Technological Developments Aiding Solid Waste Management

Nehil Shreyash, Susham Biswas [a]*

a Department of Chemical Engineering,

b Department of Petroleum Technology

Rajiv Gandhi Institute of Petroleum Technology,

(An Institution of National Importance)

Jais, Uttar Pradesh 229304, INDIA

[†] Equal Contribution

* To whom correspondence should be addressed.

Email: susham@rgipt.ac.in

Phone: +91 9919556965

Abstract

One of the globally pertinent issues is to manage the wastes generated in an organized manner. Mitigating solid waste generation is important alongside efficient management of the generated wastes is paramount. Thus, recycling has emerged as a viable alternative. Solid Waste Management comprises steps like collection, transportation, and disposal, and in an efficient waste management process, it is essential to monitor and design each process scientifically. Disposal in landfills is a general practice however; owing to inefficient segregation before disposal the wastes are highly toxic with the potential to affect the hygiene of the earth. It is observed that half of the wastes disposed of are toxic and this underpins the importance of segregation before disposing of. Also, identification of appropriate sites for landfill development is important and it is preferred to build them in areas that are sparsely populated. The mismanagement of solid wastes is evident in developing countries and as a solution, various smart technologies have been developed that monitor the accumulation of wastes. The utilization of Geographical Information System (GIS) is fairly common in analyzing waste management as it brings integrates software-based technologies with data. Apart from monitoring the accumulation, several computational technologies assist in determining appropriate disposal sites or transportation routes, etc.

1. Introduction

With the rapid increase in industrialization and urbanization, solid waste management has become a matter of concern globally. Especially in developing countries like India per capita generation of municipal solid waste is estimated to escalate with a rate of 1-1.33% in conditions when unscientific disposal of municipal solid waste is done in these countries. Land shortage for the disposal is a serious concern for Solid Waste Management (SWM). This has led to the dire need of developing an effective SWM system which could help waste management planners and decision-makers to control the issues incurred while managing the SWMs. An effective SWM ensures a hygienic environment in localities and efficiently produce energy from the waste materials. Waste significantly affects our ecosphere and can result in a rampant outbreak of many lethal diseases. If neglected they can lead to breeding grounds of flies, mosquitoes, rats, etc. resulting in severe illness from jaundice, malaria, dengue with a lethal compromise to hygiene. Even animals consuming these waste may transfer diseases with the food chain. Unscientific disposal of solid waste may result in toxic substances emissions at these landfill sites. These sites are often a prominent source for heavy metals and nitrate contamination in groundwater. Various researches carried in regions like Manisa (Turkey) and Palermo (Italy) have concluded that agricultural wastes like pesticides and fertilizers have drastically surged the concentration of nitrates in the lands and thus the agricultural productivity has reduced (Bhide et al., n.d.; Das et al., n.d.; Dipanjan et al., n.d.; El-Fadel et al., n.d.; Environmental and 1999, n.d.; Kumar et al., n.d.; Pappu et al., n.d.; Singh et al., 2008; Velis and Brunner, 2013; Yang et al., 2008).

There is an urgent need to develop an efficient, innovative, comprehensive, andeconomic system to manage the waste, and generateenergy. Optimal planning at each step and involving modern technologies in the existing system can help to overcome many challenges to waste manage management.Modern technology of Geographical Information System (GIS) is ushering new opportunities for the transformation of waste to energy. GIS system can help tocollect, manage, analyze efficiently. It presents all kinds of geographically referenced information connected to solid waste by integrating software, hardware, and data. Its way of representing data in the form of maps gives it the edge over other kinds of visual outputs like tabular data or data in written form. The idea of combining advantages of graphical and visual analysis by maps and usual database operations like statistical analysis and query makes GIS different from other systems. A proper decision support system for an efficient SWM system is provided by GIS and making it more powerful. (April and 2008, n.d.).

A requirement for the development of a better waste mechanism would be the calculation of the recycling potential of the waste. There is a need for a technique that can identify the potential of the generation of biogas, hydrogen fuel, or renewable energy for a location using solid waste. Estimation of energy potential for an area is dependent on the computation of availability of solid waste, determining their types, establishing procedures to segregate them efficiently, transporting them to disposal sites, and utilizing effective techniques to transform them into energy.GIS powered systems with cloud-based real-time monitoring and messaging techniques are providing a great framework to compute SW to Energy potential, by calculating the possible energy values, best location(s) for setting up disposal and/or biogas plant, planning routes for transporting to SW and establishing a web-based robust monitoring and scheduling system for efficient cleaning.

A discussion on the prevalent techniques for sorting, separating, disposal, and recycling of waste is necessary as a precursor to understand what we lack in the area and the way to improve upon it. Improper transportation of waste and its collection has been the reason for some of the greatest difficulties the modern world faces. The best method to get rid of waste is not uniform everywhere but depends on a number of factors. Site selection is one of the major problems that can be solved through the newer technologies, if it can be predicted that what is the most efficient and harmless way to dispose of waste. A number of people have performed studies on different means of Solid Waste Management, the authors aim to analyze the methods, their advantages and limitations and hence re-emphasize the need for a better system and awareness. Use of technologies such as Mixed Integration, Simulated Annealing, RFID, Combination among others are further discussed. Since different methods of waste recycling can display different frequency, it is possible to create models to select the most beneficial model among them all; the different techniques proposed for this have been discussed. Following that are some of the recent developments in recycling technologies and the products that can be obtained through recycling including biomass, Carbon dioxide and hydrogen.

2. Management of Solid Waste

Figure 1: Transporting vehicles for Garbage

From the collection of solid waste followed by pre-treatment to final disposal of solid waste on a landfill site, solid waste management comprises of some basic steps. Waste collection, Waste Transportation, and waste disposal are three primary processes involved in the waste management process. The first process of the Waste collection followed by logical segregation plays a significant role in resulting efficacy of the entire SWM system. To date, municipal corporation workers manually do this process. Further, the transportation of waste is carried out according to the road network for an area. Trucks, bullock carts, tractors, etc. are usually employed. Recently a sudden increase in the use of a hydraulic machine is also visible. These transporting vehicles are usually open with waste loading done manually (Figure 1). The waste collected is unloaded at the dumping site which is followed by treatment for scientific disposal of the waste. However, these processes are badly ignored and waste is usually dumped in the outskirts of the citywith no proper treatment and coverage. This may lead to the formation of breeding grounds for several flies, mosquitoes, etc. resulting in deadly disease. Further leachate production may result in severe groundwater contamination too. (Shrivastava et al., 2016).

