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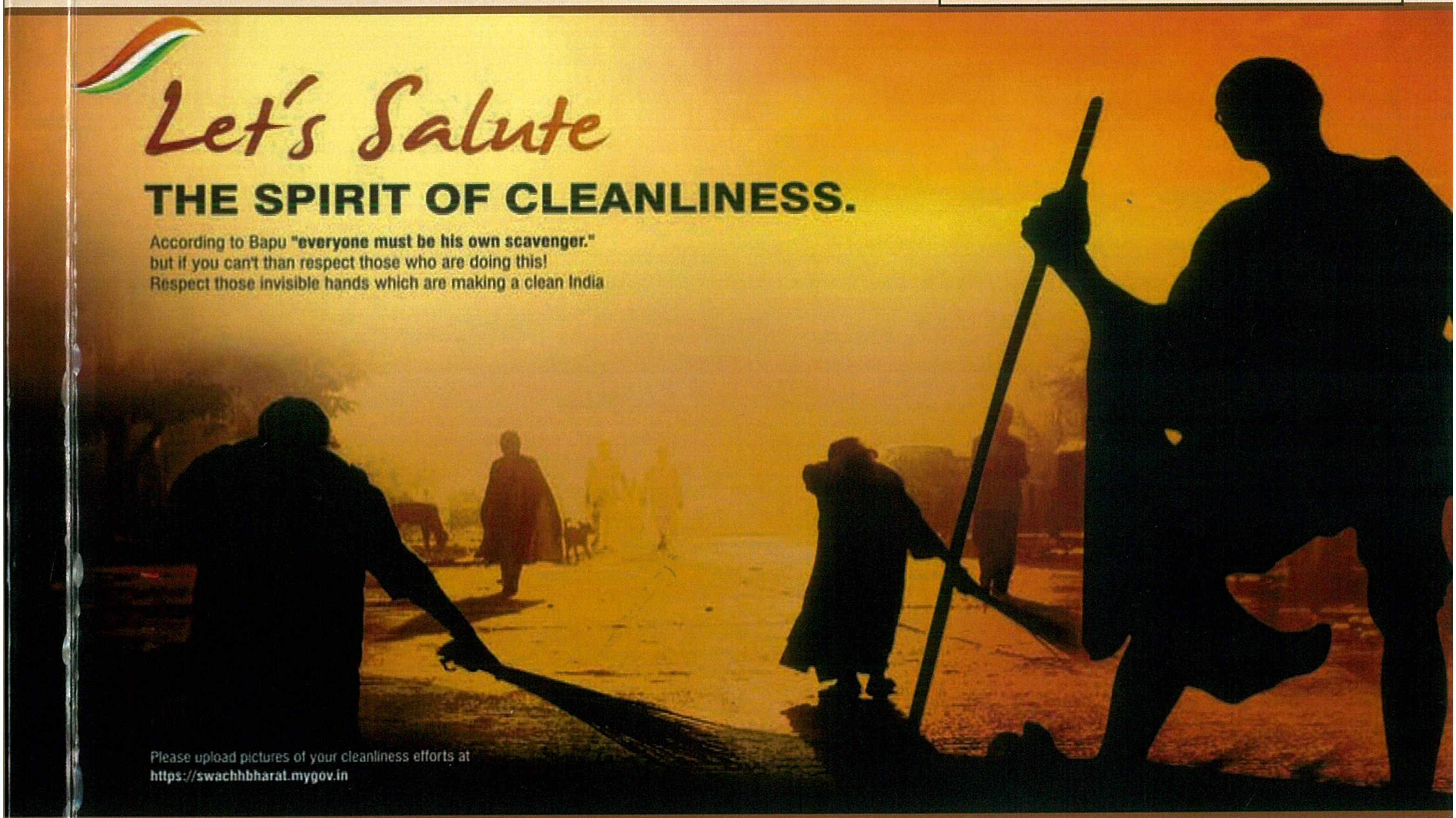

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DECENTRALIZED ENERGY POTENTIAL OF BANGALORE SOLID WASTE*

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INTRODUCTION

With an estimated population of 7.8 million, Bangalore is among the five large cities of India. It covers an area of 800 km^2 (BBMP, 2010). The city's waste is characterized by a high content of fermentable components (72%) where domestic and eatery sectors contribute over 75% of total wastes (Chanakya and Sharatchandra, 2005). Presently, Bangalore employs a quasi-centralized collection system leading to landfilling of collected wastes. Various forms of informal waste recycling processes function in the cities of Karnataka and their value addition has been described earlier (Van Beukering, 1994).

