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RESEARCH ARTICLE

SUSTAINABLE PLANTATION FOR RECLAMATION OF MUNICIPAL SOLID WASTE DISPOSAL SITE: A CASE STUDY

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ABSTRACT

Performance of selected trees on municipal dumpsite at Mumbai has been studied for 30 months and results indicate that the tree survival rate was found to be 50% to 85 % respectively. Amongst the selected plant species, Rain Tree, Gulmohar, Australian Acacia and Neem were observed to be the fastest growing trees. Study shows how a dumpsite could be transformed from a highly unacceptable zone to ecological and environmentally sustainable. Study also attempts to evaluate the trees suitable for urban environment for dumpsite based on their carbon sequestration potential and conforming Sustainable Development Goals

KEYWORDS

Dumpsite, unacceptable, ecological.

1. INTRODUCTION

Population increases with rapid urbanization, growing economy, and the growth found in the living standard of developing countries have resulted increase in the rate, amount, and quality of municipal solid waste generation (Minghua et al., 2009, Gerdes and Gunsilius, 2010). As per the Central Pollution Control Board (CPCB) of India, the per capita waste generation has increased at an exponential rate of 0.26 kg/day to 0.85 kg/day (CPCB India, 2018). Solid Waste Management (SWM) is one of the basic and important essential services provided by municipal establishments in the country to keep the urban and rural centers clean. However, almost all municipal authorities disposed the generated solid waste at a dumpyard within or outside the city unsystematically that create health hazards (DTE, 2017). It is estimated that approximately 80% to 90% of the municipal waste is disposed-off in landfills/low-lying areas without proper management practices and sometimes open burning take place that leads to air, water, and soil pollution that may contribute health impacts near the residing population (Ahluwalia and Patel, 2018).

In India cities, most of the municipal waste is landfilled sometimes also mixed with construction waste. The disposal methods followed are not in keeping with modern practices of sanitary landfilling (Mull, 2005; Adewole, 2009). The wastes are largely dumped without considering the environmental, social and health impacts. These dumpsites are mostly located at low-lying areas, sometimes prone to floods. During the rainy season, the possibility of surface and groundwater contamination increases due to flooding of these dumpsites (Chistensen et al., 1998; Ikem et al., 2002). The daily cover techniques with soil are poor, which can leads to vector problems. The birds foraging on dumpsites are also known to cause substantial problems for aircraft operating within urban cities. The bird strikes have resulted in a great deal of loss to the aviation sector (Jain, 1994).

High moisture and organic content in Indian wastes, anaerobic digestion is another suitable option (Ray et al., 2013). However, there are no complete technologies that are available for processing heterogeneous materials generated from solid wastes in urban cities. The existing technologies and methods are applicable to homogeneous materials only. The costs of processing and separation of mixed heterogeneous wastes are likely to be high and complex method (GAIA, 2017). An economical way to avoid such problems is to segregate MSW wastes at the point of the generation before it is mixed with other wastes. Kitchen and vegetable market wastes are largely suitable for this purpose. These wastes can be collected and treated at source if space available. The resulting biogas can be used for captive energy use such as street lighting and cooking etc. Few Biogas systems are currently available to treat wastes of fruit and vegetable source (Nagori et al., 1988). Although, currently unfeasible and uneconomical as a large-scale selection, Biogas systems can effectively handle localized and specific wastes and contribute to environment-friendly disposal of wastes. Alternative modes like composting and other scientific approaches are rarely used and applied. Inadequate collection/resources, besides being a health hazard and leads to environment and social issues.

The waste dumped not only affects the aesthetic and social quality of the surrounding areas but also poses severe health hazards by acting as the breeding ground for mosquitoes, fillies, rodents, known to be carrier for diseases such as malaria, cholera, plague, etc (WHO, 2019). Another impact of dumping grounds is the air pollution that cause due to release of toxic gases arising from various chemicals and biochemical reactions especially due to the burning of waste during the summer (high temperature) or mixed with industrial waste (WHO, 2000; Ettala et al., 1996). Therefore, the self-sustainability and regenerative capacities of dumpsite should be developed for the proper functioning of the ecosystems through re-vegetation or by the ecological means. Generally, areas for the tree plantations will increase in response to the future demand for wood necessities, for the restoration of degraded lands, thus, leads to benefits for carbon sequestration and its potential role in climate

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change mitigation and adaptation (Bauhus et al., 2009; Lamb, 2010, 2014; Alston and Andersson, 2011).