2. 1. Sorting and separating the solid wastes

One of the most daunting challenges in Waste Management is the Municipal Solid Waste. Local municipalities of an area are duly responsible for managing all the garbage of the particular locality, however, their operating measures are deeply affected by paucity of finances or organizational synchronization. In formulating appropriate management tactics for the wastes, it is important to know to quantify the total amount as well as the composition of these wastes, e.g. Municipal Solid Waste, Hazardous Waste, Industrial Waste, Agricultural Waste, Bio-Medical Waste, etc. Information like the calorific value of the wastes helps decide its utility as a fuel as well as predict the gaseous emissions which are ought to happen from the wastes. Considering the example of the solid wastes generated from agricultural produces like Rice husk, sawdust, and corn cob, it was found in research that these three crops can be used to produce energy upto 12.28 MJ/kg, 13.18 MJ/kg and 15.49 MJ/kg. These are appreciable values and it can be concluded that agricultural wastes can be beneficial in producing energy(Awulu et al., 2018). Other researches have also worked towards finding the energy generation capacity of different classes of wastes and their findings suggest that hazardous wastes account for energy production of 12 MJ/kg, Bio-medical wastes account for calorific value of 19 MJ/kg. ("Calorific value of waste - Design and manufacturing of incinerator technology," n.d.)Thus, after knowing about the energy production potential these wastes have, it can be said that neat segregation of wastes into different categories can help in the production of fuel and thus lower the dependence on non-renewable energy resources like coal. However, if the segregation of solid wastes is not done and the waste is sent directly for fuel generation, the amount of fuel generated may be affected negatively. A much more important reason which is a proponent of waste separation is that the cleanliness of the fuel generated might be compromised. For example, if the huge mass of waste consists of toxic materials and non-biodegradable wastes it is highly probable that the combustion of these toxic materials can lead to immense harm to the environment. Thus, it is important the wastes collected are sorted properly, however, the primary challenge lying ahead is that since about 60% of the total solid wastes are generated from households the wastes are highly heterogeneous. This heterogeneity offers a major challenge in sorting the wastes and thus, before sending the wastes for processing, a proper method must be developed for segregating these waste materials into appropriate groups. One of the oldest and most inefficient ways for sorting is hand-picking. Municipalities also use different colored bins etc. However, these methods are not always very effective and awareness of the people who are the waste generators is extremely important in proper waste segregation

2.2. Disposal of solid waste

Collection and transportation systems employed have deep effects on solid waste characterization. Various factors like poor roads, insufficient number of solid waste collection vehicles,etc have major effects on the characterization of these wastes. Most of these issues are common in the lives of the people living in developing or under-developed countries. One of the efficient ways for better waste characterization is to organize the informal sector, train the municipal authorities to better handle the solid wastes, etc. Research by Tadesse et al (Tadesse et al., 2008)has suggested that the choice of waste disposal is highly dependent on the availability of waste facilities(table). It has been demonstrated how the lack of recycling bins or containers has led to ill-waste management.Also, when these containers are transported over longer distances, it is highly probable that the wastes would be more found on the streets and the dumping grounds, leading to unsafe waste disposal. Further, it indicates the need to determine the best location to setup the disposal site for a locality (Hazra and Goel, 2009).

Table 1: Results of studies by Tadesse tabulating Measurements of Mean and Standard Deviation of different variables enquired in a survey, reproduced with permission from Elsevier(Tadesse et al., 2008)

Variable name	Measurement description	Mean	SD
Household head gender	1 if female, 0 otherwise	0.39	0.49
Age of household head	Age of the head of the household	43.8	12.5
Household head education	Number of years of schooling	7.91	6.07
Number of female household members	Number of female household members whose age is 15 and elementary school graduate as well	1.39	1.06
Family size	Number of household members	4.48	2.13
Years of stay	Number of years the household lived in the city	23.78	15.98
Homeownership	1 if the household owns the house it lives in, 0 otherwise	0.65	0.48
Household income	Household income per year (birr) (1US$ = 9.078 birr)	12739	12155
Household source separation of wastes	1 if yes, 0 otherwise	0.16	0.37
Access to waste disposal containers by households	0 if none at all, 1 if not enough, 2 if enough access	1.08	0.36
Municipal regulation of households are using the disposal containers properly	0 if none at all, 1 if regulation is weak, 2 if strong regulation	0.89	0.54
Waste quantity generated per year	1 if the total generation is between 0 and 200 kg 2 if the total generation is between 201 and 500 kg 3 if the total generation is larger than 500 kg	1.83	0.81

View of people with the placement of waste containers near their houses (NIMBY[a])	1 if agree, 0 otherwise	0.32	0.47
Distance to waste containers	Total distance in m (meters)	293	457
Participation in recycling practice	1 if yes, 0 otherwise	0.18	0.39
View of people with the placement of waste containers anywhere in the city(NIABY[b])	1 if agree, 0 otherwise	0.46	0.50
Primary waste disposal alternative that households use(dependent variable)	1 if a household uses municipal waste containers 2 if a household uses open areas and roadsides 3 if a household uses tractor-trailers to dispose of the waste 4 other alternatives (formal and informal waste pickers)	1.32	0.72

[a] NIMBY stands for *Not In My Back Yard*.

[b] NIABY stands for *Not In Anyone's Back Yard*.

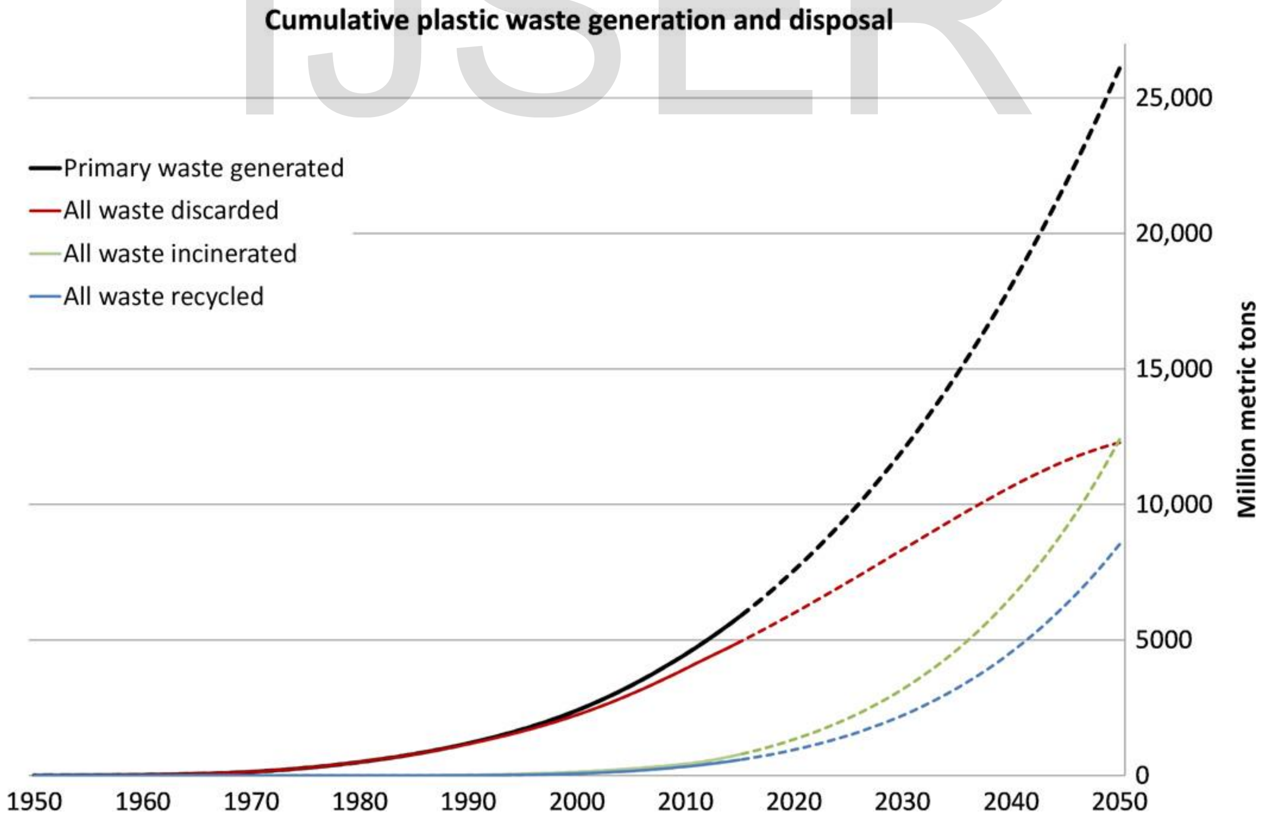

Figure 2: Graph of Plastic Waste generation and disposal reprinted with permission fromthe American Association for the advancement of science(Geyer et al., 2017)

