Carbon Sequestration within Landfill by Alkaline Waste: An Innovative Exploration

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ABSTRACT

The aim of this paper is to explore the use of construction and demolition (C&D) waste to capture carbon dioxide, generated inside the landfill as byproduct of biodegradation of solid waste. Theoretical estimation have been made of the total amount of C&D waste required to capture CO_2 generated through the biodegradation of one ton of Municipal Solid Waste of Indian characteristics, which estimates average volume of C&D waste required is 0.1794m$^{3.}$ An economic analysis has also been done which revels a net profit of Rs. 56.76 worth carbon credit for one tonne of MSW (with application of factor of safety and neglecting transpotation cost)for a conventional landfill .

1. INTRODUCTION

Industrial reforms in Asia, Europe and South American countries in last one decade reflected abnormal rise in greenhouse gases, especially of carbon dioxide and methane. The harmful effects of presence of greenhouse gasses in atmosphere are global warming, climate change, ozone depletion, sea level rise, adverse effects on biodiversity etc.The sustained rise of greenhouse gases along with El Nino and La Nina conditions, the earth is experiencing warming effects

A number of human activities, processes and consumptions, produce waste gasses or greenhouse gasses that are harmful to the environment among them Solid waste disposal on land is one of the chief sources of these gasses especially in India where population increases exponentially. Some of the reasons for this population explosion are poverty, better medical facilities, and immigration from the neighboring countries of Bangladesh and Nepal. The population density of India in 1996 was about287 persons per square kilometer (Encyclopedia Britannica, Internet). The population in India continues to increase at an alarming rate. Among many one of the negative effects of this is rise in the quantity of solid waste hence increase in emission of Green house gasses as byproduct of their biodegradation.

After all the treatment technology option for municipal solid waste, sanitary land filling is the final and ultimate disposal method of municipal solid waste. Landfill have served as ultimate waste receptors for municipal refuse, industrial or agricultural residue, wastewater sludge, incinerator ash, recycle discards, and/or treated hazardous waste. The sanitary landfill has proved to be the most economical and acceptable method for disposal (Khajuria et al., 2008). A sanitary landfill is a carefully constructed space on the ground to store waste, as it gradually breaks down into chemically inactive material. The landfill is filled by the garbage and it's also covered by clean layer of soil. These actions make landfill a safe place to bury garbage but in future, such waste disposal will demand a wide large land area for landfill disposal purpose. Land is considered greatest among the other natural resources.

According to the report "Real Estate Construction- India" The current size of the real estate construction industry in India is estimated to be approximately US$44 billion. The industry is expected to witness an annual average growth rate of approximately 26 percent till 2014.Construction and demolition waste is generated whenever any construction/demolition activity takes place such as building roads, bridges, fly over, subway, remodeling etc. It consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, wood, plastics etc. A part of this waste comes to the municipal stream. These wastes are heavy, having high density, often bulky and occupy considerable storage space either on the road or communal waste bin/container. It is not uncommon to see huge piles of such waste, which is heavy as well, stacked on roads especially in large projects, resulting in traffic congestion and disruption. Waste from small generators like individual house construction or demolition, find its way into the nearby municipal bin/vat/waste storage depots, making the municipal waste heavy and degrading its quality for further treatment like composting or energy recovery. Often it finds its way into surface drains, choking them. Itconstitutes about 10-20 % of the municipal solid waste excluding large construction projects). It is estimated that the construction industry in India generates about 10-12 million tons of waste annually.As India is one of the fast developing country where cities are growing very fast with improving their infrastructure as land islimited, improvement in infrastructure is carried out by demolishing the previous or obsolete one which leads to generation of more and more construction &demolition (C&D) waste and the proper disposal of this huge quantity of C&D waste is itself a problem.

As we are facing two problems simultaneously the one emission of carbon dioxide, a chief Greenhouse gas, in atmosphere through biodegradation of huge quantity of Solid waste which is increasing rapidly and the second one is the proper disposal of huge amount of C&D waste. If we think wisely we will find both of them are complementary to each other as one is the solution of the others. It is experimentally proved that among many alkaline waste C&D waste is one of the potential source for landfill CO_2 sequestration. So if we can use judiously these C&D waste inside the landfill along with soil as covering layer of each cell or around the vent pipe, used for capturing landfill gas, we would kill two birds by one stone i.e.we can sequester CO_2 inside the landfill by C&D waste and have the proper utilization of these resources whose proper disposal is itself a burning problem.A lot of work has been done to capture methane from the landfill but still none of work has been done to capture the CO_2(40% to60% of total landfill gas)generated from the landfill. In India still there in no regulation of CO_2 emission control but according to Kyoto Protocol there is an urgent need to frame such regulation.Thus this novel idea or research will help us in moving one step forward in this direction.

Carbon sequestration describes long-term storage of carbon dioxideor other forms of carbonto either mitigate or defer global warming and avoid dangerous climate change.The chief methodologies through which we can sequestrate CO_2 are: *(1).Geological sequestration:*It involves injecting carbon dioxide directly into underground geological formations. Declining oil fields, saline aquifersandunminablecoal seams have been suggested as storage sites. (*2). Ocean-based sequestration:*Another proposed form of carbon sequestration in the ocean is direct injection. In this method, carbon dioxide is pumped directly into the water at depth, and expected to form "lakes" of liquid CO_2 at the bottom. The liquid CO_2 reacts to form solid CO_2clathrate hydrates, which gradually dissolve in the surrounding waters. (3)*Mineral Sequestration:*Mineral sequestration aims to trap carbon in the form of solid carbonate salts. This process occurs slowly in nature and is responsible for the deposition and accumulation of limestone over geologic time.