Successful biological reclamation largely depends on the selection of sustainable and appropriate tree species for re-vegetation. The selection of tree species for re-vegetation of overburden dumps (closure sites) depends on important parameters such as climate, physical and chemical properties of dump materials, topography, viability, and surrounding available vegetation. Thus, screening of plants is important before largescale reclamation. Therefore, field studies have been carried out on the Cinchooli dumpsite in Mumbai (India) to assess the growth performance of selected plant species and their benefits. The major goals of the sustainable plantation are to reduce erosion, stabilize dumpsite and develop process for suitable landuse patterns. In this paper, an attempt has been made to assess the growth performance of plant species on overburden solid waste dumpsite located in Malad.

2. Benefits and Role of Tree Plantation For UN Sustainable Development Goals and Carbon Sequestration

The plant species contributes numerous benefits not only to urban cities but also to rural zone and meet 15 outof 17 abide with UN Sustainable Development Goals (SDGs). Based on the literature cited, plant species can help to meet many goals as described in the UN SDGs as listed in Table 1. Another important consideration is that not all plant species are equal. Some benefits may be more noticeable in specifically correlated species (Chen et al., 2017; Xiao and McPherson, 2016). Benefits differ within a plant species as well based on the morphological characters and climatic conditions. For example, a small internal road in a city, having a plant does not give the same benefits as a large plant does. Matured and old plant species can give the greatest benefits as compared to immature/growing plant (Lindenmayer and Laurance, 2017).

Table 1: Role of Plant Species Conforming UN Sustainable Development Goals

Compliance with Sustainable Development Goals	Advantage of plant species	Benefits of plants highlights with references
• Goal 3: Good health and well-being, • Goal 11: Sustainable cities and communities, • Goal 16: Peace, justice, and strong institutions.	• Plant species helps to improve physical and mental health for humans being. • Plant also helps and support community ties and reduced rates on crime.	• Decrease in pollution (McDonald et al., 2016; Nowak et al., 2006; Nowak, et al., 2014; Nowak et al., 2018) • Improvement in physical and mental capability (Berman et al., 2012, Li et al., 2018, Ulrich, 1984) • Support to improve community ties (Garrity, 2004; Morley et al., 2017) • Increase in physical activities (Kuo and Sullivan, 2001; Kuo, 2003; Bell et al. 2008). • Reduction in violence and aggressiveness issues of health related (Kondo, 2017, Mooney and Nicell, 1992) • Reduction in crime rate and misconduct behaviour, (Donovan and Prestemon, 2012; Kuo, 1998)
• Goal 4: Quality education	• Plants increase a student's ability and memory to do well in school and higher education.	• Progress in student performance and concentration levels (Berman et al., 2008; Kuo et al., 2018; Browning et al., 2018) • Minimize stress levels for students (Kuo et al., 2018) • Reduce attention symptoms deficit disorder (ADD)/ attention deficit hyperactivity disorder (ADHD) in students (Rief, 2012; Faber et al., 2001) • Increase in attention and activeness with discipline manner (Kuo et al., 2018; Li and Sullivan, 2016; Matsuoka, 2010; Faber, 2002)
• Goal 1: No poverty • Goal 2: Zero hunger • Goal 7: Affordable and clean energy • Goal 8: Decent work and economic growth • Goal 10: Reduced inequalities • Goal 12: Responsible consumption and production	• Plants are helps for economy and they help to reduce energy consumption bills. • They deliver several resources and sources of foods, such as fruits, leafy vegetables, spices, etc to a community.	• High return-on-investment if properly managed and applied (McPherson et al., 2010) • Support and maintain the tourist visits for attractions (Nesbitt et al., 2017) • Increase in land and home prices and rental rates also for farms lands (Nesbitt et al., 2017) • Reduces energy use and its bills (Nowak and Greenfield, 2018; Pandit and Laband, 2010) • Promote food sustainability (to avoid damaging or wasting natural resources (Dawson et al., 2013; Clark and Nicholas, 2013) • Supply and demand for various resources (e.g. home building and firewood) (Turner, 2015; Kaoma and Shackleton, 2015; Poe et al., 2013; Sherrill, 2003; Favez et al., 2009)
• Goal 3: Good health and well-being • Goal 13: Climate action • Goal 15: Life on land	• Plants help to cool the environment, making vegetation a simple and effective way to reduce Urban Heat Islands and store and sequester carbon. • They play important role for habitat in natural environment.	• Benefits in Urban Heat Island Effect (Patz et al., 2005; Ward et al., 2016; EPA, 2008; McDonald et al., 2016) • Help to store and sequester carbon and its management (Nowak and Crane 2002; Schwab, 2009) • Provide and rise in critical habitat in natural environment (Tyrvainen et al., 2005; Schwab, 2009; Fahey et al., 2015)
• Goal 3: Good health and well-being • Goal 6: Clean water and sanitation • Goal 9: Industry, innovation and infrastructure • Goal 11: Sustainable cities and communities • Goal 12: Responsible consumption and production • Goal 14: Life below water • Goal 15: Life on land	• Plants are important role in the forms of infrastructure, particularly for storm water managing and so on.	• Help to manage storm water (Berland et al., 2017; Braden and Johnston, 2004; Livesley et al., 2016) • Reduce and control the pollution levels (French et al., 2006; Schwab, 2009) • Safeguard life and protection under water and on land also (Hauer and Johnson, 2003)

