International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Forecasting of Municipal Solid Waste Generation for Small-Scale Towns and Surrounding Villages Located in the State of Gujarat, India

Arti Pamnani†* and Srinivasarao Meka‡

†Department of Civil Engineering, Faculty of Technology, Dharmsinh Desai University, Nadiad, Gujarat; India
‡Department of Chemical Engineering, Faculty of Technology, Dharmsinh Desai University, Nadiad, Gujarat; India

Accepted 30 Jan 2015, Available online 05 Feb2015, **Vol.5, No.1 (Feb 2015)**

Abstract

Municipal solid waste management (MSWM) is major concern of planners, researchers and administrators all over the world. Major portion of population lives in small-scale towns and villages surrounding them in developing countries. Due attention is not paid for MSWM of small-scale towns and their surrounding villages. Forecasting of MSW quantity is necessary for development of sustainable MSWM strategy. We propose Artificial Neural Network based mathematical models for forecasting of MSW generated from small-scale towns and their surrounding villages located in the state of Gujarat, India. Population, geographical location and socio economic condition are taken as independent variables. The efficacies of proposed models are satisfactorily demonstrated with the help of validation data set.

Keywords: *Forecasting, Municipal solid waste, Population, Small-scale towns*

1. Introduction

Municipal solid waste management has attracted considerable attention of the researchers worldwide. Forecasting of solid waste quantity is vital for efficient planning and sustainable design of MSWM [Pappu *et al*, 2007]. Most of the research work available in the open literature is related to forecasting of MSW in developed countries and major cities. Due attention is not paid to the forecasting of MSW generated from small-scale towns and surrounding villages of developing countries. Significant portion (72%) of population in developing countries (India) resides in these semi urban centers and their surrounding villages. Forecasting of MSW in semi urban areas is necessary for comprehensive planning of sustainable MSWM system in these areas.

Forecasting of MSW is a challenging task as solid waste generation is a very complex function of various independent variables. MSW generation depends upon population, socio economic condition of the residents and geographic location of the study area. Increase in population increases solid waste generation. World Bank observer Beede and Bloom have reported that one percent increase in population is associated with a 1.04 percent increase in solid waste generation, and one percent increase in per capita income is associated with a 0.34 percent increase in total solid waste generation [D. N. Beede and D. E. Bloom, 1995]. Population forecasting is necessary for forecasting of MSW generation in the area under consideration. Worldwide population growth rate is 1.14% with estimated doubling time of 61Yrs [S. Kumar, 2009]. To predict population growth four empirical models a) arithmetic projection b) geometric projection c) incremental increase method and d) decreasing rate of growth are widely used. No single model is universally applicable for population forecasting. Selection of model depends on the area under consideration and available population data. To predict MSW generation, population data along with other independent variables are used.

Beigl *et al.*, (2008) presented a comprehensive review on various models used for MSW forecasting. Group comparison, single regression and multi regression models found to be suitable for population forecasting of various settlements with population in the range of 1000 to 20000. Group of 3-40 such settlements considered for modeling purpose. Vatsal Patel, 2014 has worked for forecasting of solid waste generation for 86 medium scale-towns of a developing country. He has considered 86 towns as his study area and used ANN model for MSW forecasting. In the present study, we propose to extend the work for 83 small-scale towns and 1000 villages surrounding them. We propose to use ANN model for both short term and long term forecasting of MSW generation from small-scale towns and their surrounding villages located in a developing country, India.

*Corresponding author: **Arti Pamnani** is a Ph.D student and **Srinivasarao Meka** is working as Professor

2. Identification of Study Area

India is second highly populated country in the world. Around 72% of total population of India resides in towns and villages surrounding them. To prepare sustainable MSWM plan forecasting of MSW generation from each of the source town/village is crucial. Gujarat one of the fastest developing states of India, identified as our study area. The Population of Gujarat according to the census 2011 stands at about 60 million, making it the 10th most populated state in India. Total urban population is 25,745,083 while rural population is 34,694,609 persons in Gujarat state. In Gujarat, 42.60% people live in urban regions while 57.40% people live in the villages. The state makes up about 5% of the country's population a figure that was about 4.8% during the last census in 2001. The state is spread over an area of about 190000 sq. km. making it the seventh largest state in the country in terms of area. The density of population per sq. Km. is about 300 people. The state has a growth rate of about 19 percentages that slightly exceeds the national growth rate of about 17percentage. Since last decade Gujarat has shown rapid industrial growth which lead to urbanization. This results to high rate of MSW generation.