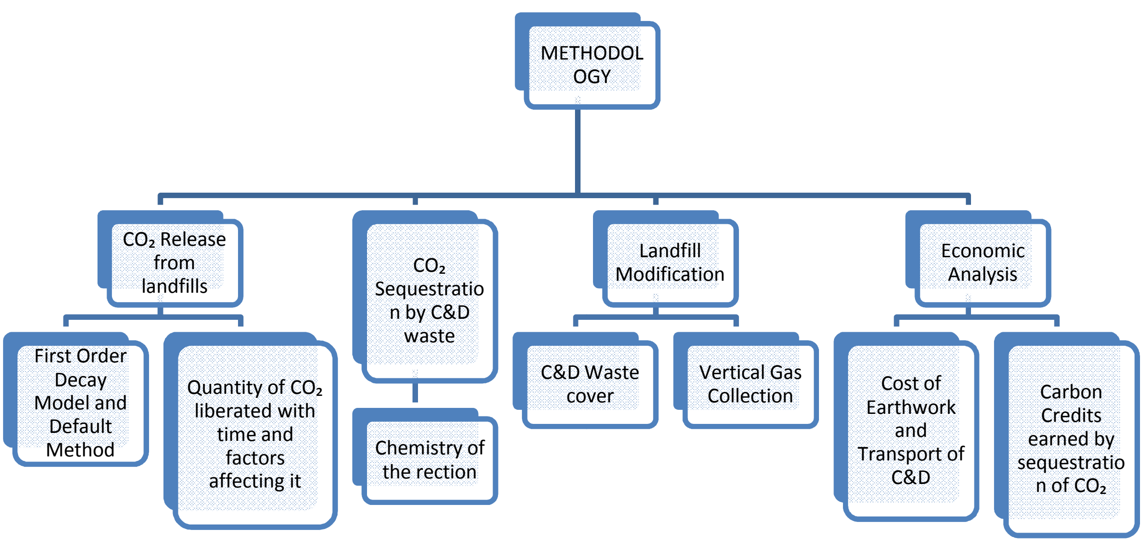
2. LITERATURE REVIEW

A lot of work has been done on Carbon sequestration by various scientists such asHuijgen&Comans (2005) have introduce the use of solid residues as an alternative feedstock for mineral carbon sequestration .They find out that that C&D-waste, steel slag and MSWI (municipal solid waste Incinerator) bottom ash has high potential of CO_2 sequestration. Uibu&Kuusik(2009) have studied the behavior of lime as the key component of ash in various conditions was studied and the mechanism of process deceleration was proposedMineral CO_2 Sequestration in alkaline solidresidueswas carried out by Huijgen et al, (2004). In this work they have shown that carbonation of steel slag is possible at relatively mild conditions.

Mineral sequestration studies were pioneered by Seifritz(1990) and further researchwas conducted by Dunsmore (1992). Carbonation reaction could be achieved byvarious pathways like underground injection method (Gunter et al, 1993) mineral derived Mg $(OH)_2$ process (Lackner et al, 1995) aqueous phase reaction (Kojima et al, 1997) and carbonic acid pathway(O'Connor et al, 2000).Huijgen&Comans(2003)has studied theCarbon dioxide sequestration by mineral carbonationand found that the mineral CO_2 sequestrationtechnology seems to be an attractive and achievable option for carbon dioxide storage.Mineral carbonation process involves bringing in contact high concentration of CO_2 with metaloxides, resulting in formation of stable carbonates (Seifritz, 1990; Lackner et al, 1995). Carbonationreactions have been investigated widely in alkaline waste material, showing potentially a feasibleoption to decrease the CO2 emissions in the atmosphere (Bertos et al, 2004; Huijgen et al, 2005).The work on Sequestering CO_2 by mineral carbonation: stability against acid rain exposure is done by they showed the stability of such carbon sinks against acid rain and other sources of strong acids is examined and it is acknowledged that in the presence of strong acid, carbonates will dissolve and release carbon dioxide. Cost Assessment of CO2 Sequestration by Mineral Carbonationis carried out by Yeboah (2006) they assesses the cost of sequestering CO2 produced by a ZEC (zero emission coal) power plant using solid sequestration process

CO_2 Sequestration Potential of Construction and Demolition Alkaline Waste Material in Indian Perspective is done by Gupta et al (2011), they demonstrated the evaluation of CO_2 sequestration potential of C&D waste.According to their result C&D waste could be an attractive and potential method to reduce the CO2 emissions in the atmosphere. Their experimentation investigation forms the first feasibility study to demonstrate that degree of carbonation achievable in C&D waste, for 16hr at w/s ratio of 0.4 is 38.44%. This confirms the possibility for utilization of C&D waste for future mitigation of CO2. Thus it seems that the use of C&D waste holds promising for sequestration of CO2 by carbonation reaction as it does not find economical importance in construction industry.

3. METHODOLOGY



In this section of the project, we try to estimate the amount of carbon dioxide that is released from the landfills and how can C&D waste be used for the sequestration of this CO_2 and thus preventing it from being released into the atmosphere.The methodology is divided into the following subparts which are represented in the form of a flow chart.

3.1How to estimate CO_2 released from landfills-

There are various models in use for the estimation and calculation of the amount of CO_2 that is released from the landfills. Two of the most accurate and commonly used models are the following-

1. First Order Decay Model

2. Default Method

LandGEM Model- Landgem is a model developed and made available by US-EPA (2010). It is a first order decay model with separate decay values for **k** conventional regions

3.1.1First Order Decay Model-

DOC_f= Fraction DOC dissimilated. It is a portionof DOC that is converted to LFG. Theestimates are based on a theoretical modelthat varies only with the temperature in theanaerobic zone of a landfill site. The modelis described as 0.014T+0.28, whereT=temperature in degree centigrade (Tabasaran, IPCCdocument 1996). It is assumed that temperatureremains constant at 35°C in theanaerobic zone of the landfill. The value isthus computed as 0.77 and adopted.F= Fraction of methane in LFG (default is0.5). The fraction of methane in LFG isassumed 0.5 as default value and adoptedThus calculating the above values and modifying the Land GEM according to our data solves the purpose and fits the Land GEM model according the Indian MSW configuration.

