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Mining from Landfills as a Remediation Strategy Regarding Open Dumpsites using Artificial Intelligence Hybrid Models

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Due to the subsequent environmental effects of volatility, precise data on waste properties and their seasonal change are essential for sustainable waste management planning. As traditional waste characterization methods are time consuming and costly in most developing countries, it is necessary to approach the problem from a modelling perspective. Objective of this study was to identify the most efficient combinations of network architecture, activation function and formation strategy to reliably estimate the proportion of physical waste streams using meteorological parameters. The city of Gwalior is also affected by this global issue. The goal of this case study was to look at the potential and issues related to solid waste in Gwalior. Extensive investigations on the collection, transportation, treatment, storage, destruction, and disposal of solid waste generated in the city of Gwalior were done. Through interactions with people and website visits, GDS-related data is gathered. This study demonstrates that the city lacks a suitable system to deal with the solid waste generated, resulting in waste being dumped into vacant space, creating a number of issues for the local population as well as the environment. The three regions that make up the city of Gwalior are the city of Gwalior, Morar and Laskhar regions.

Keywords: Gwalior, Solid waste, Waste characterization, Waste streams

Introduction

Rapid economic and population growth has encouraged the massive construction and renovation of residential buildings and infrastructure, leading to exploitation of urban land resources. Excavation, land clearance, road construction and building renovation are some of the activities that generate a lot of solid waste, which leads to environmental problems.[1] In response, rethinking the entire supply chain of production, distribution, and material recovery according to the "cradle to cradle" approach ensures the circulation of building materials within the week fully shut.[2] As a result, increasing resource efficiency through methodical Municipal Solid Waste (MSW) offers a new perspective in line with the Sustainable Development Goals (SDGs) and the concepts of the Circular Economy (CE).

Landfills are used to manage 52.6% of Municipal Solid Waste (MSW) in the United States, 85% in Malaysia, 59.1% in Brazil, 79% in Venezuela, 94.5% in China.[3]

Owning to its financial advantages, the landfill method remains a widely used and recognized alternative for the final disposal of solid waste. Handling, compacting and backfilling waste in appropriate places is considered in landfill operation.[4–8] Landfilling is now easy, can be adjusted at a lower cost than other disposal methods, and is the only way to dispose of all waste. In the global integrated solid waste management system, landfills can still have a big impact even though the amount of solid waste being disposed of has decreased.[9–11] Proper burial is one of the technological options for treating and disposing of solid waste. According to studies that compare different Waste Management (WM) procedures (land filling, composting, incineration, etc.), Open-air or sanitary landfills are common in most countries due to their low costs and it not being high technology based.[12–17]

Initiatives to Mine Landfills over Time

Landfills have a long history of being regarded as the most economical last choice for trash storage. It is now well acknowledged that these behaviours have a number of associated repercussions. In addition to the waste of refined natural resources and resource- and energy-intensive production, the breakdown of organic waste in these mines results in long-term methane emissions that contribute to global warming,

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Despite being the only activity recorded for many years, landfill mining began in Israel in 2013 to provide fertilizer for orchards as indicated in Fig. 1. But in 2015, interest in this strategy grew. Since the abrupt cessation of research into garbage mining in 2015, only groundbreaking innovations have been documented in the scientific literature. This shift in activity can result from a variety of causes, including the global economic crisis or initiatives that reduced the need for landfill space in different parts of the world to improve waste management and recycling.

The Future of Landfills

There are instances when there is more waste than can be recycled, used, or burned. Not all trash can be burned or recycled. For some of them, landfilling is the only choice, and the garbage won't be kept there unless the recycling plant or incinerator is unable to burn it due to upkeep, repair, or malfunction. This implies that certain waste kinds should be disposed of in landfills even though they can be recycled and used again. They serve as a "safety net" in the WM audio system. Landfills should be built with sustainable practises to reduce harm the environment in the future generations. A desired model for sustainable municipal waste management is indicated in Fig. 2.