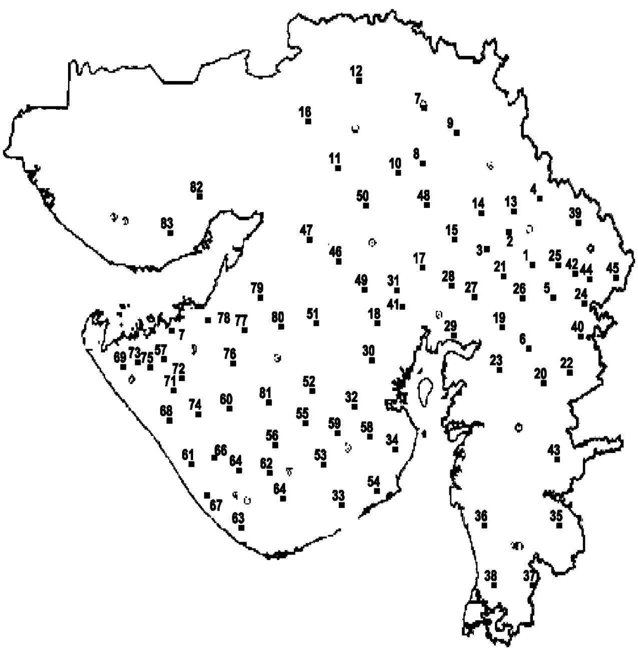

Fig.1 Geographical location of study towns identified for the present study

Gujarat is located at northwestern part of India. The state is located between latitude 20.07 to 24.36 and Longitude 68 to 74.25. The rainfall period is generally for four months from the middle of June to the middle of October. The amount of annual rainfall varies considerably in different parts of the state. The southernmost area receives annual rainfall as high as 200 centimeters. The rainfall in central Gujarat is between 70 and 90 centimeters; and Kachchh and the western part of Saurashtra receive less than 40 centimeters. The maximum temperature in the year occurs in May, when it is as high as 40° C in north Gujarat, Saurashtra, and Kachchh. January is the coldest month of the year, when the temperature varies between 5oC and 30° C.

Municipal Solid Waste (management and handling) Rules 2000 under the provisions of the Environmental Protection Act 1986 make treatment and disposal of MSW mandatory for all municipalities (Urban local bodies). There are 33 administrative districts in the state (as of 2011). Urban local bodies (ULB) are classified as A, B, C, D categories on the basis of population. ULB with population ranging from 50,000 to 1 Lac is considered as Class-B, similarly population ranging from 25000 to 50000 is considered as class-C and towns with population from 15000 to 25000 are classified as class-D towns. Class-B, Class-C and Class-D towns selected for study present. Total 83 class D towns and around small villages with population 1500 or more considered for study purpose. Figure (1) presents geographical location of the study area.

3. Collection of Data

Population data as and MSW generation rate for 49 ULB are collected from census 2011 Government of Indian and urban development department Government of Gujarat respectively. Table (1) shows population of towns, total population of villages surrounding each town. We presented per-capita waste generation rate for each town. Analysis of the data has shown that the rate of MSW generation for towns falling under same municipality is approximately same. We estimate the MSW generation rate from villages surrounding selected towns. Mean value of MSW generation rate obtained was approximately 209 gm/person/day. A typical town Akalav with MSW generation rate equal to mean MSW generation rate selected for further investigation. Solid waste generation from surrounding villages of Akalav is experimentally determined. From the data presented in Table (1) it can be observed that average MSW generation rate for villages is estimated to be 88 g/person/day. Waste generation rate from surrounding villages of the other towns estimated from available data. We assume the deviation from mean values for MSW generation rate of villages is in proportion to the deviation in MSW generation rate for respective nearby town. The estimated MSW generation rate is validated using experimental data obtained from town of Sojitra. We find the deviation is well within the acceptable limits of <8%.

Experimental data for MSW generation obtained at by collecting MSW from community bins. Collected MSW weighted with digital weighing balance and rate of generation was calculated. Experimental data show, that rate of per-capita generation of waste from town is 0.1 – 0.3 Kg/day for study area while that of villages is in the range of 0.07-0.1 Kg/day.