3.1.1.1Default Method-

The default method is based on the following equation- Methane emissions (Gg/yr) = (MSWT x MSWF x MCF x DOC x DOC_Fx F) x (16/12-R) x (1-OX)Where, MSWT : total MSW generated (Gg/yr)MSWF : fraction of MSW disposed to solid waste disposal sitesMCF : methane correction factor (fraction)DOC : degradable organic carbon (fraction) (kg C/ kg SW)DOC_F : fraction DOC dissimilatedF : fraction of CH4 in landfill gas (IPCC default is 0.5)16/12 : conversion of C to CH4R : recovered CH4 (Gg/yr)OX : oxidation factor (fraction – IPCC default is 0)It is to be noted that in a conventional landfill, the amount of methane generated isapproximately 47.4% and the amount of Carbon dioxide generated is 47% and hence theamount of CO_2 liberated can be assumed equal to that of CH_4 and can be calculated by the above model.

3.1.2Quantity of CO_2 liberated with respect to time-

It is very important in the case of landfill to calculate the amount of CO_2 that is liberated peryear as the degradation of the MSW takes place in the landfill. Of the following rate graphs presented, in our project we concentrate on a hybrid of the Sheldon Arleta Model and the Emcon MGM model.The constant rate model has been ruled out because the rate of CO_2 emission is not reportedto be constant in the case of landfills. Moreover, the Scholl Canyon model assumes that theCO_2 emission decreases exponentially. Whereas in our study, we find thatthe CO_2 emission rate gradually increases and reaches a peak at about 6years from the time of placement and then starts to decrease. Hence, theabove mentioned models, i.e. Sheldon Arleta and Emcon MGM Models are consistent with this approachIt is seen that the amount of Carbon dioxide released from the landfill first rises exponentially and after reaching a peak value, starts decreasing. Hence it is important to keep in mind this variation in the amount of CO_2 released with time while designing the landfill and calculating the amount of alkaline waste material that is required to sequester the released amount of CO_2.

3.2 CO_2 Sequestration by C&D waste

When the released CO_2 comes in contact with the C&D waste, the following reactions take place leading to the formation of Calcium and Magnesium Carbonates and thereby trapping the released CO_2.

(1) (Mg, Ca)xSiyOx+2y+zH2z + $xCO_2 \rightarrow x(Mg, Ca)CO_3 + ySiO_2 + zH_2O$

(2)$1/3\ Mg_3Si_2O_5(OH)_4 + CO_2 \rightarrow MgCO_3 + 2/3\ SiO_2 + 2/3\ H_2O$ + 64 kJ/mol

(3) $1/2\ Mg_2SiO_4 + CO_2 \rightarrow MgCO_3 + 1/2\ SiO_2$+ 90 KJ/mole

The above equations represent how CO_2 reacts with C&D waste and gets sequestered by getting converted into Carbonate. The composition and exact chemical formula of C&D waste depends on the composition of the waste and varies from place to place.A more simplified mechanism of the reaction of Alkaline waste with CO_2 can be represented in the form the following two equations (Huijgen and Comans, 2005)

(1) Calcium Silicates:$CaSiO_3 + CO_2 \rightarrow CaCO_3 + H_2O$

(2) Portlandite: $Ca\ (OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Studies on the extent of Carbonation by C&D waste have already been carried out (Gupta and Nema, 2012) and the shows the potential of sequestration of various alkaline wastes as-

Table:-1CO_2 sequestration potential (%) presented as the mass of CO2 that can be sequestered per dry mass of waste Source:-(Gupta andNema, 2012)

Alkaline waste	CO2 Sequestration Potential (%)
Fresh Raw ESP Dust	31.26
Marble Dust	31.59
Hospital Incineration Ash	17.76
Fly Ash	5.73
Limestone mine Soil	26.25
Bag House Dust	28.13
Construction & Demolition Waste	23.62
Landfill Soil	11.57
Mill Dust	26.50
Cement Bag Filter Dust	30.25
Raw Mill Filter Dust	25.94

3.3 Modification of the Landfill-

The overview of the landfill after covering each unit of Municipal Solid Waste (MSW) by a layer of alkaline waste material and how it would modify the landfill is represented in the following diagram-

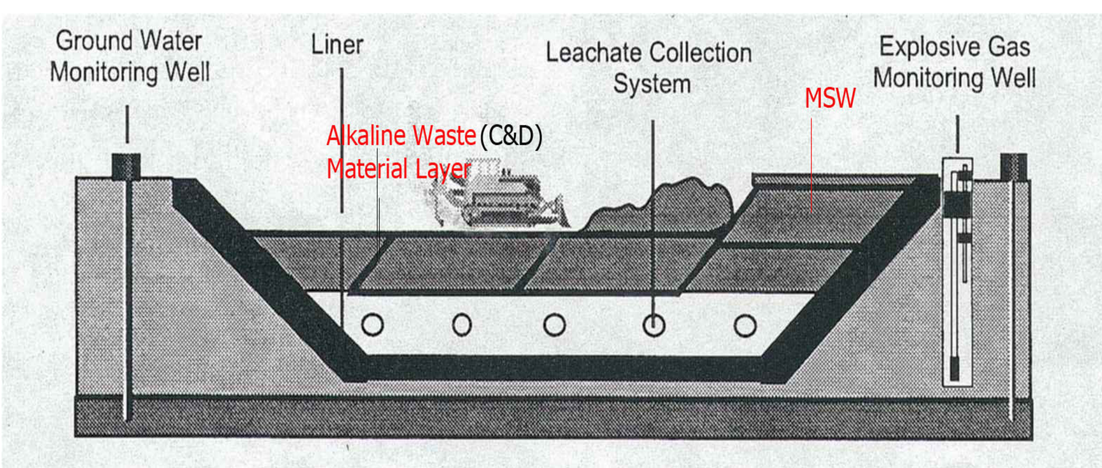


Fig:-1. The cross section of the above landfill is magnified and shown in the diagram below-