Carbon sequestration is gaining importance in carbon credit and trading after the Kyoto Protocol (Ravindranath et al, 1997; Chavan et al, 2010). CDM projects have estimated the quantity of carbon in various systems and their dynamics linked with it. With these valuations, several approaches and interpretations have developed quantifying and reducing the carbon footprint (IPCC, 2006). Clearly, carbon sequestration can be accomplished through various methods, but trees are the largest terrestrial sink of carbon dioxide. Therefore, the tree plantation is granted one of the most resourceful and largest terrestrial carbon sequestration technique (Moulton and Richards, 1990). Out of the five most significant terrestrial carbon sequestration method (above-ground biomass, below-ground biomass, litter, wood debris, and soil organic carbon), the above and below-ground biomass are the top two in the references (IPCC, 2006).

The tree biomass matures when plants intake the carbon dioxide from the atmosphere in association with sunlight and adapt them into starch in their tissues (Dilling, 2006). Research revealed that the carbon content in plant tissues is almost half their biomass (Khurana, 2012; Pandya et al., 2013). Accordingly, with their growth factor, trees perform sequestration of CO2 from the surrounding and accumulation in their tissues as in the form of carbohydrates and thus, endure till the death of the trees (Gorte, 2009). The rate of carbon sequestration is more during the early stages of tree growth, when trees try to produce more and more amount of food to grow. After the tree death and decay, the carbon is again returned to the surrounding atmosphere to finalise the carbon cycle. Trees also influence air temperature in the urban cities, besides adding aesthetic value (Nowak, 1993). Thus, quantification of carbon in the form of biomass can also help in understanding the existing state of the carbon concentration in the surrounding atmosphere and forecasting the future status related to its local and global climatic settings (Heath et al., 2011).

The truth is that carbon store in the plant biomass for a maximum period and the amount of carbon removal from the surrounding atmosphere increases with each consecutive year making the trees to be the best available terrestrial scrubber for carbon dioxide. Some studies recommended that the girth at breast height (GBH) and height of a plant plays an important role in carbon sequestration potential. Further, some trees are good players of carbon sequestration in polluted areas than their counterparts in the non-polluted area. Several statements and formulations claim the assessment of plant biomass with respect to carbon sequestration potential for recognizing the species that are suitable to use for green belts with respect to industrial zones (Zheng et al., 2004). The present study also attempts to evaluate the plant species suitable for the urban environment for dumpsite based on their carbon sequestration potential.