Fig. 1 — Landfill mining

It's critical to establish a trustworthy model for quantitative forecasting of MSW generation. This model may then be used to improve waste management frameworks and develop waste management infrastructure and handling of garbage.[18,19] Various forecasting procedures include statistical analysis, time series analysis, material flow analysis, and artificial intelligence methods.[18,20] Waste management models have frequently been implemented using artificial intelligence approaches. In this study, a potential method for making decisions was taken into account when designing and developing a technology for trash collection, transportation, and final treatment in urban areas.

In summary, with limited data, ANN models can be used to model the amount of Muncipal Solid Waste. A wide range of additional factors, demographic, including economic, social, technological, geographic, legal, and behavioural considerations, can be taken into account on account of neural network techniques' versatility. Despite the superior performance of independent ANN models, respective training techniques can stall or converge slowly. Optimization algorithms are seen as potential alternatives to traditional training approaches

Unlike many other prediction techniques, ANN does not impose any restrictions on the input variables (like how they should be distributed). Additionally, many studies have shown that ANNs can better model heteroscedasticity i.e. data with high volatility and non-constant variance, given its ability to learn hidden relationships in the data without imposing any fixed relationships in the data. This is something very useful in financial time series forecasting (e.g. stock prices) where data volatility is very high.

The contributions of the study are:

Fig. 2 — Current and desired future model of landfilling

- Take into account how economic, demographic, and societal factors affect the amount of garbage generated.
- Use conventional neural network models to estimate the amount of waste, and then aggregate and analyse their performance using a variety of assessment indicators.
- Better performance metrics for the generated prediction models.

Analytics of Hybrid Models for Municipal Solid Waste

Hybrid systems, which mix many AI methodologies to discover thorough answers to particular issues, are one interesting field of research. In order to overcome specific deficiencies of various techniques, the combined methods cumulate their strengths. For instance, it is possible to alter the fuzzy inference system "FIS," which is incapable of effective learning, in order to reflect domain expertise and manage uncertainty. However, machine learning methods with strong learning capabilities, such as NN, will not tolerate uncertainty or error. As a result, the combination of complementary AI approaches can create powerful intelligent systems capable of handling real-world computing problems.

Aims and Objectives

The major objective of this study is to investigate the incorporation layout of MSW management systems into current AI models. The aim of the study is to develop an AI-bases MSW management solution for municipal engineers to estimate urban MSW output at different design stages. To fulfil the study's overarching goal, the following particular objectives have been identified and targeted.

a) Use combined Artificial Intelligence (AI) models to formalise predictive and reduction methods for the minimum MSW in computer systems.

b) Integrate the IT system for MSW management into the current platform.

c) Conduct research on techniques for formalising MSW management at the design stage.

d) Assess the performance of ANN-based MSW management tool.

Materials and Methods

Study Area

The main collection system in Gwalior consists of cleaners who clean up and send waste to the nearest collection point or open space. To achieve this goal, 460 collection bins have been installed at different locations. The average distance from the crates is 3.5 km. Manual lifting is used to load waste from roadside bins into vehicles. To transfer waste to landfill, additional vehicles such as tractors, dumpers, mobile compactors, etc. are also used.

There is no published data on the composition of Gwalior wastes. In India, the composition of waste is about 9% plastic, 50% biodegradable material, 25% inert waste, 8% paper, 4% scrap and 1% glass as indicated in Fig. 3. Waste generation rate, as observed for Gwalior city, is indicated in the Fig. 4.

Depending upon the geographical conditions and average population Gwalior city is divided into three different zones as Gwalior town, Lashkar and Morar region as shown in Fig. 5. Feasibility of decentralized solid waste management in each zone is assessed.