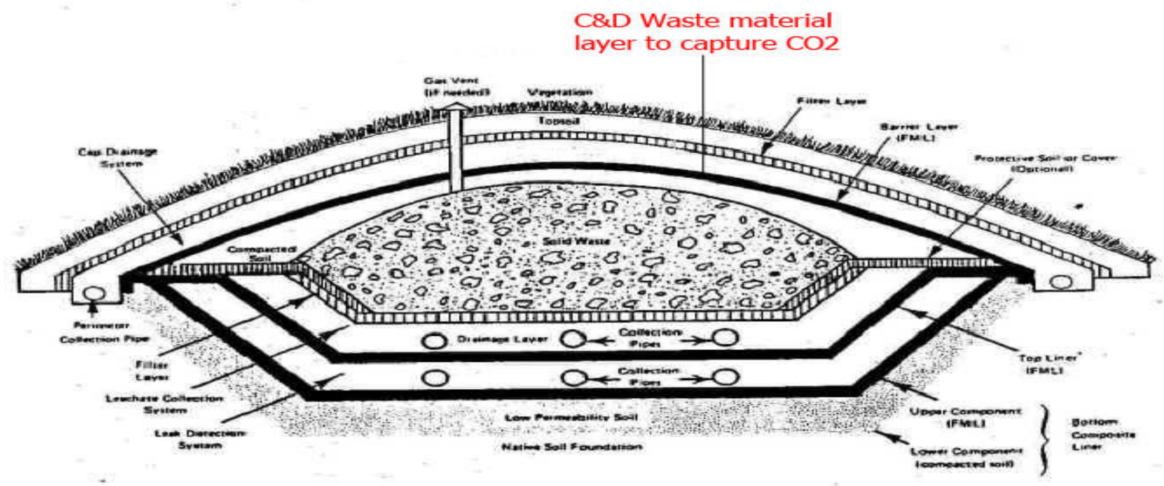


Fig-2.Calculation of the amount of CO_2 generated by 1 ton of MSW-

The calculation of the amount of CO_2 that is generated by 1 ton of MSW is done using both the aforementioned methods, i.e. the First order decay analysis and the Default method after making suitable changes in the calculation parameters which are suited to Indian conditions

First of all we calculate the DOC_f in India using data of various years. (Using Composition of MSW reports published by CPCB for these years.)

DOC_f = 0.4A + 0.17B + 0.15C + 0.3DWe get,

For 1971-73, DOC_f=[0.4*(4.14+3.83) + 0.15 * 41.24] /100= 0.9374

For 1982-85, DOC_f= 0.9567

For 1995-97, DOC_f= [0.4*(5.78 + 3.50) + 0.15 * 41.80]/100= 0.9982

For 2009-10, DOC_f = [0.4* 14.58 + 0.17 * 8.1 + 0.15 * 40 + 0.3 * 2.5]/100 = 0.14047

Taking average of above values, DOC_f = 0.107425Using Default Method, [Where, MSWT : total MSW generated (Gg/yr), MSWF : fraction of MSW disposed to solid waste disposal sites, MCF: methane correction factor (fraction), DOC : degradable organic carbon (fraction) (kg C/ kg SW), DOCF : fraction DOC dissimilatedF : fraction of CH4 in landfill gas (IPCC default is 0.5), 16/12 : conversion of C to CH4, R : recovered CH4 (Gg/yr)OX : oxidation factor (fraction – IPCC default is 0)]

Amount of CO_2 liberated = (MSWT ● MSWF ● MCF ● DOC ● DOCF ● F) ● (16/12-R) ● (1-OX)= 1 * 1 * 0.6 *

0.77 * 0.1074 * 16/12 * 1 = 0.06615 ton

Amount of C&D Waste required to sequester the CO_2 = 0.06615 *(100/ 23.620) ton(Sequestration Potential = 23.62)= 0.2801 ton

Volume of C&D Waste required = 0.2801 / 2.54 m^3 = 0.11027 m^3

(Average Bulk Density of C&D Waste = 2.54 tonnes/m^3)Using Land GEM Model,

The amount of CO_2 liberated can be calculated using the Land GEM model as discussed earlier. The basic first order equation that the Land GEM uses is-

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10} \right) e^{-kt_{ij}}$$

Where,

QCH4 = annual methane generation in the year of the calculation *(m3/year)*

i = 1-year time increment,

n = (year of the calculation) - (initial year of waste acceptance)

j = 0.1-year time increment

k = methane generation rate (*year-1*)

Lo = potential methane generation capacity (*m3/Mg*)

Mi = mass of waste accepted in the i^{th} year (*Mg*)

t^{ij} = age of the j^{th} section of waste mass Mi accepted in the i^{th}year

The amount of CO_2 liberated is approximately equal to that of methane and can be calculated using above formula.