Table 1 Population and per-capita waste generation from small-scale towns and their surrounding villages

District	Study Town	Population as per Censes 2011		Rate of generation of waste gm/day/person	
		Towns	Villages	Towns	Villages
Sabarkantha	Prantij	23596	83698	210	96.5
	Talod	18298	70509	184	84.5
	Antrolivas	11623	42515	184	84.5
	Vadali	20646	71711	247	113.4
	Bayad	17886	81468	211	96.9
	Sathamba	17213	23829	211	96.9
Banaskantha	Tharad	25954	115322	211	96.9
	Dhanera	10773	121316	221	101.5
	Bhabhar	21894	61425	203	93.2
Patan	Chanasma	15932	18838	364	167.1
	Dhinoj	10396	28002	364	167.2
	Harij	20253	45802	216	99.2
Mehsana	Vijapur	11938	33334	111	50.9
	Kukarvada	12602	35786	111	50.9
	Kharod	10708	48196	111	50.9
	Kheralu	21843	42339	145	66.6
Kheda	Mahudha	17722	48534	248	113.9
	Alina	13491	19417	248	113.9
	Kathlal	22071	70904	210	96.4
	Apruji	10503	20041	210	96.4
	Thasra	15805	29549	228	104.7
	Kuni	11388	23610	228	104.7
	Kalsar	10904	52620	228	104.7
	Kheda	25575	31613	86	39.5
	Naika	16232	30213	86	39.5
Anand	Aaklav	19804	47959	210	96.4
	Bamangam	10822	20198	210	96.4
	Sojitra	16056	30368	186	85.4
	Kasor	12029	17257	186	85.4
	Deva	10517	18523	186	85.4
Gandhinagar	Pethapur	23497	26117	208	95.5
Ahmedabad	Barwala	17251	26131	219	100.5
	Khambhada	13995	23740	219	100.5
	Navda	11164	18578	219	100.5
	Bareja	19690	41292	252	115.7
Valsad	Umargam	17855	138988	164	75.3
	Sarigam	19903	23850	150	68.8
Dang	Saputara	12968	14566	210	96.4
Vadodra	Chhota Udaipur	25787	50413	210	96.4
	Savli	18467	35906	200	91.8
	Desar	16396	28412	200	91.8
Porbandar	Ranavav	26018	48548	159	73.0
	Bapodar	21757	40964	159	73.0
	Kutiyana	16851	35444	250	114.8
	Mahiyari	14001	24786	250	114.8
Jamnagar	Kalavada	25314	57569	250	114.8
	Dhrola	25883	48578	210	96.4
	Jamjodhpur	25892	48132	259	118.9
	Sadodar	23116	43516	259	118.9
	Satapar	25964	32645	259	118.9
	Bhanvad	22562	29968	210	96.45
	Bhangol	24257	40396	210	96.45
Rajkot	Bhayavadar	19404	27669	250	114.8
	Upleta	18775	32168	250	114.8
	Maliya	15964	39454	220	101.5
Junaghad	Chorvad	22720	41190	249	114.3
	Malia	16018	35496	249	114.3
	Visavadar	19515	120508	250	114.8
	Sutrapad	26132	32181	210	96.4
	Singasar	14488	36057	210	96.4
	Khambha	13153	24582	210	96.4
	Talala	21060	29812	241	110.6
	Junvariya	11472	28449	241	110.6

	Mandorna	12646	20387	241	110.6
Kutchh	Bhachhau	19532	83057	220	101.0
	Rapar	25407	117529	217	99.6
Surendranagar	Hadvad	12024	30681	201	92.3
	Juna Devaliya	14592	26125	201	92.3
	Dasada	18733	32079	208	95.5
	Zinzuwada	17593	23064	208	95.5
	Patdi	17725	22926	208	95.5
	Chotila	21364	36074	199	91.4
	Thangadh	22351	13286	199	91.4
Amreli	Lathi	23914	34897	172	79.0
	Chalala	16721	20505	178	81.7
	Babra	25270	29889	210	96.4
	Khambhala	24964	42463	210	96.4
	Khijadiya Kord	11109	31659	210	96.4
Panchmahal	Kalol	32084	107489	170	78.0
	Sahera	19175	126446	294	135.0
Dahod	Devgadbaria	21030	75955	132	60.6
	Piplod	10304	76600	132	60.6
Bhavnagar	Vallbhipur	15852	26313	176	80.8
	Nasitpur	12101	26651	176	80.8

As per NERRI report for rate of generation of solid waste for towns with population <= 20000 have generation rate 0.15 – 0.5 kg/cap/day (NERRI, 1999). MSW generation rate in the study area is considerably less than 2kg/cap/day of the advanced counties (Beede and Bloom, 1995, Beukering et.al, 1999). However, experimental data is showing that lesser per-capita MSW generation rate in comparison with national average. To the best of our knowledge MSW generation rate for villages is not reported in the open literature.