USW GENERATION

Bangalore city generates around 3000 to 4000 tpd of USW– the daily collection is estimated at 3600 tpd (Chanakya*etal.*, 2009). It comprises of wastes generated from residences, markets, hotels and restaurants, commercial premises, slums, street sweepings and parks. Residence contributes 55% of total of wastes and is highest among all sources (TIDE, 2000). Waste generated from hotels and eateries form about 20%, fruit and vegetable markets contribute about another 15%, trade and commerce about 6% and from street sweeping and parks form about 3%. The slum areas contribute only 1% of total USW, since in Bangalore slum population and area is low in comparison to other towns and cities.

USW COMPOSITION OF SEVEN CITIES OF KARNATAKA

The waste composition of Bangalore comprising: 72% fermentables, 11.6% paper and cardboard, 1.01% cloth, rubber, PVC and leather, 1.43% glass, 6.23% polythene, 0.23% metals and 6.53% of dust and sweeping (TIDE, 2000) is given in Table 1. In one study we have conducted in year 2010 in seven important cities (Tumkur, Puttur, Mandya, Hassan, Davangere, Chikkaballapur, Belgaum and Nanjangud) of Karnataka. We have selected 15 houses randomly at the ward level and it has been monitored for three continuous days. Waste composition of seven cities show 82% fermentable, 11% paper and cardboard, 8% plastic and 1% of metal. City-wise waste composition is given in Table 2. Among all cities, Chikkaballapur and Hassan have high percentage of fermentables. Percentage of paper and cardboard and plastic are highest in Tumkur.

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Table 1
Physical composition of USW in Bangalore

Waste type	Composition (% by weight)						
	Domestic	Markets	Hotels/ eatery	Trade and commercial	Slums	Park /street sweepings	Avg. All sources
Fermentable	71.50	90	76	15.6	29.9	90	72
Paper and cardboard	8.39	3	17	56.4	2.49	2	11.6
Cloth, rubber, PVC, leather	1.39		0.33	3.95	0.54	0	1.01
Glass	2.29		0.23	0.65	8.43	0	1.43
Polythene/ plastics	6.94	7	2	16.6	1.72	3	6.23
Metals	0.29		0.26	0.38	0.23	0	0.23
Dust and sweeping	8.06		4	8.17	56.7	5	6.53

Source: TIDE, 2000

Table 2
Physical composition of domestic USW in seven cities of Karnataka

Waste type	Composition (% by weight; source – unpublished CST report)								
	Tumkur	Puttur	Mandya	Hassan	Davan-gere	Chikka-ballapur	Belga um	Nanj angud	Aver age
Fermentable	84.37	78.95	77.94	91.37	81.43	92	83.83	69	82.36
Paper and cardboard	35.35	5.62	13.02	4.99	6.24	4	7.33	8.50	10.63
Leather and Cloth / textiles	0	0.90	0	0	1	0	1.31	0	0.40
Glass	3.77	4.11	0	0	2	0.38	2.34	1	1.70
Polythene /plastics	18.64	7.37	9.04	3.64	9	2	5.50	7.13	7.79
Metals	0	2.78	0	0	2	0.64	0.41	0.02	0.73
Inert and dust	0	0	0	0	3.14	0	0.71	14.97	2.35
Recyclables	0	0.27	0	0	0	0	0.17	0	0.05

When we compare physical waste composition of small cities with metropolitan cities, it is clear that both have high percentage of fermentables. Fermentables incorporate food waste, garden waste, vegetable waste and fruit waste. The elemental composition of these constituents of fermentable is derived based on elemental mass percentages on dry basis as listed in Table 3. The average elemental composition of the organic fraction of the USW is presented as $C_5H_{8.5}O_4N_{0.2}$ (Bizukojc and Ledakowicz, 2003). Degradation of fermentables in the open environment emitsGreen House Gases (GHG) like methane (CH_4) and nitrous oxide (N_2O) along with leachate containing Carbon and Nitrogen impacts the underlying lithological strata. High percentage of wet and fermentable waste, require daily removal and treatment. In a decentralized system, wastes gathered from primary collection by handcarts may be subject to immediate treatment by aerobic composting or biomethanation within the locality or ward. In wardwise waste treatment with biomethanation, as the wastes gradually becomes enriched with decomposable material; it also becomes an increasing source of energy. From 1988 to 2000 there is reasonable change in waste composition: fermentable, paper and plastic has increased by 7%, 3% and 0.2%, respectively.