Amount of CO_2 liberated= 0.14909 ton

Amount of C&D Waste required to sequester the CO_2 = 0.14909 * (100 / 23.62) ton

(Sequestration Potential = 23.62)

= 0.6312 ton

Volume of C&D Waste required = 0.6312 / 2.54 m^3 = 0.2485 m^3

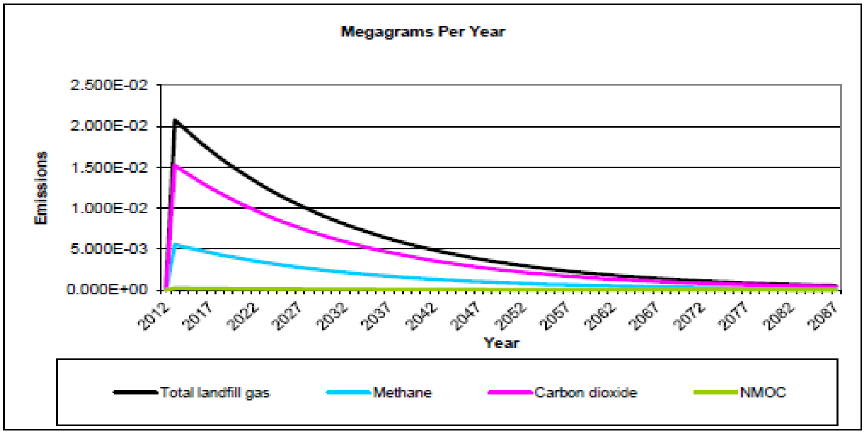
(Average Bulk Density of C&D Waste = 2.54 tonnes/m^3)

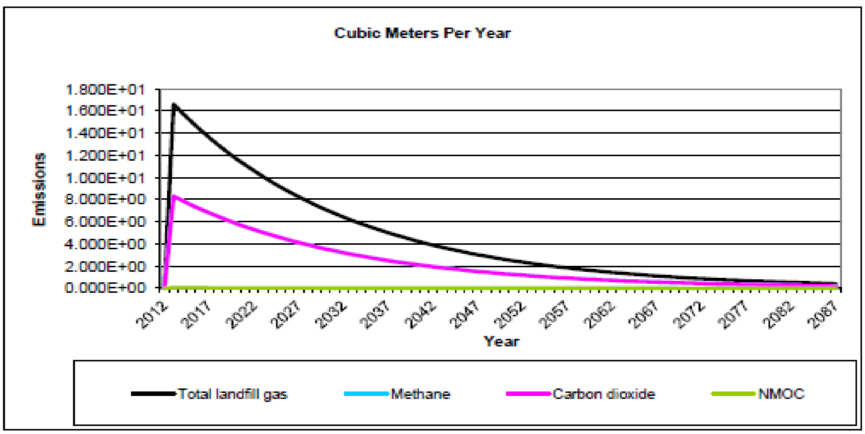
Results (Continued)