4. Identification of independent and dependent variables

Population, socio economic condition and geographical location reported to have strong influence on MSW generation rate. We found correlation coefficient between input variables population, fraction of population belonging to socially backward classes, and geographical location. It is fond population has strong correlation with the MSW generation compared to the other independent variables. Based on the correlation analysis population and social background of the people and geographical location are considered as independent variables. Solid waste generation rate for towns and their surrounding villages considered as dependent variables.

5. Population Projection

Population forecast is one of the major components for prediction of waste generation. Population data for past 50 years from census of India is collected. However, for some of the towns the data is available only for past 20 years. We tested Arithmetic projection, geometric projection and incremental increase method for forecasting of population where data is available at least for past 5 decades. P values obtained from T Test for arithmetic, geometric and incremental increase projection methods ranges between, 0.001-0.008, 0.001-0.005 and 0.0001 – 0.005 respectively. Hence, we decided to use incremental increase method for further study.

6. Proposed ANN based Model for Prediction of MSW Generation

We propose both static and dynamic Artificial Neural Network models to predict MSW generation. We use population, social factors for the given year along with geographical factors: longitude and latitude as inputs to the neural network. Static ANN predicts MSW generation during the same year. We developed two such ANN to predict MSW generation in towns and villages respectively. Two hidden layers are provided with tan-sigmoid transfer functions and pure linear transfer function used for output layer. ANN is trained using Lavenburg - Marquate algorithm using MATLAB software. Estimated results are tested with validation metric, percentage prediction error. Static feed forward ANN model is given in Figure (1). We use static network for case -I and case -II models. We use case-I and Case- II for prediction of msw generation in towns and villages respectively.

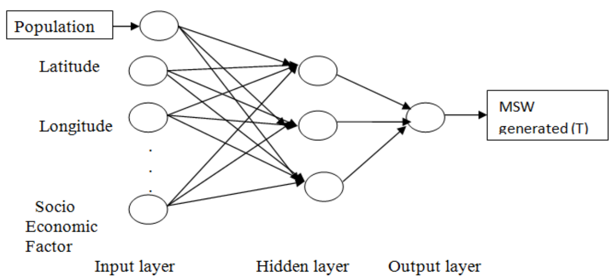

Fig.2 Static feed forward ANN model

Results obtained for Case I and case II are presented in Table results show that these models are able to predict the MSW generation satisfactorily.

Case III and Case IV represent dynamic model for towns and villages respectively with given conditions. In these cases, MSW generation for the next year is predicted given the present year data related to population socio economic and geographical conditions. The ANN model estimated output is recycled as input to ANN for long term predictions. ANN Similar to static network as explained earlier considered for dynamic network except the estimated output is recycled for the future predictions. Population predicted by incremental Increase Model considered as one of the dynamic input. While training the network batch training is adapted by giving training set for present year as input and MSW data for next year as output. The validation results obtained from the dynamic network are presented in Table (1). Analysis of results indicates that the data forecasted by ANN model is giving satisfactory results.

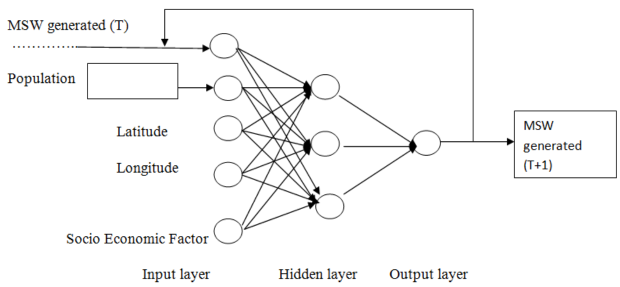

Fig.3 Data forecasted by ANN model

Case V we propose ANN model with MSW generation for both towns and villages as outputs. Inputs to the model are population social and geographical factors along with present years' MSW generation. This model is a combined model for forecasting MSW generation for entire study area. Validation results are showing that the model predictions are satisfactory.