Taking into consideration the disposal of plastic waste, it is a known fact that plastics are non-biodegradable substances, and dumping them can lead to severe environmental pollution. With the huge volumes of plastic wastes generated everywhere(Figure 2) it is almost impossible to find enough dumping grounds and still maintain the environmental sanity. This is the reason why there are reports of wastes being dumped into aquatic resources like lakes, rivers, and oceans, however, this is not a solution as these plastic wastes would still harm the environmental and ecological balance. Plastics are hydrocarbons and have a calorific value in excess of 30 MJ/kg and hence, a possible option is to use these wastes for power generation. This recycling is also essential since it mitigates the need to produce electricity by using fossil fuel, which is a cause of carbon-emission. Although, upon burning plastic wastes, there is an increment in the pollution efficient waste management techniques that can lead to reduced greenhouse gas emissions.(Nameni et al., 2008; Sharholy et al., 2008).

2.2.1. Disposal of municipal solid waste

It has been discussed in the preceding sections that lack of management in the collection and disposal of solid wastes is the cause of pollution. For industrial waste processing, there are certain regulations set by the government that industries have to adhere to before disposing of their wastes but in case of household waste management, the regulatory measures are not followed very strictly. On a global scale, it has been estimated that about 70% of the solid wastes are disposed of by dumping on certain landfills and about half of these dumped substances are non-biodegradableand toxic, which is sufficient to cause enough harm to the environment as well as raise serious health concerns. Hence, these open landfills have to be developed and converted into a technologically furnished landfill. A typical landfill designing requires excavation and has to be lined up with layers that protect the groundwater since the leachate migration to the ground layers is prevented. It also allows collecting the leachate which can be further sent for treatment. (Brems et al., 2012; Morris, 2005; Slack et al., 2005; Weigand et al., n.d.).

2.3. Management and recycling of solid waste

It has been found that recycling is promoted in places where the disposal charges are too high or where there is not enough room for disposing of the large number of wastes collected. Proper waste management is strongly dependent on the availability of disposal resources and also, on the awareness of the people. For example, if public bins are situated at larger distances away from the homes of the people, waste management would have a stronger dependence on the awareness level of the people. It is possible that people would not prefer to travel to dispose of their wastes and thus, the wastes would be littered all around in public roads and localities. However, it is also possible that the people would sort the wastes themselves and in that case, the management of wastes would improve.Recycling is a process in which old and used up items are processed for use in some other area of application and to promote recycling of wastes, the most common suggestion that comes up is to encourage the business places to use recycled materials like using recycled paper bags and not plastic bags. As discussed earlier, waste management is the biggest challenge faced by a municipal corporation, and policies that enforce the adoption of rational management techniques towards natural resources can prove helpful. Waste valorization, for example,is a process suggesting that the sorting of the wastes must happen at the source itself which must then be combined with recycling technologies. For better handling of the waste,the wastes must be disposed of at proper sites. However, in many second and third world countries, the disposal is arbitrarily done at dumping grounds, generally at places sparsely populated(Figure 3). For proper characterization of wastes, the quantity, composition and categorization are very important in connecting various recycle-based and recovery-based technologies to waste management. With growth in population and standard of living of the people, the amount of wastes generated is ought to increase and thus waste management technologies have to be applied someday. In the 1st world nations, the waste products are utilized to produce renewable energy and products like compost and are used in agricultural activities which not only manages the wastes but also enhances the productivity of the agricultural land, producing more organic produce. (González-Torre and Adenso-Díaz, 2005; Matete and Trois, 2008; Nissim et al., 2005; Scheinberg et al., 2010).

Figure 3: Landfill Site on the outskirts

3. Overview of Waste Disposal Sites Identification

The selection of suitable landfill location involves consideration of various factors like government regulations, environmental problems, economic and social effects. A significant amount of evaluation and processing of spatial data associated with site suitability is involved in this(Al Sabbagh et al., 2012; Brunner, 2013; Wilson et al., 2007). Due to heavy disturbance that any landfill site can cause to the ecology and biophysical environment of the surrounding, environmental issues are a significant problem for the selection of any landfill site(Ojha et al., 2007). For trench-type landfills areas having slightly rolling and flat hills are best suited. However, with a slope greater than 15 percent the site stands unsuitable for the candidature(Erkut et al., n.d.; Lober, 1995; Siddiqui et al., 1996; Su et al., 2010). The five territorial indices are kept in consideration for site suitability(Bagchi, 1994; Şener, 2004; Şener et al., 2011a): Human health, surface water, atmosphere, groundwater, and soil. This helps in quantifying the suitable environmental factors important for site selection. In a recent study it was shown that 1) Technical and engineering protocols for physical environment benefits 2) Local population approval driven by various socio-economic and political reasons are major factors for landfill site selection(Baban and Flannagan, 1998).

In any case, thought ought to be given to other natural and physical highlights prior to waste disposal site selection. For instance, Chang et al. (2008) (Chang et al., 2008)recommended that a waste dumping site ought to be situated inside a one km radius from the transportation network. They further proposed that waste removal locales ought not to be sited excessively far away from the mainstream connected transportation to diminish the expense of transportation. So also, Sener et al. (2011) (Şener et al., 2011b)had indicated that the separation between the source and dumping grounds of waste removal should exceed a kilometer and the haul separation between the head city site and the solid disposal site ought not to surpass 30 km. They additionally noticed that land-use (LU)types, for example, forests, grasslands, bushlands, etc. ought to likewise be thought of and allowed a proper land-use suitability index. Thus unused or unwanted LU areas can be thought of as used for solid waste disposal sites. Thus, unused or unwanted LU areas can be thought to be used for solid waste disposal sites. However, it is a unanimously known fact that the acceptance of a landfill site by the locals fluctuates with the kind of LU.

4. Monitoring the waste accumulation using smart technologies

4.1. GIS Integrated Waste Production Modelling

There exist various models that give an inventive way to deal with recognizing the locations and the number of waste bins. The information is then exploited by ground-based temporal examination and further, a plan is formulated for the spatial-temporal geodatabase. For evaluating the populace thickness and the populace dissemination , the ground-based tests are carried out. The diurnal production of wastes is additionally determined by remembering boundaries like business units of waste creation. The presentation of this data is later done in the spatial-temporal database. The evaluation of this information is done with the help of a data modeling engine. This is then represented in a final map which includes the number of bins required. The purpose of this model is to consider the networking of the routes and the blocked off areas where the vehicles carrying the wastes cannot reach. Considering all the above issues,finally waste loading points are distributed and the number of receptacles is determined(Figure 4). This proposition is a decent option in contrast to the arbitrary appropriation of the waste containers however it doesn't consider factors like sort of waste created for example recyclable, composite, and so forth which may additionally improve the framework.(Shrivastava et al., 2016).