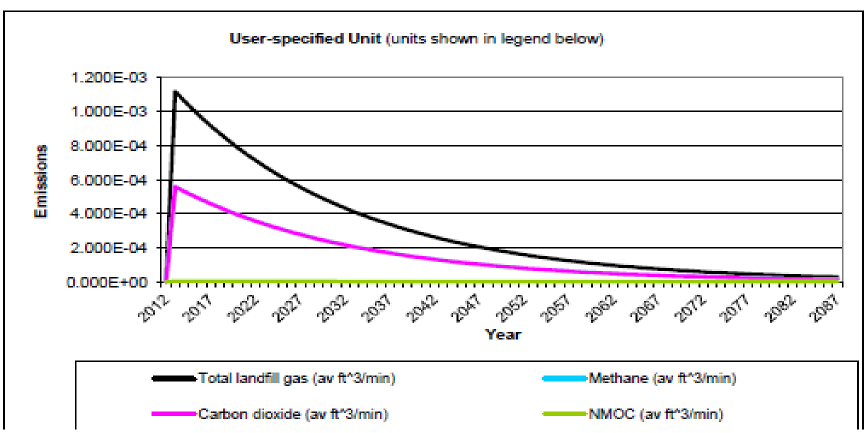
Year	Carbon dioxide			NMOC		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2012	0	0	0	0	0	0
2013	1.521E-02	8.312E+00	5.585E-04	2.383E-04	6.649E-02	4.468E-06
2014	1.447E-02	7.906E+00	5.312E-04	2.267E-04	6.325E-02	4.250E-06
2015	1.377E-02	7.521E+00	5.053E-04	2.157E-04	6.017E-02	4.043E-06
2016	1.310E-02	7.154E+00	4.807E-04	2.051E-04	5.723E-02	3.845E-06
2017	1.246E-02	6.805E+00	4.572E-04	1.951E-04	5.444E-02	3.658E-06
2018	1.185E-02	6.473E+00	4.349E-04	1.856E-04	5.179E-02	3.479E-06
2019	1.127E-02	6.157E+00	4.137E-04	1.766E-04	4.926E-02	3.310E-06
2020	1.072E-02	5.857E+00	3.935E-04	1.680E-04	4.686E-02	3.148E-06
2021	1.020E-02	5.572E+00	3.744E-04	1.598E-04	4.457E-02	2.995E-06
2022	9.701E-03	5.300E+00	3.561E-04	1.520E-04	4.240E-02	2.849E-06
2023	9.228E-03	5.041E+00	3.387E-04	1.446E-04	4.033E-02	2.710E-06
2024	8.778E-03	4.795E+00	3.222E-04	1.375E-04	3.836E-02	2.578E-06
2025	8.350E-03	4.562E+00	3.065E-04	1.308E-04	3.649E-02	2.452E-06
2026	7.943E-03	4.339E+00	2.915E-04	1.244E-04	3.471E-02	2.332E-06
2027	7.555E-03	4.127E+00	2.773E-04	1.184E-04	3.302E-02	2.219E-06
2028	7.187E-03	3.926E+00	2.638E-04	1.126E-04	3.141E-02	2.110E-06
2029	6.836E-03	3.735E+00	2.509E-04	1.071E-04	2.988E-02	2.007E-06
2030	6.503E-03	3.553E+00	2.387E-04	1.019E-04	2.842E-02	1.910E-06
2031	6.186E-03	3.379E+00	2.271E-04	9.690E-05	2.703E-02	1.816E-06
2032	5.884E-03	3.214E+00	2.160E-04	9.218E-05	2.572E-02	1.728E-06
2033	5.597E-03	3.058E+00	2.054E-04	8.768E-05	2.446E-02	1.644E-06
2034	5.324E-03	2.909E+00	1.954E-04	8.341E-05	2.327E-02	1.563E-06
2035	5.065E-03	2.767E+00	1.859E-04	7.934E-05	2.213E-02	1.487E-06
2036	4.818E-03	2.632E+00	1.768E-04	7.547E-05	2.105E-02	1.415E-06
2037	4.583E-03	2.503E+00	1.682E-04	7.179E-05	2.003E-02	1.346E-06
2038	4.359E-03	2.381E+00	1.600E-04	6.829E-05	1.905E-02	1.280E-06
2039	4.146E-03	2.265E+00	1.522E-04	6.496E-05	1.812E-02	1.218E-06
2040	3.944E-03	2.155E+00	1.448E-04	6.179E-05	1.724E-02	1.158E-06
2041	3.752E-03	2.050E+00	1.377E-04	5.878E-05	1.640E-02	1.102E-06
2042	3.569E-03	1.950E+00	1.310E-04	5.591E-05	1.560E-02	1.048E-06
2043	3.395E-03	1.855E+00	1.246E-04	5.318E-05	1.484E-02	9.969E-07
2044	3.229E-03	1.764E+00	1.185E-04	5.059E-05	1.411E-02	9.483E-07
2045	3.072E-03	1.678E+00	1.128E-04	4.812E-05	1.342E-02	9.020E-07
2046	2.922E-03	1.596E+00	1.073E-04	4.577E-05	1.277E-02	8.580E-07
2047	2.779E-03	1.518E+00	1.020E-04	4.354E-05	1.215E-02	8.162E-07
2048	2.644E-03	1.444E+00	9.705E-05	4.142E-05	1.155E-02	7.764E-07
2049	2.515E-03	1.374E+00	9.231E-05	3.940E-05	1.099E-02	7.385E-07
2050	2.392E-03	1.307E+00	8.781E-05	3.748E-05	1.046E-02	7.025E-07
2051	2.276E-03	1.243E+00	8.353E-05	3.565E-05	9.945E-03	6.682E-07
2052	2.165E-03	1.183E+00	7.946E-05	3.391E-05	9.460E-03	6.356E-07
2053	2.059E-03	1.125E+00	7.558E-05	3.226E-05	8.999E-03	6.046E-07
2054	1.959E-03	1.070E+00	7.189E-05	3.068E-05	8.560E-03	5.752E-07
2055	1.863E-03	1.018E+00	6.839E-05	2.919E-05	8.143E-03	5.471E-07
2056	1.772E-03	9.682E-01	6.505E-05	2.776E-05	7.745E-03	5.204E-07
2057	1.686E-03	9.210E-01	6.188E-05	2.641E-05	7.368E-03	4.950E-07
2058	1.604E-03	8.761E-01	5.886E-05	2.512E-05	7.008E-03	4.709E-07
2059	1.525E-03	8.333E-01	5.599E-05	2.390E-05	6.667E-03	4.479E-07
2060	1.451E-03	7.927E-01	5.326E-05	2.273E-05	6.341E-03	4.261E-07
2061	1.380E-03	7.540E-01	5.066E-05	2.162E-05	6.032E-03	4.053E-07

The report obtained from the LandGEM Model is given below-

Graphs







4. ECONOMIC ANALYSIS

This section presents the overall economic analysis of the process of using C&D waste for Carbon dioxide Sequestration. This is done by calculating the total cost of earthwork and transportation required for carrying the C&D waste to the landfill site. (Ref. Delhi Schedule of Rates- 2012, CPWD- New Delhi)

Earthwork filling rates- Rs. 87.6 / m^3 of C&D wasteTransportation Charges- Rs. 12 / m^3 / km

Taking average value of the volume of C&D waste required as calculated by the two methods, we have-Volume of C&D waste required = 0.1794 m^3Hence earthwork filling rate = Rs. 87.6 * 0.1794= Rs. 15.715Transportation charges for carrying the C&D waste for 15 km (Value chosen keeping in mind average distance travelled in Metropolitan cities like Delhi) = Rs. 12 * 0.1794 * 15= Rs. 32.29Total cost incurred = Rs. 48.01Value of 1 carbon credit in Indian Rupees = Rs. 535.55Hence, Value gained by sequestration of 0.15 ton of CO_2 = Rs. 80.33*Hence, Net Profit per ton of MSW = **Rs. 32.32***Moreover, the transportation charges can be neglected as already the C&D waste has to be carried to some other place even if it is not used for carbon dioxide sequestration in the landfill. *Hence, Net Profit per ton of MSW (Neglecting transportation cost)=**Rs. 64.62***Some part of the C&D waste may also remain unreacted with the CO_2 and as a precaution, we include a Factor Of Safety in our calculation of 1.5Hence, total volume of C&D waste required applying factor of safety = 0.1794 * 1.5 m= 0.2691 m^3Earth filling rate (after applying factor of safety) = Rs. 87.6 * 0.2691 = Rs. 23.57

*Hence, Net Profit per ton of MSW (Applying factor of safety and neglecting transportation) = **Rs.56.76***

The monetary benefits become even more significant when we talk about the total amount of CO_2 sequestration in daily scenario. The MSW deposited approximately 6 years before would at the present time give its peak of CO_2 emission according the rate of CO_2 emission model discussed previously.