3. Method and Materials

One acre (43560 Sq. ft) of the land area of Cinchooli dumpyard site was used for the study purpose on an experimental basis. The emphasis was to establish the plant used for remediation of urban solid waste with a view to improving the aesthetic value of the site, bring back ecological diversity up to some extent, reducing air pollution and providing an integrated method of urban dumpsite. The main goal of the assessment was to recover/ improve the aesthetic environment of the overburdened dumpsite using local plant species. The methodology used in the assessment is based on the preparation of dumpsite, selection of plant species, and plantation technique and their assessment.

3.1 Site Preparation

Site preparation is the important aspect and implementing plan was prepared. The height of placed old solid waste at Cincholi dumpsite was around 10-12 meters over the entire plot, which was not properly leveled. Proper leveling of the selected area for the plantation purpose was carried out with the help of a JCB machine. The semi-decomposed part of solid waste is normally good media for plantations. Therefore, the upper mound of solid waste was pushed towards the lower side of the dump. The slope of the site was adjusted so that it does not allow the leachate to stagnate and during the rainy season excess water drains away from the study site. Channeling was properly done so that the natural flow of water was not disturbed during the monsoon to avoid water logging.

The site was cleaned manually and leveled with the help of manpower and JCB. After leveling the area, plastics and paper/rags, etc. were removed manually from the surface as much as possible. After removing the non-biodegradable materials seen, the site was leveled again. The study site was properly fenced to protect the area from human encroachment such as rag pickers and animals such as dogs, pigs, and cows. Water for plant irrigation was made available with the help of water tankers. A separate water tank of a capacity of around ten thousand liters was placed for water storage for plantation purpose at study site. The critical season for maintaining irrigation at the dumpsite is from mid-February to July end when the peak summer temperature is encountered. Deployment of guards and watchmen at the site were placed for preventing rag pickers and animals from encroaching at the study site.

3.2 Selection of Tree Species for Dumpsite

Many factors contribute to the growth of a healthy urban forest for plant selection. One of the most important considerations in selecting the right plant species for the right location by examining the environmental and site conditions, and growth characteristics. It is important to select strong and sturdy tree species that are locally available and, able to survive in poor degraded soils with concrete compaction also. These species should also be resistant to diseases and should be fast-growing also. The species should be wind firm, deep-rooted, forming a dense canopy and providing optimum penetrability. The plant species have been selected on the basis of their potential to evapotranspirate, the degradative enzymes they produce, growth rate and the depth of their root zone and their ability to bioaccumulate the contaminants at the site.

The species selected based on the overall visual survey in the Mumbai area are listed in Table 1. A mixed type of vegetation is eco-friendly and the probability of spread of diseases and death of trees becomes minimal. During plantation, the height of the plants ranged from 3 to 4 feets. The plants were obtained from local available nurseries. Plants were watered during the non-rainy day and the survivals rate of these was monitored. Insecticides were sprayed periodically on the plants as dumpsite host wide-ranging pests and insects. The height and diameter of the trees/plant during each month were recorded. The status of plant health was also recorded. A total of 200 trees were planted of 22 species as listed in Table 2.