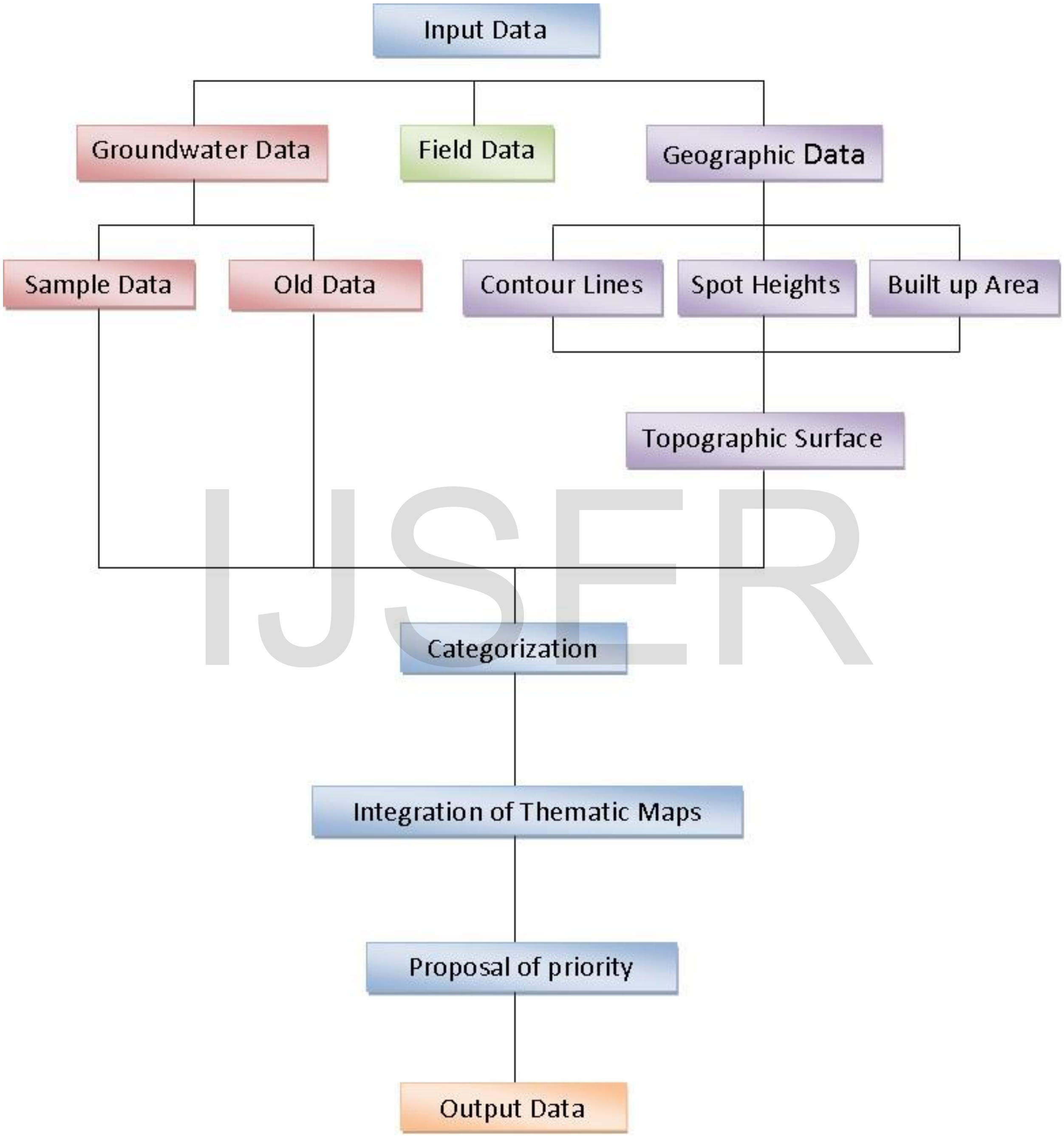

Figure 4: The General method used for evaluation using the GIS method

4.2. Mixed-integer programming model

Various aspects are to be planned for SWM e.g., determination ofthe possible location(s) for disposal site, planning of transportation schedules, setting up of types of facilitiesalong with their capacities, i.e.,Biodegradation of Solid Waste, Recycling of Solid Waste, Treatment of Solid Waste, Waste to Energy generation, etc. It becomes a typical problem of optimization. A Mixed Integer Programming Model (MIPM) has been tried for the landfill site selection with the characteristic site features (e.g.site compactness). Spatial connection of site-related features with GIS demands integration of MIPM with GIS for optimized solutions. Previously GIS was only of little help even when the case was of large sitting area, but with this integration, it is offering powerful solutions.The improvements on these constraints were made by the creation of a mixed-integer spatial optimization model dependent on vector information for finding appropriate waste disposal site as help to decision-makers (Kao and Lin, 1996).(Benabdallah and Wright, 1992)utilized a raster-based linear mixed-integer model in order to provide a solution to the issues related to the multiple site land use. Larger is the available number of integer variables, larger is the time elapsed for model solving, in case of a mixed-integer linear programming model. Nevertheless, it was found that an increment in non-integer variables hardly has any effect.(Kao and Lin, 1996).At the point when coordination with GIS is done, the model is equipped for handling advanced spatial information productively to encourage landfill siting investigation. MIPM is beneficial in area assignment models when fused with the natural components inside a drawn-out arranging system during the siting of a landfill(Chang et al., n.d.). To manage the siting issue in arranging a provincial SWM plot, another scientific model "Fluffy stretch multi-objective blended number writing computer programs" was proposed by

Chang et al. (1997)(Chang et al., n.d.). The model explicitly demonstrated how the inside messages identified with the information boundary esteem and the fluffy objectives relating to the chief's yearning levels are imparted into the multi-target advancement forms. It is powerful in creating a lot of progressively adaptable ideal answers for pertinent issues related to SWM. The model methodology has led to considerable improvement in the hypothesis of multi-target programming as well as in the application for long haul arranging of an SWM framework (Chang et al., n.d.).

4.3. Solid Waste Monitoring and Management using RFID, GIS, and GSM

RFID bestows a significant impact on this framework as it aids in conquering the manual chronicle work, a work which is traditionally performed by the driver of the vehicle. The RFID labels are joined on the receptacles which contain all the information logs and the receiving wire and RFID per user is installed in the truck. At the point when the truck arrives at waste container RFID tag would be distinguished by the RFID peruser and all the data will be mapped on the GIS map, sent with the help of GSM. This procedure is possible to completely programmed with no presence of driver required. The vehicle position is traced utilizing GPS and is put away in a focal database where it tends to be effectively checked. GIS and GSM are picked for correspondence between vehicle position monitoring and the server(Figure 5). The GIS checking terminal will get all the information and would help continuously observing of the framework. Further, it finds the briefest conceivable course to the landfill or dumping site in this manner diminishing the fuel cost making the framework financially savvy. The present system of Solid Waste management is now proving quite weak as compared to this modern technique. It is practical eco-friendly, economic, and gives constant real-time data. It tends to be made progressively compelling if arranging of waste containers is done preceding assortment, it will better affect the administration of strong waste.(Shrivastava et al., 2016).