We find that about 6 years before that is in 2005, **daily amount of MSW generated in metropolitan cities (reference Delhi) was about 5, 922 tonnes** (Ref.CPCB, with the assistance of National Environmental Engineering Research Institute (NEERI)) . We assume that on an average even if about 70% of this MSW is subjected to landfill decomposition, then the daily profit produced today would be-

Hence, Net Profit per day = Rs. 2, 35, 293

As the above calculations suggest, we conclude that, Overall, the total capital saved exceeds the capital investment made and hence a net profit is obtained.

5. SUMMARY AND CONCLUSIONS

Calculation of the amount of CO_2 released during the decomposition of one Ton of Municipal Solid Waste of Indian characteristics have been done by both Default model and Land Gem model and .06615 ton & .14909 ton of CO_2 was calculated by respective models, then the amount of Construction & Demolition waste required to sequester these amount of CO_2 is done which estimated 0.11027m^3 and 0.2485m^3 of C&D wastefor different value of CO_2, calculated by different models .After that an Economic analysis is done, taking the average value of both the values of C&D waste and found Net Profit per ton of MSW (Applying factor of safety and neglecting transportation cost of C&D)= **Rs.56.76** worth carbon credit .The monetary benefits become even more significant when we calculated the total amount of CO_2 sequestration in daily scenario. The MSW deposited approximately 6 years before would at the present time give its peak of CO_2 emission according the rate of CO_2 emission model. Hence taking the data of MSW generated in 2005, the calculated ***Net Profit per day***(Applying factor of safety and neglecting transportation costof C&D) **=*Rs. 2, 35, 293***which is really a surprising amount and force us to think about that. Through this paper an effort have been made to draw the attention of people in searching the solution, within the problem. A lot of work have been done to capture the CH_4 releases through landfill but none of work still is carried out to capture the approx equal amount of CO_2 released through the same source, this paper explores the possibilities of research in this direction which would not only be an innovative technique to mitigate the global warming but would also be a source earning handsome Carbon Credits.

REFERENCES

[1] Agamuthu, P., Fauziah S.H., Khidzir, S.H., K.M. and Noorazamimah, A.A.(2007)'Sustainable waste management - Asian perspectives'. Proceedings of the International Conference on Sustainable Solid WasteManagement.5-7 September, 15-26 (2007). Chennai, India.

[2] Allen DJ, Brent G.F.(2010)'Sequestering CO(2) by mineral carbonation:stability against acid rain exposure', *Environ Science Technol*, 2010 Apr 1;44(7):2735-9.

[3] Annepu R. K.(2012), 'Sustainable Solid Waste Management in India', Columbia University in the City of New York January 10, 2012.

[4] Badarinarayana M. C.(2003), 'National Solid Waste association of India' Workshop on Bio-medical Waste Management, Mumbai, India, April 26, 2003.

[5] Central Bureau of Statistics(2007):CPCB (2000) 'Status of Solid Waste Generation, Collection, Treatment and Disposal in Metrocities', Series: CUPS/46/1999–2000.

[6] Central Pollution Control Board(2005-06)**, '**Health Status of Conservancy Staff and Other Community Associated with Municipal Solid Wastes Management in Kolkata and Chennai', Control of Urban Pollution Series: CUPS/62/2005-06.

[7] Central Pollution Control Board (CPCB)(1998).'Collection, Transportation and Disposal of municipal solid waste in Delhi

[8] (India')- a case study, Central Pollution Control Board, Delhi.

[9] Dunsmore. H.E.(1992), 'A Geological Perspective on Global Warming and the Possibility of Carbon Dioxide Removal as

[10] Calcium Carbonate Mineral', Energy Convers. Mgmgt, 1992, 33 (5-8), pp 565-572.c

[11] Emcon Associates and Jacobs Engineering Co. 1976."A Feasibility Study of Recovery of Methane from Parcel I of the Scholl Canyon Sanitary Landfill" for the City of Glendale, CA, United States.

[12] Eric Adams.E and Ken Caldeira, (2008), 'Ocean Storage of $CO_{2,}$ Mineralogical Society of America'-2008.

[13] Frank E., YeboahTuncel, M. Yegulalp&Harmohindar Singh, Cost Assessment of CO2 Sequestration byMineral Carbonation, ESL-IE-06-05-42.

[14] GDP per capita(2001): http://en.wikipedia.org/wiki/Gross_domestic_product, 2001.

[15] Government Of India Central Public Works Department, Delhi Schedule Of Rates 2012, ISBN :-JBA Book Code : 38690.

[16] Gunter, W.D., Perkins, E.H., and McCann, T.J., 1993. 'Aquifer Disposal of CO2 rich gases:Reaction Design for Added Capacity', *Energy Conversion and Management* 34, pp. 941-948.

[17] Gupta.A and Nema A.K.(2009)'Review on Landfill Gas Emission to the Atmosphere', *European Journal of Scientific Research* ISSN 1450-216X Vol.30 No.3 (2009), pp.427-436, EuroJournalsPublishing, Inc. 2009http://www.eurojournals.com/ejsr.htm.

[18] Gupta, A., Bhavya M., and Nema, A.K.(2011)'CO2 Sequestration Potential of Construction and Demolition Alkaline Waste Material in Indian Perspective', *World Academy of Science, Engineering and Technology* 78 2011.

[19] Gupta, A and Nema, A.K.(2012) 'Assessment of Mineral Sequestration of Landfill CO2 Achievable using Alkaline Waste Residues', *European Journal of Scientific Research,* ISSN 1450-216X Vol.73 No.4 (2012), pp. 480-488 © EuroJournalsPublishing, Inc. 2012http://www.europeanjournalofscientificresearch.com.

[20] Huijgen W.J.J, and Comans, R.N.J., (2003) 'Carbon Dioxide Sequestration by Mineral Carbonation Literature Review, Energy Resource Center of the Netherlands', *ECNC-03-016, 2003*.retrieved on 29.12.2010.