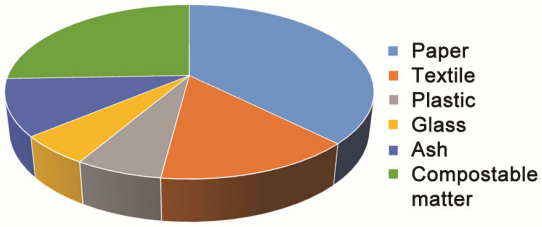

Fig. 3 — The MSW Trends in Gwalior (percent by weight)

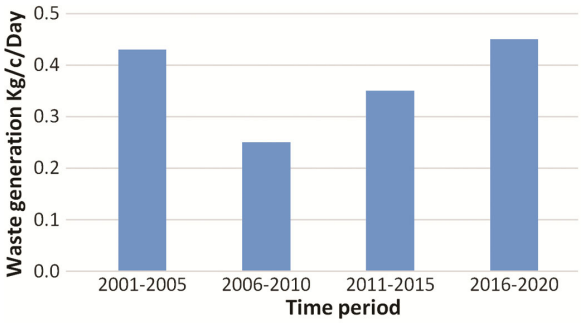

Fig. 4 —Waste generation rate

Fig. 5 — Zones for Decentralized MSW Treatment

Waste from garden in each ward of zone is also considered for receiving in decentralized treatment facility. Wards are allocated to the workers and they collect the waste from the dustbins and the other collection points and dispose it of directly at the disposal sites.

Artificial Intelligence (AI) Systems

Present work focuses on theories relating to AI systems. In research, theory is crucial since it clarifies the observed events and gives us recommendations for future activities. In this way, theory promotes the growth of knowledge and offers a standard framework for managing research procedures. Seymour and others the presence of a well-established theory emphasises how developed the subject of study is. Specifically, we'll look at how artificial intelligence theory, assessment methods, strategic planning, and decision-making work, and how they affect research. This paper concludes with a discussion of knowledge base systems, machine learning approaches, hybrid systems and evolutionary algorithms.

A Feed-Forward Artificial Neural Network

Structure of human brain is an inspiration for a machine learning algorithm called ANN. The nonlinear relationship between input and output components is represented by this network. It has been frequently utilised to address challenges with waste management, including the kind or amount of trash produced and its connection to socio-economic factors. Its clear advantages over competing systems, including transparent network architecture, high performance standards, and ease of implementation, have fuelled its rising popularity depicted via neural network's structure in Fig. 6. It has input, output, and hidden layers. The network's input layer receives data, which is subsequently processed by hidden layers to produce the intended outcome and signalled at the output layer.

Artificial Intelligence System Development

At a Dartmouth meeting organised by academics interested in artificial intelligence, the phrase Artificial Intelligence (AI) was first used. To address fundamental problems about AI including neural networks, self-improvement, automated computing, language usage, and abstract computing, key questions in the subject of AI are given. Generally

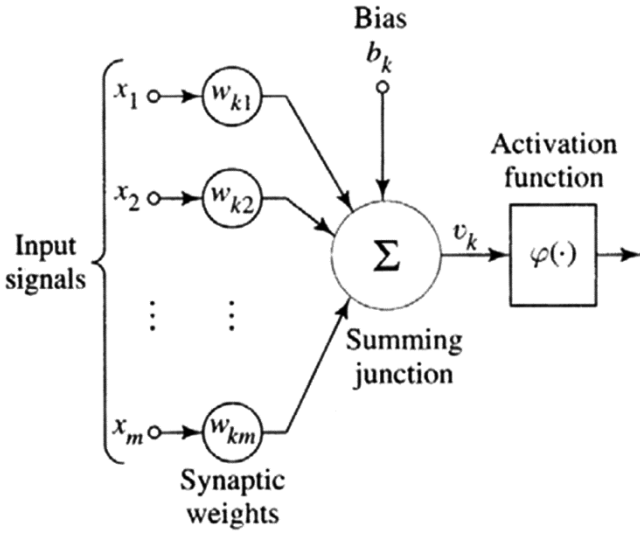

Fig. 6 — Model of the artificial neuron or processing element (PE)

speaking, a machine with any level of intelligence is referred to as AI. It comprises devices that simulate human decision-making and thought processes. A wide range of industries and applications, such as gaming, clustering, computer vision, speech recognition, natural language processing, and image processing, are impacted by AI. Artificial neurones or Processing Element (PE) models are the foundation of Artificial Neural Networks (ANNs).