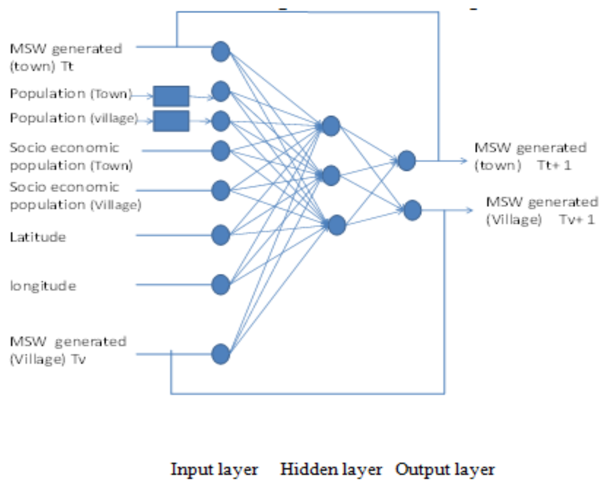

Fig.4 Validation results

Analysis of results presented in Table (2) indicating that the percentage prediction error in most of the cases is less than 2%. Results are quite satisfactory considering considerable variation in the MSW generation rate in the study area. We demonstrate the efficacy ANN model for both static and dynamic prediction of MSW generation in small scale towns and their surrounding villages.

Table 2 Percentage Prediction Error for different forecasting condition

Case	PPE Mean	PPE Max	PPE Min	PPE STD
I	0.44	4.22	-12.74	1.60
II	0.73	7.60	-7.80	1.78
III	0.21	1.43	-3.28	0.34
IV	0.03	8.27	-1.02	0.3256
V	0.22	1.14	-1.29	0.3256
	0.03	9.56	-1.75	0.22

Conclusions

For this study, Rate of generation of MSW for small-scale town is calculated from data collected by experimental town and report of government of Gujarat. Calculation for rate of generation of villages nearby was done accordingly. Results obtain from experiment are validated by existing results. Forecasting for waste generated for study period of 25yrs is done by static and dynamic model of Artificial Neural Network. It can be concluded from the study that ANN modeling method gives near to perfect result for prediction of solid waste for inputs of population, geographical location and socio economic conditions. Results indicated that percentage prediction error for each case is low thus predicted value is close to real value. This study concludes that ANN model can be use for prediction of MSW generation for proper MSWM.

References

Pappu A., Sxena M., Asolekar S. R., (2007), Solid Waste Generation in India and their Recycling Potential in Building Materials, Indian Journal Of Environmental Protection, pp 2311-2321.

Beede D. N. and D. E. Bloom., (1995), World Bank Research Observer, volume 10 no 2, page 113-150

Kumar S., Bhattacharyya J. K., Vaidya A. N., Chakrabarti T., Devotta S., Akolkar A.B., (2009), Assessment of the Status of MSWM in Metro Cities, State Capitals, Class I Cities, and Class II Towns in India: An Insight, Waste Management, Vol. 29, pp 883-895.

Dube R., Vaishali N., Ramana G., (2010), Sustainable MSWM in Indian Cities - Challenges and Opportunities by GTZ, pp 1-8.

Chen H. W., and Ni-Bin Chang, (2000), Prediction Analysis of Solid Waste Generation based on Grey Fuzzy Dynamic Modeling, Resources, Conservation and Recycling, Vol. 29, pp. 1-18.

Karadimas N. V., Alessandra O., (2006), MSW Generation Modelling based on Fuzzy Logic, Proceedings 20th European Conference on Modelling and Simulation, ISBN0-9553018-0-7/ISBN 0-9553018-1-5 (CD), pp 1-6.

Vidanaarachchi C.K., S.T.S. Yuen & S. Pilapitiya, (2006), Municipal Solid Waste Management in the Southern Province of Sri-Lanka Problem, Issues and Challenges. Waste management 26.920-930.

Sharholy M., Kafeel A., Gauhar M., Trivedi R.C., (2007) MSWM in Indian Cities – A Review, Waste Management, Vol. 28, pp 459–467.

ITARSI, (2001), Special Paper on Solid Waste Management – ITARSI, IL&FS-Infrastructure, pp 2-7.

Sastry D.B.S.S.R., (2007), Composition of MSW– Need for Thermal Treatment in Present Indian Context, Earth Engineering Center, Columbia University, pp 2-12.

Beigl, P.G., Wassermann, F., Schneider, and Salhofer, S., (2008), Forecasting MSW Generation in Major European Cities, European Commission's Fifth Frame work Programme (EVK4-CT-2002-00087), pp 1-6.

GoI (2011), Guidelines for Preparation of Detailed Project Reports for Solid Waste Management using 12th Finance Commission Grants, GoI.