[21] Huijgen, W.J.J., Witkamp, G.J., Comans, R.N.J., (2005). 'Mineral CO2 sequestration by steel slag carbonation', *Environmental Science & Technology* 39 (24), pp. 9676–9682.

[22] Intergovernmental Panel on Climate Change (IPCC), (1996).Report of the Twelfth Season of the Intergovernmental panel on Climate Change, Mexico City, 11–13 September 1996.

[23] Juan Carlos Abanades, Rodney Allam, Klaus S. Lackner, FrancisMeunier, Edward Rubin, Juan Carlos Sanchez, KatsunoriYogo& Ron Zevenhoven, Mineral carbonation and industrial uses of carbon dioxide, IPCC Special Report on Carbon dioxide Capture and Storage.

[24] Khajuria, A., Y. Yamamoto and T. Morioka: Solid waste management in Asian countries: problems and issues. Proc. of 4th International Conference on Waste management and environment, June, 2-4, 109, 643-653 (2008).

[25] Kim A.G. and Kissell F.N. (1986) Methane formation and migration in coalbeds. In, Methane control research: summary of results, 1964-80. U.S. Dept. of the Interior, Bureau of Mines Bulletin/1988, Bulletin 687, Deul M. and Kim A.G (eds.) Chapter 3, pp. 18-25.

[26] Kojima, T., Nagamine, A., Ueno, N., Uemiya, S., 1997. "Absorption and Fixation of CarbonDioxide by Rock Weathering", Proceedings of the Third International Conference on Carbon dioxide Removal, Cambridge Massachusetts, September 9-11, 1996, Energy Conversion and Management 38, pp. 461-466

[27] Maroto-Valer, M.M., and Fauth, D.J. “Activation of magnesium rich minerals as carbonation feedstock materials for CO2 sequestration”, *Fuel Processing Technology* 86, pp.1627-1645 ., 2005.

[28] Maroto-Valer, M.M., and Fauth, D.J. (2005). ‘Activation of magnesium rich minerals as carbonation feedstock materials for CO2 sequestration’, *Fuel Processing Technology*86, pp. 1627-1645.

[29] Nandi S.P. and Walker, Jr. P.L. (1965) ‘The diffusion of nitrogen and carbon dioxide from coals of various Rank’. *Fuel **44***, 385-393.

[30] National Solid waste Association of India, (2003).*’Urban Municipal Solid Waste Management’*. Special Bulletin of the National Solid Waste Association of India (inaugural issue), Mumbai, 2003.

[31] O’Connor, W. K., Dahlin, D. C., Turner, P. C., and Walters, R.P.(2000) “Carbon Dioxide Sequestration by Ex-Situ Mineral Carbonation”, Technology 7S, pp. 115-123.

[32] O’Connor, W.K., Dahlin, D.C., Rush, G.E., Dahlin, C.L., and Collins, W.K.(2002)’Carbon dioxide sequestrationby direct mineral carbonation: process mineralogy of feed and products’, Minerals& Metallurgical Processing

[33] 19(2), pp. 95-101.

[34] RanjithKharvelAnnepu, (2012)’*Sustainable Solid Waste Management in India’*, A research report, sponsored by Waste- to-Energy Research and Technology Council (WTERT) January 10, 2012

[35] “Real Estate Construction - India” available at http://www.reportbuyer.com/go/IAP00001.

[36] Ron Zevenhoven and Jens Kohlmann(2001), ’CO_2 Sequestration By Magnesium Silicate Mineral Carbonation In Finland’, Second Nordic Minisymposium on Carbon Dioxide Capture and Storage, Göteborg, October 26, 2001.

[37] Schroeder, U.S. Department of Energy, National Energy Technology Laboratory, E. Ozdemir& B.I. orsi, ” Sequestration of Carbon Dioxide in Coal Seams”, University of Pittsburgh Chemical & Petroleum Engineering Department 1244 Benedum Hall Pittsburgh, PA 15261.

[38] Seifritz, W.(1990), ‘CO2 disposal by means of silicates’, *Nature* 345 (6275), pp. 486. DOI:10.1038/345486b0.

[39] The Expert Committee, (2000), *’Manual on Municipal Solid Waste Management’*. The Ministry of Urban Development, The Government of India, Volume 1 and 2.

[40] UNEP: http://www.unescap.org/stat/data (2001).Uibu.M, R. Kuusik, (2009), ’Mineral Trapping Of Co2 Via Oil Shale Ash Aqueous Carbonation: controllingMechanism Of Process Rate And Development Of Continuous-Flow Reactor System’, ISSN 0208- 189X, Estonian Academy Publishers-2009, Oil Shale, 2009, Vol. 26, No. 1, pp. 40–58 ISSN 0208- 189X doi: 10.3176/oil.2009.1.06.

[41] Wouter Huijgen1, Geert-Jan Witkamp& Rob Comans, (2004)’Mineral Co2 Sequestration In Alkaline Solid Residues’, The Seventh International Conference on Greenhouse Gas Control Technologies(GHGT-7) in Vancouver, Canada 5th -9th September, 2004, ECN-RX--04-079.

[42] Yeboah, F. E., Yegulalp, T. M., Singh, H.(2006), ’Cost Assessment of CO2 Sequestration by Mineral Carbonation’, *L-IE-06-05-42,* Proceedings of theTwenty-Eighth Industrial Energy Technology Conference, New Orleans, LA, May 9-12, 2006.

[43] Zevenhoven Ron And Jens Kohlmann(2001), ’Co2 Sequestration By Magnesium Silicate Mineral Carbonation In Finland’, Second Nordic Minisymposium On Carbon Dioxide Capture And Storage, Göteborg, October 26, 2001.