Table 3
Elemental composition of these constituents of fermentable

Waste type	Mass percentages on a dry basis				Elemental composition, based on molecular weight of elements
	C	H	O	N	
Food waste	44.83	6.38	32.13	2.83	$C_{18}H_{32}O_{10}N$
Yard or garden waste	42.35	5.33	31.89	1.62	$C_{29}H_{44}O_{17}N$
Vegetable peals	49.06	6.62	37.55	1.68	$C_{34}H_{55}O_{20}N$
Fruit peals	47.96	5.68	41.67	1.11	$C_{51}H_{72}O_{33}N$

Source: Rhyner *et al.*, 1995; Tillman, 1991 as referenced in Meraz *et. al.*, 2003

ENERGY AND RESOURCE RECOVERY CLOSE TO SOURCE OF GENERATION

Case 1: Potential recovery with aerobic composting

Ideal USW processing requires near perfect source segregation of USW at the point of generation – namely households. This requires a great social/attitudinal change and is likely to be slow in happening. A medium term measure is possible: segregation immediately outside houses - during collection immediately thereafter. There are many dispersed attempts to do so - the RMV II experience in Bangalore is cited here. This field data collected for 21 days in a ward 'RMV extension stage II' near IISc campus. BBMP is managing the MSW at this locality. The ward councillor was interested in improving waste management system. A 60 days project was started by NGO 'Exnora Green Cross' in this locality. The system planned included primary collection with gradually increasing level of source segregation (into organic and inorganic waste), storage and disposal of different types of solid waste in an environmentally friendly manner. Trained waste collectors were appointed for door-to-door collection and for waste segregation. Every day on an average around 2.6 kg fermentable wastes were collected from each of the families. The fermentables (including food waste and garden wastes) were composted on raised platforms to ensure better aeration and lower smell. With the progress of time number of composting beds was increased. This increased number of compost beds increased the associated problems like smell and flies. After 21 days this project was stopped by ward councillor fearing election reversely. However, meticulous data was collected as to the types and quantities of recyclables that were brought to this site. Based on this project information, economic costs are calculated for decentralized waste management with compost plant as given in Table 4. Under the existing scenario, we show that with compost as the main product and in an enterprise mode and under conditions existing in Bangalore the cost recovery period would be in the range of 4 years (Table 4, assuming 100% recycling). This is however identified and may not be achieved easily. The potential capability to recycle may then be between 50-80% of recyclables in the wastes. Under this optimum scenario it is clear that capital recovery may not be possible at all.

Table 4
Decentralized Waste Management with compost plant

Decentralized Waste Management with compost		
Categories	**Rs/year**	**Optimum Scenario**
Capital Investment	206500.00	
Cap costs Rs/yr@10.00%	20650.00	
Depreciation	38225.00	
Maintenance	30975.00	
Operation cost (Rs/yr)	493946.00	
Total expenditure per year	**583796.00**	583796.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Compost sale	229950.00	183960.00
Total net income per year	**584469.11**	**467575.29**
Surplus of income over expenditure	673.11	-116220.71
Capital Recovery Period	306.8	