Results and Discussion

The amount of waste generated in Gwalior town, Morar Region and Lashkar Region are measured and presented in Table 1.

AI Hybrid Model Development for Landfill Mining Prediction

A hybrid AI model for waste prediction and reduction is developed. The MSW data for model construction was prepared. An exploratory data analysis is conducted to further our understanding of the data's nature. Data occurrence and distribution with input parameters is analysed for creating prediction models. After normalisation, the data was split into a test set and a training set.

Based on climatic variables, humidity, wind speed, the highest and lowest temperature are identified as inputs. The Pearson correlation coefficient (R), Willmott's Index of agreement (WI), Coefficient of Efficiency (CE), Mean Bias Error (MBE), and Root Mean Squared Error (RMSE) indices of the ANN and ANN-PSO model in this study are indicated in Table 2, respectively.

Table 1 — Waste Generation in Gwalior, Morar, and Lashkar Region

Dates of Nov. 2017	Ward No.	Household	Population	Total Waste (Kg.)	Dry Waste (Kg.)		Wet Waste (Kg.)	Waste Per capita per day (GPCD)
					Plastic & Polythene	Recyclable		
Waste Generation in Gwalior Town								
16, 17, 18	12, 16, 17, 35	289	1,543	402	35	172	195	260.38
22, 23, 24	1, 4, 5, 63, 64	683	3,649	1,184	48	456	680	324.44
24, 25, 26	6, 7, 8, 9, 10,11, 13, 14, 15, 31, 32, 33, 36	2,386	12,741	4,210	190	1,784	2236	330.40
Total	24 Nos.	3,358	17,934	5,796	273	2,412	3,111	305
Waste Generation in Morar Region								
16, 17, 18	34, 37, 38, 39, 40, 41	735	3,925	1,348	42	691	614	343.44
22, 23, 24	42, 43, 44, 45, 46	763	4,074	1,452	176	402	874	356.41
24, 25, 26	47, 48, 49,50, 51, 52, 53,54, 55, 56	1,213	6,479	2,159	253	638	1268	333.23
Total	21 Nos.	2,711	14,479	4,959	472	1,731	2,756	344
Waste Generation in Lashkar Region								
16, 17, 18	18, 19, 20, 21, 22, 23, 24	1,067	5,698	1,986	182	696	1108	348.52
22, 23, 24	25, 26, 27, 28, 29, 30, 57	871	4,653	1,644	182	510	952	353.27
24, 25, 26	58, 59, 60,61, 62, 63, 64, 65, 66	853	4,557	1,463	98	497	868	320.99
Total	23 Nos.	2,792	14,908	5,093	462	1,703	2,928	341

Table 2 — Metrics for evaluating the network neural models' performance

Performance Measure	Neural Network Model	
	ANN	ANN–PSO
R	0.79	0.98
WI	0.86	0.99
CE	0.13	0.94
MBE	32,763.04	6,750.77
RMSE	39,681.68	13, 564.96

Conclusions

Municipal Solid Waste (MSW) of city of Gwalior is studied in respect of current status, prevalent practices, accomplishments and challenges. Its solution through possibilities of public-private partnerships is a challenge. The town of Gwalior generates 330 GPCD of trash on average (average of the three regions). Wards in the Morar region have a maximum of 356.41 GPCD and wards in Gwalior town have a minimum of 260.38 GPCD. When earlier work is compared, the forecast of MSW generation (including glass, biodegradable, plastic and metal, paper and cardboard and other wastes) in different Polish cities, the reported R was 0.9114. However, the value of R when ANN is hybridised with PSO is reported to be 0.98. AI based system has been developed for optimal use of resources, efficient disposal and processing of the MSW in existing local environmental conditions. The performance metrics given in the literature are therefore improved by the suggested paradigm when the findings of this study are compared with previous research study.