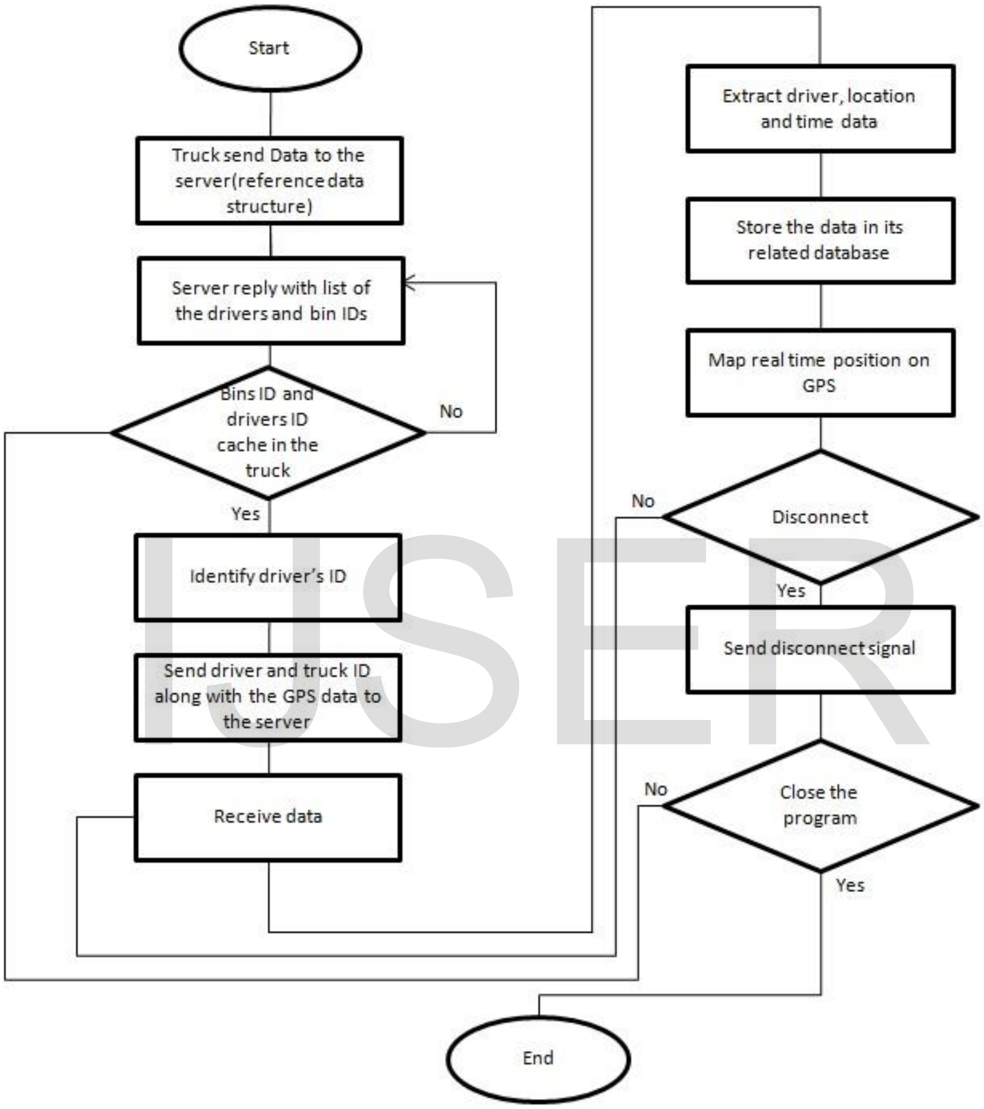

Figure 5: The normal method used for Solid Waste Monitoring through RFID, GIS, and GSM, reproduced with permission from Elsevier(Hannan et al., 2013)

4.4. Weighted linear combination.

Even today the most relied upon the method to examine site suitability is of Weighted Linear Combination (WLC). It involves map combination by the application of a factor weight with the parameter and standardized score to every class of some given parameter(Catena and 2008, n.d.). Summation of all the weights should be unity(Salmon Mahini and Gholamalifard, 2006). It is a necessary criterion for the process of MCE(Multi-Criteria Evaluation) utilizing a WLC. WLC principally relies on the idea of a weighted average. It involves standardization of the critical criteria to a common numeric range followed by their combination using a weighted average(Drobne and Lisec, 2009). Decision-maker assigns relative weights to all the attributes present in the map layer. However, WLC utilizes aggregation for assigning of the relative weights to every factor. This gives WLC an edge over the other methods. To develop a map layer using weighted average values(Ayalew et al., n.d.)generally WLC method is used provided all the classes of individual parameters are rated and followed by assignment of factor weights to the parameter. Hanbali et al.(Al-Hanbali et al., n.d.)conducted a study in Jordan where they utilized different thematic layer integration with the help of GIS, remote sensing technology, and WLC for the accomplishment of requires landfill sites. Real-time information can be updated by the remote sensing technology. By the means of WLC methods, GIS-based MCE considers conflicting objectives and multiple criteria and thereby evaluates the possible number of choices for the siting problem. The WLC method has greater flexibility than other Boolean approaches and it permits full trade-off among all factors.

4.5. Scoring Modelfor waste characterization

The United States Environment Protection Agency's (USEPA) subsidiary, the Indiana Solid Waste Management Board developed a model built upon the ranking system of the USEPA(US EPA, n.d.). This is a model meant for scoring the hazard the waste poses to its surroundings. It checks the distance that is between the waste and the population, also depends on any migration that occurs of the waste. The nature of the substance is also taken in stride such as if it is explosive or inflammable and if its emissions could cause any damage.

In case of the waste leaches into the groundwater and contaminates it, it would greatly increase its scoring on the scale. That is because groundwater affects a huge population of people in several ways. The migration to groundwater can occur in several ways. The accessibility to groundwater through inclination, land structure, and the amount of rainfall is calculated. The geographical location should be such that it is away from any surface source of water.(Muttiah et al., 1996).

Transmission through the air is equally hazardous. The contaminants in the air could include particulate content or emissions. Nano-sized particles can cause great distress to the population in unexpected methods. The quality of waste that could be getting into air is checked based on compatibility with the present air. The spread of the waste matter and the distance to which this waste would remain relevant is a matter of concern. The presence of a settlement near the area of the spread will be a dangerous phenomenon. Finally, the presence of water bodies is also a factor.

Explosive and inflammable substances are classified based on their reasons for ignition, the resultant damage that it could cause, and its possibility. The disposal of any inflammable waste near any settlement is unacceptable a radius of 2 miles is taken into consideration(Muttiah et al., 1996). The emissions from the burning and explosions may be more harmful and these factors are kept in mind when ranking this waste.

The application of a more meticulous waste ranking system will always be relevant to be able to prioritize the waste. The highly dangerous elements are always picked up first. With a score provided to the urgency of cleaning waste, a model can provide the most efficient and least harmful method of disposal and management of waste.

4.6. Simulated Annealing

Simulated Annealing is a method used in optimizing models without any certain objectives in mind(Muttiah et al., 1996). They can be defined by taking the example of a liquid, heating it to a certain temperature, and cooling it down slowly to minimize the energy losses. This reasoning is used in several processes, waste management through GIS is one of them (Figure 6)In simple words it uses raw processing power to optimize a method without a very specific input. Its name was derived from the process of annealing and the model is so dependent on the process that an actual variable for temperature is incorporated in its architecture.