Case 2: Potential recovery with biomethanation process

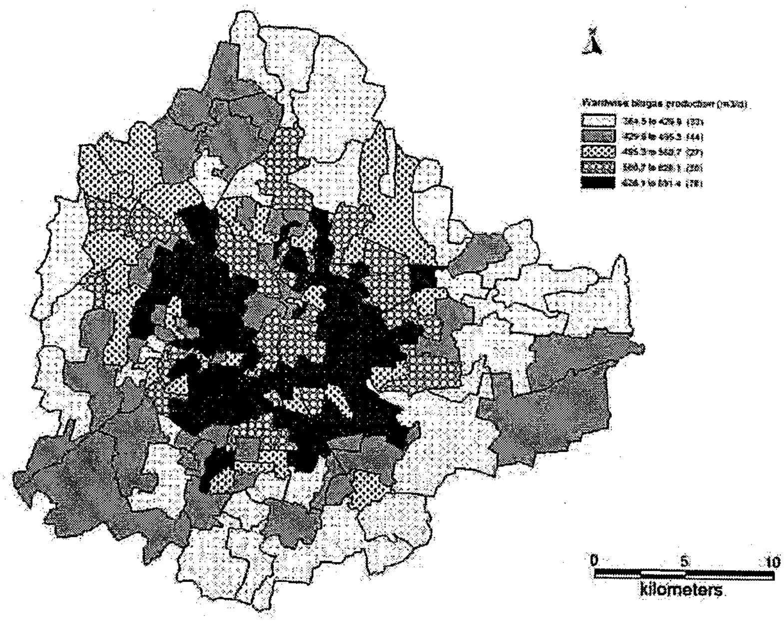
The decentralized processing and recycling system based on compost and 100% recovery shows a small promise of profitability in an enterprise mode assuming this is carried out on a soft lease basis (no land costs). It is obvious that it is economic only at 100% recovery and this may be difficult to achieve. There is clearly a need for another source of revenue generation to make the enterprise profitable. Thus instead of aerobic composting the organic fraction (leading to only one saleable product – compost), it is proposed to convert it to biogas and compost (two saleable products) by installing a biomethanation plant of the CST design – similar to the one successfully operated for over 5 years in Siraguppa (Rahman*etal*, 2009). We examine the conversion of the fermentable to biogas and expect that sale of biogas locally would offset the financial deficit projected above.In this scenario, the extent of recyclables recovered and earnings accrued does not change from the previous scenario, the income from collection fees also remains the same. The various costs and returns on investment are worked out for a decentralized waste management with a biomethanation plant as given in Table 5. In this scenario, it is clear that under ideal situation of 100% recovery of recyclables, collection costs and biogas and compost revenues, the payback period is only 2 years. Even under an 80% recovery situation, the viability is good.

Table 5
Decentralized Waste Management with biogas plant

Decentralized optimum Waste Management with biogas plant		
Categories	**Rs/year**	**Optimum Scenario**
Capital Investment	586500.00	
Cap costs Rs/yr@10.00%	58650.00	
Depreciation	35425.00	
Maintenance	39975.00	
Operation cost	493946.00	
Total expenditure per year	**627996.00**	627996.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Income from biogas	325215	260172.00
Compost sale	229950.00	183960.00
Total net income per year	**909684.11**	**727747.29**
Surplus of income over expenditure	**281688.11**	**99751.29**
Capital Recovery Period (years)	2.1	5.9

DECENTRALIZED ENERGY POTENTIAL OF BANGALORE USW-USING BIOMETHANATION

An estimated quantity of USW of 3600tpd of Bangalore can generate 0.1944 million m^3 of biogas/d, which can be used as source of energy LPG substitute. The city has 198 wards with variations in area and population spread. A decentralized wardwise biogas generation is planned using average per capita waste generation (BBMP, 2010) and population statistics of Bangalore. Since a major fraction of wastes come from residential area, so to capture this waste, we considered the per capita waste generation of the city. Assuming that all the city wastes collected from houses reaches to treatment sites, we have calculated the biogas from all the wards of Bangalore. Usually, one ton of fermentable generates 75 m^3 of biogas in plug flow model of biogas plant designed in CST. We also assumed that in each of ward has collection and segregation facility and treated in plug flow biogas plants. A wardwise biogas production is given in Fig 1. Total quantity of biogas varies from 364 to 691m^3/d. In central part of city where population is dense it shows high production of biogas in comparison to periphery of the city, where population is less dense. Waste generated from commercial places other than restaurants could then be sort for recycling – while that remaining as unfit for recycling would be small and sent to landfills. In this way compared to the nearly 100% landfilling practiced today, the net USW to be landfilled in this scenario will be <10% currently generated.



CONCLUSION

The costs of USW collection, transport, processing and disposal have gradually become high. There is a need to treat the waste nearer to source to offset there high costs. Biomethanation process provides a clean energy source (biogas) along with compost for treatment of fermentables. This approach requires setting up decentralized anaerobic digestion (biomethanation) within residential. Decentralized systems run so far (other than biogas plants) have had aesthetic (smell and insect) and economic problems and have always been short lived. Biomethanation plants also provide many sources of revenue from sale of biogas, compost and by-products. In this paper we also present wardwise distribution of biogas potential in the city. It also gives an idea where waste generation is more. It is therefore important that this concept be tried with at various municipalities so that we could become zero-waste cities of the future and we will look at wastes as a source of energy.

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