Table 2: Tree Species selected for the Dumpsite

Sr.No.	Botanical Names	Local Names	English Name
1.	*Acacia auriculiformis*	Australian Acacia	Earleaf Acacia
2.	*Albizia lebbeck*	Siris	Kokko, Black Siris
3.	*Alstonia scholaris*	Satvin	Dita Bark
4.	*Azadirachta indica*	Nim, Limba	Margosa Tree
5.	*Bauhinia racemosa*	Apta	Burmese Silk Orchid
6.	*Cassia fistula*	Amaltas, Bahava	Indian Laburnum
7.	*Cassia siamea*	Kassod	Siamese Cassia
8.	*Ceiba pentandra*	Pandhari	White silk cotton tree
9.	*Delonix regia*	Gulmohar	Falamboyant Flame Tree
10.	*Dillenia indica*	Karambel	Indian Dillenia
11.	*Erythrina indica*	Pangara	Indian coral tree
12.	*Lagerstroemia speciosa*	Jaral, Taman	Queen Crape Myrtle
13.	*Leucana leucocephala*	Safed Babool	Subabul
14.	*Madhuca indica*	Mahua	Butter tree
15.	*Peltophorum pterocarpum*	Copper Pod	Rusty Shield Bearer
16.	*Pongamia pinnata*	Karanj	Indian Beech
17.	*Psidium guajava*	Peru	Common gauva
18.	*Putranjiva roxburghii*	Putranjiva	Wild Olive
19.	*Samanea saman*	Rain Tree	Rain Tree
20.	*Spathodea companulata*	Rutoora	American Tulip Tree
21.	*Syzigium cumini*	Jambhoon	Black plum
22.	*Tectona grandis*	Sagwan	Teakwood

3.3 Plantation Technique

Considering the status of the dumpsite, the pits were required to be of larger size than the conventional size. Pits of one cubic meter capacity were made with a spacing of 1 meter. The pits were filled with farmyard manure and garden soil in 1:1 proportion. When the pits were done, the excavated material was again segregated and the non-biodegradable materials such as plastic, glass, etc. were removed. The remaining inert material was spread on the surface of the remaining covered area.

4. Results and Discussion

Monthly height, diameter, health of the tree species data was recorded. Observations of individual tree in terms of height, diameter and survival rate were recorded for the period of two years and are depicted in Figure 1.

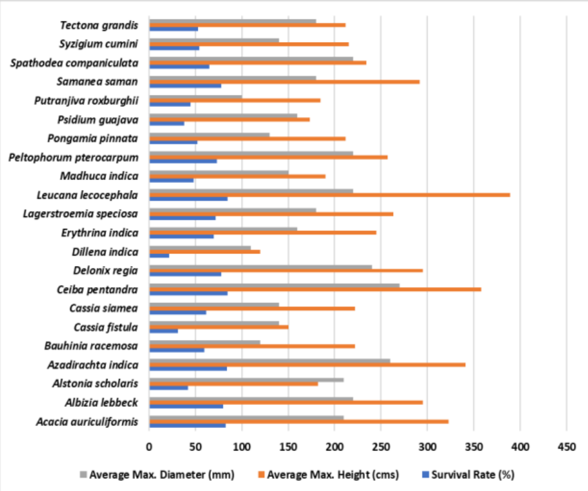

Figure 1: Performance of Plant Species Planted on Dumping Site

Based on the performance data, it is observed that *Delonix regia* (Gulmohar), *Samanea Saman* (Rain Tree), *Leucana lencocephala* (Subabul), *Ceiba pentandra* (Cotton Tree) and *Acacia auriculiformis* (Australian Acacia) are fast growing trees and have been comparatively good conditions in dumpsite (Kaur et al., 2018; Aluri et al., 2005; Dupel et al., 2013). On the other hand, *Erythrina indica* (Pangara), *Bauhunia racemosa* (Apta), *Sapthodium companiculata* (Rutoora), *Cassia fistula*, *Syzigium cumini* (Jambhoon) *Putranijira* sps and *Lagerstroemia speciosa* (Jaral) showed slow growth. *Cassia fistula* (Bahava). *Dillenia indica* (Karambel) and *Jacaranda minosifolia* (Jacarand) showed very slow growth and even high rate of mortality (MPCB, 2020). Teak plants were found to be fast growing tree but required more water. *Pongamia pinnata* (Karanj) showed slow growth, but its canopy cover considerably good.