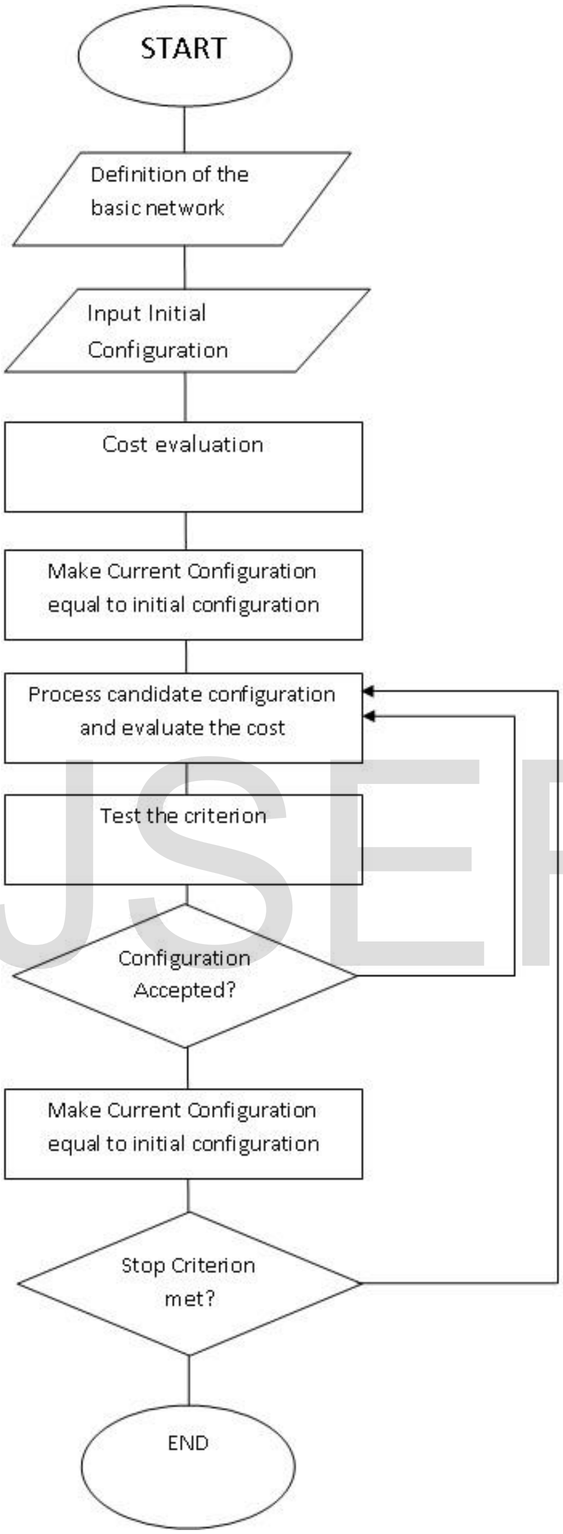

Figure 6:Generally followed a model of Simulated Annealing

Finding the problematic waste disposal sites falls right into the area of functioning of the simulated annealing process. It computes all the layers of data provided in the forms of a map by the GIS and gives as an output theorizing the optimal solutions spaces. Sometimes due to increased information the solution space can be extended too, analysts are then required to find out an even deeper solution. The major consideration kept in mind is also the cost of the activity. (Muttiah et al., 1996).

The temperature variable is used to identify the dependency on the cost variable. Space is disturbed in different directions from the initial point based on maximizing or minimizing the cost as required, and the number of the iteration is based upon cost dependency which is in turn based on temperature. The new location is analyzed for its cost-efficiency, if it matches the criteria required by the programming then it is accepted. The complicated process then recursively changes the initial positions with the newly discovered ones.

This process may seem too chaotic and random but it has been proven to give acceptable results. By combining the scoring criteria and using simulated annealing the optimal sites canbe found. Here the optimal site would refer to the hazardous waste disposal areas. Proper measures to either prevent waste from being deposited there or to make sure that it is done perfectly can then be put into use.

5.Recycling Potential Calculation

A method to calculate the potential of waste materials is paramount. Biogasdoneright is one such procedure, first started in Italy. Farmers there redesigned their farming systems. Farm-based anaerobic digestions, double cropping was adopted

Even in India, 960 million tonnes of solid waste is produced, their potential is also an important thing to pay attention to. In a study by(Pappu et al., 2007) it was shown that for different activities, the wastes produced if left unchecked could cause some seriously distressing phenomenon. Other than being harmful to places on different levels they also occupy large pieces of land. They can easily become resources. Another study portrays the calculation of the returns the waste could provide(Yang et al., 2012) in China.

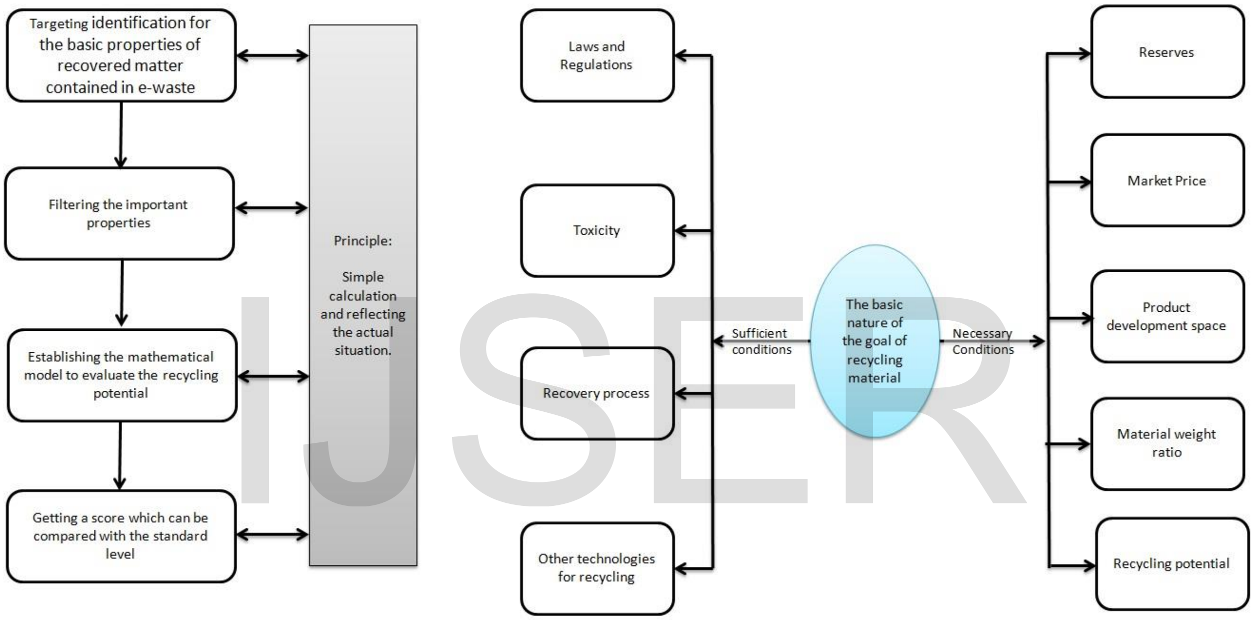

Figure 7: Flowchart of Calculation of Waste Recycling Potential, reprinted with permission from Elsevier(Zeng et al., 2017)

(*Recycling Potential Assessment Model and Environmental Benefits Analysis d*, n.d.)suggested another method to evaluate recycling potential. This study focused on LCD as an instance to assess the benefits of their methods. The method involved identification of the nature of materials, selection of the main attractive material, using the benchmark to assess the recycling characteristics, and then further analyzation to determine the need for waste processing. And then the better methods were selected through toxicity, socio-economic analysis, and analysis of other factors. Using the technique prescribed it is simpler to judge the recycling potential with a value provided through studies on all fronts the process affects(see figure)(Zeng et al., 2017) suggested an economic analysis model evaluate potential; individually for the municipal corporations and the construction and demolition streams. With extensive data availability, they were able to correctly evaluate the potential in recycling in terms of monetary description. This economic system inculcated the benefits and losses in recycling in all terms to be able to produce the final statement on profit and loss achieved overall.

