multi crop plot is high than the double crop land, indicating the high favorable condition of land for intensified crop production for the whole year. As such, 19 crops are grown here in the rotation basis to sustain the whole productive system (Figure. 5). Fertilizer requirement in this site, is therefore, inversely related with the availability of the garbage. According to the farmers, to maintain the optimum production in a triple crop land, about 20 trucks of garbage is required for one year, if any external fertilizer is not applied.

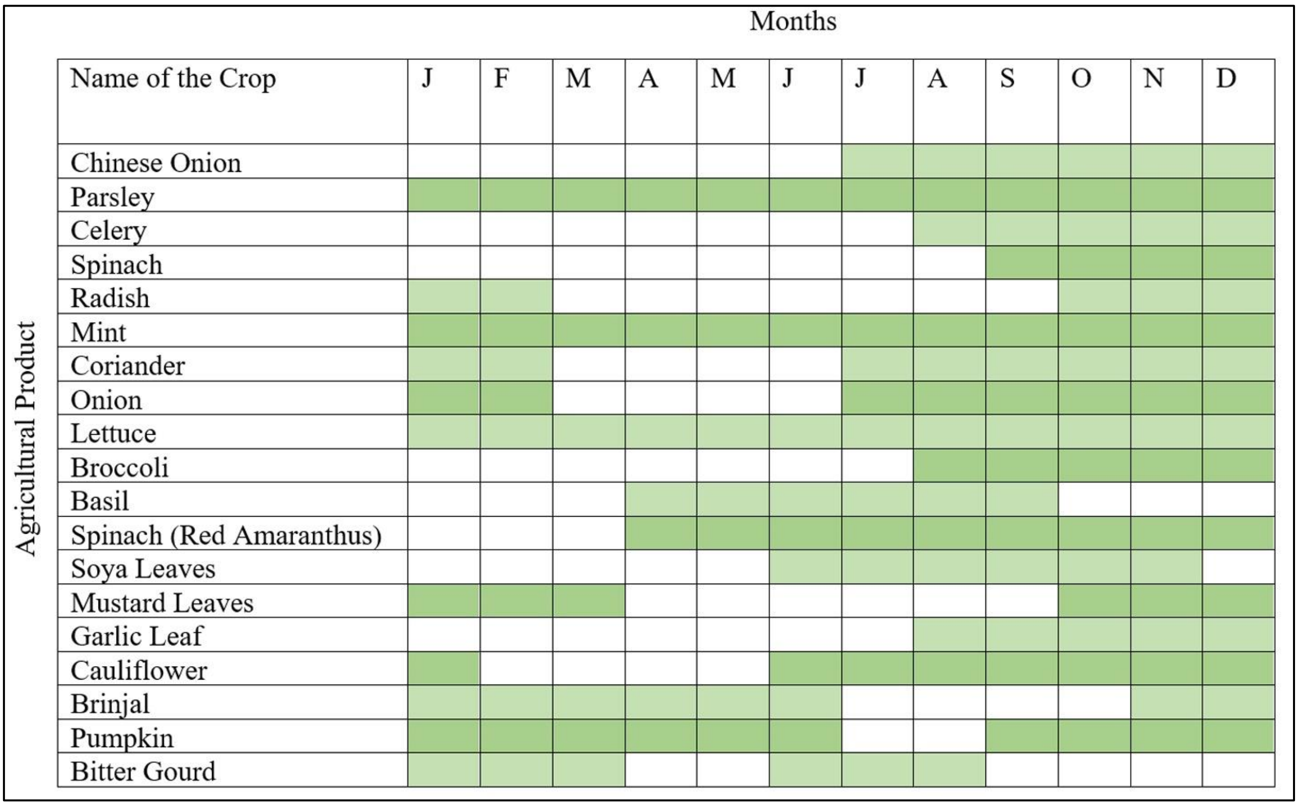

Fig. 5. Crop calendar of the study area, showing different crops and their growing period.

Economic valuation

The economic use value of each good and services, extracted from the Titagarh municipal dump site, is shown in Table 4. Result shows that, the decomposed dumping materials of this landfill area, which have been turned into organic manure, have the highest economic benefit from their use in the adjacent agricultural fields. In that case, the replacement value created by the use of these manure instead of chemical fertilizers has been calculated, which is about ₹ 1.16 million. Furthermore, waste pickers separate recyclable dumping materials such as plastic goods, broken glass, furniture, footwear, and other items from this site and transfer them to local recycle shops.

Consequently, this dumping ground earns about ₹ 450000 lakh a year as a Gross Financial Value (GFV) from this work also. Therefore, the total economic value of this landfill site considering the financial value of both abovementioned sources, is about 1600000 Indian rupees.

Conclusion

This paper has focused on the physical and chemical properties of waste materials, as well as how waste materials can be used as a platform for agriculture, potentially encouraging waste management in other parts of the world. Sustainable waste management is one of the main is-sues of administrative bodies these days, and Titagarh municipality is addressing it in an environmentally sustainable and economically beneficial manner. In that case, authorities collect garbage from each home, with the concept of "segregation at root" in mind, so that biodegradable and non-biodegradable wastes can be used for organic manure and recycling, respectively. However, this work has not yet been 100% successful. Consequently, about 25 rag-pickers are assisting with the segregation of waste at the landfill site in order to meet the government's goals. Regardless, the local farmers use the decomposed manures created by this dumpsite in their fields. Accordingly, our findings indicate that the NPK value of agricultural fields is nearly similar to the value recommended by the Central Island Agricultural Research Institute (4:2:1), implying that the NPK budget of any agricultural field can be preserved using fully decomposed garbage-based organic manure without applying any chemical compounds. So, it is possible to make a lot of earnings by exporting non-biodegradable waste to recycling companies and turning biodegradable waste into organic manure. However, some farmers complain that they no longer get the manure as in the past, they are forced to resort to chemical fertilizers. This is something that the government and municipal authorities should think about.

Acknowledgements

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Table 4. Economic valuation of Dumping Site.

Waste Segregation (a)	No of Beneficiaries	Continuation of participation	Percentage of sold	Per capita Income (₹)	Total Income	
	25	Everyday	100	50.00	450,000.00	
Waste as a Manure instead of conventional Fertilizers (b)	Calculation of Replacement Value					
	Commonly Used Fertilizers	Where waste is available and used	Where waste is not available	Amount of Savings in quantity	Unit Price of savings	Total Profit
	Urea (CH_4N_2O)	150 kg	300 kg	150 kg	Rs. 22	3300.00
	NPK (10:26:26)	200 kg	500 kg	300 kg	Rs. 25	7500.00
	Phosphate (PO_4^{3-})	0 kg	30 kg	30 kg	Rs. 25	750.00
	Potassium (K)	0 kg	6 kg	6 kg	Rs. 40	240.00
	Calcium Nitrate ($Ca(NO_3)_2$)	10 kg	30 kg	20 kg	Rs. 48	960.00
	Neem Cake	0 kg	50 kg	50 kg	Rs. 42	2100.00
	Mustard cake	0 kg	60 kg	60 kg	Rs. 28	1680.00
Total Value= (a + b) = (450,000.00 + 1,165,034.00) = 1,615034.00 (₹)						

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