References

1 Abraham A, Intelligent systems: Architectures and perspectives, *Rece Adv Intell Paradig Appl*, (2003) 1–35.

2 Abraham A, Meta learning evolutionary artificial neural networks, *Neurocomputing*, **56** (2004) 1–38.

3 Abraham A, Hybrid intelligent systems: evolving intelligence in hierarchical layers. Do smart adaptive systems exist? Best practice for selection and combination of intelligent methods, (2005) 159–179.

4 Abrahamsson P, Salo O, Ronkainen J & Warsta J, Agile, Software development methods: Review and analysis, *arXiv preprint arXiv:1709.08439* (2017), https://doi.org/10.48550/arXiv.1709.08439.

5 Abrishami S, Goulding J S, Pour-Rahimian P & Ganah A, Integration of BIM and generative design to exploit AEC conceptual design innovation, *J Inf Technol Constr*, **19(1)** (2014) 350–359.

6 Adachi Y, Overview of partial model query language, *Proc ISPE Conf Concurrent Eng*, (2003) 549–555.

7 Nandwana R & Chhipa R C, Impact of solid waste disposal on ground water quality in different disposal site at Jaipur, India, *Int J Eng Sci Res Technol*, **3** (2014) 93–101.

8 Bundela, P S, Gautam S P, Pandey A K, Awasthi M K & Sarsaiya, S, Municipal solid waste management in Indian cities–review, *Int J Environ Sci*, **1(4)** 591–606.

9 Cobb C E & Ruckstuhl, K, Mining and reclaiming existing sanitary landfills, *In Proc National Waste Process Conf* (Detroit, MI, USA) 1988, 145–151.

10 Kumar S, Bhattacharyya J K, Vaidya A N, Chakrabarti T, Devotta S & Akolkar A B, Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight, *Waste Manag*, **29(2)** (2009) 883–895.

11 Kurian J, Esakku S, Palanivelu K & Selvam A, Studies on landfill mining at solid waste dumpsites in India. *In Proc Sardinia*, **3** (2003) 248–255.

12 Singh C R & Dey M, Surface Water Quality with respect to municipal solid waste disposal within the Imphal municipality area, Manipur, Magnesium (mg/l), **3** (2.15) 0–7.

13 Abbasi M, Hanandeh E A, Forecasting municipal solid waste generation using artificial intelligence modelling approaches, *Waste Manag*, **56** (2016) 13–22.

14 Kolekar K A, Hazra T, Chakrabarty S N, A review on prediction of municipal solid waste generation models, *Procedia Environ Sci*, **35** (2016) 238–244.

15 Soni U, Roy A, Verma A & Jain V, Forecasting municipal solid waste generation using artificial intelligence models—A case study in India, *SN Appl Sci*, **1** (2019) 1–10.

16 Sayyahi F, Farzin S & Karami H, Forecasting daily and monthly reference evapo transpiration in the Aidoghmoush basin using multi layer perceptron coupled with water wave optimization, *Complexity*, **2021**, 1–2.

17 Noori R, Abdoli M A, Ghazizade M J & Samieifard R, Comparison of neural network and principal component-regression analysis to predict the solid waste generation in Tehran, *Iran J Public Health*, **38(1)** (2009) 74–84.

18 Jalali G Z M & Nouri R E, Prediction of municipal solid waste generation by use of artificial neural network: A case study of Mashhad, *Int J Environ Res*, **(2)** (2008) 13–22.

19 Yaghini M, Khoshraftar M M & Fallahi M, A hybrid algorithm for artificial neural network training, *Eng Appl Artif Intell,* **26 (1)** (2013) 293–301.

20 Bahrami M, Akbari M, Bagherzadeh S A, Karimipour A, Afrand M & Goodarzi M, Develop 24 dissimilar ANNs by suitable architectures & training algorithms via sensitivity analysis to better statistical presentation: Measure MSEs between targets & ANN for Fe–CuO/Eg–Water nanofluid, *Phys A: Stat Mech Appl*, **519** (2019) 159–168.