6. Utilization of solid wastes

6.1.Production of hydrogen using plastic waste

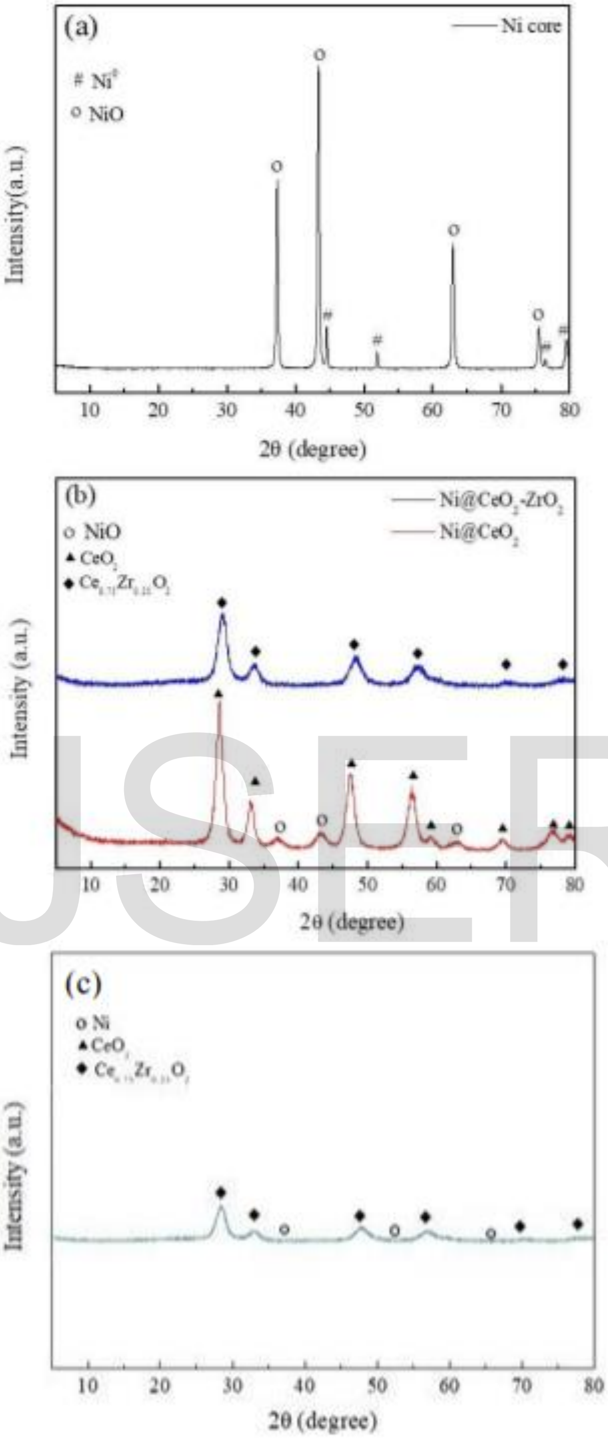

Figure 8: XRD patterns of the calcined (a) Ni core (b) core-shell catalysts, and (c) $Ni@CeO_2$-ZrO_2 catalyst after reduction reprinted with permission from Royal Society of Chemistry(Wu et al., 2020)

Among various solid waste produced across the globe, plastics are the most common and serious solid wastes due to their non-biodegradability having an incremental production rate (348 million tons in 2017) due to increased demand(Lopez et al., 2018). Thus, solid waste recycling is a very important step that can help in generating various valuable & renewable products(Liu et al., 2017; Namioka et al., 2011). Also, utilizing such waste for producing a clean form of future energy(hydrogen) would be a laudable approach to waste management. Shan-Luo et al.produced a core-shell catalyst (Ni@CeO_2-ZrO_2) stable at a high temperature used for solid waste(plastic) gasification. A short explanation of why certain metals and catalyst type is preferred by Shan-Luo et al.(Wu et al., 2020) is discussed here.

Nickel is the most preferred metals by the industries for utilization within catalysts because it is economically cheap albeit it is prone to sintering and poisoning which can be easily modified by improving the amount of metal added and active coating methods(Chen et al., 2014; Singha et al., 2017). But nickel alone (without supporting material) is having low pore volume and the surface area thus coating it with a shell composed of CeO_2 would improvise the surface area from 12.3 m^2 /g to 32.8 m^2 /g. CeO_2 has a prominent role in carrying and transporting oxygen throughout the catalyst as ceria alone is thermally unstable(Gallego et al., 2009; Montini et al., 2016) and has additional benefits of being incorporable within thermally stable catalyst supports. Apart from this Zirconia in combination with ceria is known to improve the thermal activity and catalytic activity at low temperatures(Arslan and Doğu, 2016; Mondal et al., 2015) and the specific surface area of a shell structure composed of CeO_2-ZrO_2 is in the vicinity of CeO_2 shell. Core-shell type catalysts are widely used because of their exclusive properties as it does not deactivate at high temperature and one can supervise its catalytic performance by managing the pore size as shown in figure 1(Feyen et al., 2010; Wang et al., 2018; Zhao et al., 2005).

To test the catalytic decomposition ability of high-density polyethylene waste the catalyst was exposed to a two-stage pyrolysis catalysis system where the syngas produced from reactor number 1 (pyrolysis reactor) was entered into reactor number 2(catalytic reactor) at a reaction temperature of 600-800 °C. After the pyrolysis reaction, the number of hydrocarbons produced was much more than that of hydrogen. Hydrocarbons with carbon numbers above 6 were produced in large amounts between 600 °C and 700°C. In the first stage reaction, the major products were light hydrocarbons making sure that all of the high-density polyethylene is converted to gaseous products. Thus, the main reason for employing the second reactor was increasing the concentration of H2 produced. To escalate the surface area and pore volume of core-shell type catalysts porogen (cetyltrimethylammonium bromide (CTAB)) can be added to make shell structure porous(mesopores) along with favorable and accessible pores for diffusing reactants in and products out. The properties of the above-mentioned catalyst were studied using the N2 adsorption and desorption method, also it was found that it is highly stable in high coking conditions. The amount of carbon produced within the process is not allowed to sit on the shell structure and is easily oxidized by the redox properties of ceria. Again, the characterization of the spent catalyst performed via thermogravimetric analysis and transmission electron microscopy revealed that no carbon was found deposited on the core as well as the shell structure.