5. Conclusion

Highly developed urban region hardly accords any space for development of greenery as seen in Greater Mumbai. Absence of breathing lungs for the city is often felt and numerous appeals have been made repeatedly for growing of trees along roads, around houses and in open areas. The study showed how a site could be transformed in 2 to 2.5 years from a highly unacceptable zone to aesthetically pleasing and environmentally sustainable. The sites used for municipal solid waste landfill can be easily transformed into ecological acceptable site with many beneficial impacts. Such exercise carried out suggests that if an integrated manner municipal solid waste landfill sites are managed, if can lead to many beneficial aspects such as:

- Stabilization of the urban landfill or dumpsite site becomes rapid leading to volume reduction in sustainable manner
- Improvement of nearby air quality due to absorption of methane and others gaseous pollutants generated from dumpsite
- Less contribution of infections and odorous dust in the atmosphere
- Transformation of the municipal solid waste landfill site from highly avoidable places to ecological acceptable locations
- Good working atmosphere for workers or ragpickers engaged in the area
- Highly acceptability of the site by the residents nearby

Based on the extensive experiments carried out over a period about 30 months, it can be concluded that with proper conditions with good monitoring practices, a number of plant species can be grown on dumpsites in similar manner. The plants, which showed good and luxuriant growth, are as follows:

- *Azadirachta indica* (Neem)
- *Acacia auriculiformis* (Australian Acacia)
- *Ceiba pentandra* (Cotton Tree)
- *Delonix regia* (Gulmohr)
- *Samanea saman* (Rain Tree)
- *Leucana leucocephala* (Subabul)
- *Albizia lebbeck* (Sirish)

These plant species have been suggested to improve the aesthetics, ecological, and environmental balance of the surrounding area of the urban dumpsite. Further, tree-like neem (*Azadirachta indica*) and Cotton tree (*Ceiba pentendra*) attract birds by their flowers and fruits and provide very suitable shelters to a large number of birds. The development of these areas will give an impetus to avifaunal activity. The presence of these will further enhance the ecological enhancement of the site, the greenery will also provide the much-needed oxygen, which is usually lacking in cities. In the future, places like these can be used for educational and children's parks.

Carbon sequestration is gaining its importance in carbon credit and trading after the Kyoto Protocol. Identification of many CDM (Clean Development Mechanism) projects has offered special flexibility and relevance in the carbon reduction and has helped improve the national economy. These projects have estimated the quantity of carbon in various systems and their dynamics associated with it. With these estimations, several strategies and formulations have evolved quantifying and reducing the carbon footprint Carbon sequestration is gaining its importance in carbon credit and trading after the Kyoto Protocol. Identification of many CDM (Clean Development Mechanism) projects has offered special flexibility and relevance in the carbon reduction and has helped improve the national economy.

The total municipal solid waste generated in Maharashtra state, from 396 ULBs (Urban Local Bodies) and 7 CB (Cantonment Boards) is 22633 MT/d out of which 7577 MT/d (33.5%) waste is directly disposed to landfill/ dumpsite. If we implement such a study at all 27 dumpsites in Municipal corporations only, approximately 300 plant species at the periphery of each dumpsite, then the big transformation of ecology will happen. The organic carbon sequestrated in species like *Azadirachta indica* is 2.39 tonnes/year, *Acacia auriculiformis* (1.37 tonnes/year), *Delonix regia* (2.21 tonnes/year), *Samanea saman* (4.34 tonnes/year), *Leucana leucocephala* (1.60 tonnes/year) and *Albizia lebbeck* (2.50 tonnes/year) as per study. In general, trees with thick GBH are good CO_2 sequesters. Further, the rate of carbon sequestration was more during the early stages of plant development as evidenced by GBH. These trees can be integrated schematically in the urban areas for removing carbon dioxide from the atmosphere. This would also put a significant impact on the carbon credit and the trading concept of a nation.

Based on the study carried out, the following recommendations emerge:

- Dumping sites which are operating at present within the state, such sustainable practice can be implemented for integrated operation and management of the sites,
- It can be implemented on operating sites with a view to reducing air pollution, stabilization, and high aesthetic values,
- The concept should be replicated as the study showed a good management practice leads to the high survival rate of plants,
- Plantation plays an important role and benefits to support and meet 15 of the 17 internationally supported UN Sustainable Development Goals,
- Carbon credit and trading can be applicable if implemented in all solid waste dumpsites within Maharashtra State, with proper guidelines.

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