6.2. Utilization of CO_2 with solid wastes like plastics

The content of carbon dioxide within the atmosphere has increased since the past century leading to various problems including global warming thus it is mandatory to capture CO2 for utilization Various methods including catalytic hydrogenation for converting CO2 having higher efficiency demand hydrogen at high pressure along with noble metals which are highly costly and unfriendly for the environment(Han et al., 2012; Kang et al., 2012; Rosen et al., 2011; Wang et al., 2011, 2015; Zhong et al., 2018). Therefore, the discovery of a new method would be highly considered for utilizing CO2.

Meanwhile, the elevated demand for plastics (especially chlorinated ones) has increased significantly and threatened the environment globally due to marine debris and toxic chemicals emission including furans, biphenyls, etc.(Andreoni et al., 2015; Barbarias et al., 2018; Betts, 2008; Verma et al., 2016) Although, various legislations are imposed to restrict plastic usage inadequacy to manage those wastes leads to a problem. PVC is the most common chlorinated plastic used widely whose treatment is very challenging(Ignatyev et al., 2014). Therefore, an efficient eco-friendly method for treating such chemicals is required.

T. Yoshioka et al. showed that the dichlorination process of PVC is feasible in NaOH/EG solution, where the Cl group is substituted by a hydroxyl group. The reduction of NaHCO3 to formate can be performed under hydrothermal conditions by isopropanol(Shen et al., 2011). This can be taken as an inspiration for utilizing waste PVC to reduce CO2 in the hydrothermal situation. Then Lihui Lu et al. produced a concept of the same where solid waste containing PVC is considered as a hydrogen source for the process of reduction of hydrogen carbonate to formate giving 16% yield and complete dichlorination at once (100% selectivity). In the chlorine-alkali sector, the byproduct of NaCl throughout the planned cycle may be added, thereby ensuring chlorine recovery(Kumagai et al., 2015). Eventually, this cycle may be conceived as a viable way not only of transforming CO2 into valuable chemicals but also of handling PVC waste.

6.3 Biomass Production through Agricultural Wastes

Fruit-processing causes a lot of wastage daily, bananas are a major source. AD(Anaerobic Digestion) technique has been applied with the aim of energy production and waste reduction. Biogas can be generated and have been extensively studied by(Achinas et al., 2019). Organic loading(OL) and Cow manure(CM) effects on the biomass were observed. An inoculum from the mesophilic digester, cow manure, and banana peels from local areas was collected. With an anaerobic bath system, they were worked upon to conclude that OL and CM could in-fact affect degradation performance. This made it clear that before working upon waste a study to be able to decisively find its best performance needed to be conducted.

With a bit tweaking into the Biogasdoneright model a much more efficient version was produced by(Valenti and Porto, 2019). With the action of a GIS system and technical assessment, it was apparent that unprecedented levels of energy can be produced from wastes. Citrus pulp and Olive pomace were the main components studied. The best areas for biogas production were also found(see figure). Transportation cost minimization, logistic cost minimization, and other socio-economic factors were also paid attention to.

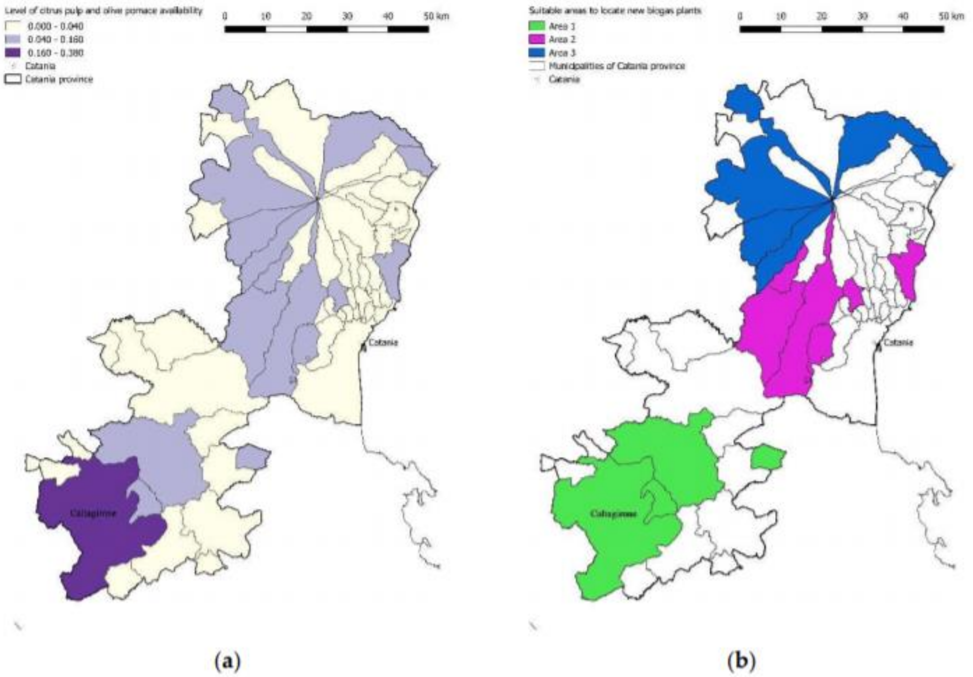

Figure 8: Representation of the areas with better waste potentials in a map evaluated from the method proposed by, reprinted with permission from MDPI(Valenti and Porto, 2019)

7. Conclusion

Solid wastes and its management is an important global issue as it concerns the health of the people as well the health of the environment. It has been witnessed, especially in the developing countries, that solid waste management efficiency is not very appreciable and there are many factors responsible for this. The wastes generated by the households are generally collected and disposed of by the local municipal bodies and it has been seen that right from the first step in waste management, which is the collection step to the ultimate step of disposal and recycling, there is lack of planning. Various aspects like applying proper segregation methods, choosing appropriate disposal sites, choosing the best transportation route for the commutation of the solid wastes from its source to its final destination are responsible for designing a proper technique for efficient waste management. The damage that open disposal of all the kinds of wastes can cause is massive. It has been evaluated that half of the household wastes disposed of in open lands are extremely toxic. These toxic substances include batteries, plastics, and other non-biodegradable wastes. It is known that technology can be a great friend to mankind if used with wisdom and the same is the case with the technical application in the process of waste management. In this article, we have aimed to review a variety of different technologies that are meant to aid the different aspects of waste management. For instance, the Geographical Information System (GIS) is one of those technologies which provide a computational analysis of solid waste by analyzing various factors like the appropriate locations for disposal or the routes which may be used for better transportation, etc. There are other models such as the Mixed Integer Programming Model (MIPM), Scoring Model, Simulated Annealing, etc. The results obtained from these technologies can help the humans to develop an understanding to manage the wastes in a better manner, for example, by reutilizing the CO2 produced from plastic-based wastes or by producing biomass from the agricultural wastes which can later be used either as compost and give a better agricultural yield or can also be used to produce biofuels and therefore, replace the non-renewable sources of energy. For the management of a particular waste, there is one particular method which is the most efficient one to treat that kind of waste. Many analyses are carried out to devise that particular pathway for different wastes. It can be said that these technologies can facilitate a more efficient method of waste management, however, as responsible human beings, it is our responsibility that we must control the amount of solid waste we generate in our daily lives and we must also have the awareness of minimizing the use of those wastes which are harmful to the health of the earth as well as to the health of its inhabitants.

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