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Urban Solid Wastes: a non conventional resource of energy; estimation of the availability in Mexico

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Resumen

Se llevó a cabo un análisis para determinar la disponibilidad de Residuos Sólidos Urbanos (RSU) en México generados en el periodo 2005-2014, con el fin de estimar el potencial energético considerando la fracción orgánica de residuos viables a una conversion anaerobia. Además, con el objetivo de realizar una comparación con los escenarios sostenibles implementados por la Organización de las Naciones Unidas (ONU) que corresponden a 17 metas enfocadas a un desarrollo sostenible y bienestar social, se estimaron los valores del potencial energético para el 2020 y 2030.

Se obtuvo que la mayor generación de RSU se encuentra en el centro del país. Se identificaron las ciudades que contribuyen con al menos 200 mil kg de RSU per cápita, teniendo a los estados de México, Ciudad de México, Guanajuato y Jalisco como los generadores más importantes, y considerando el potencial energético, junto con Veracruz, éstos se encuentran en los primeros lugares.

Los resultados de este trabajo permitieron considerar la posibilidad de utilizar los RSU como fuentes de energía alterna que permitan implementar escenarios sostenibles en México para un mayor desarrollo y bienestar social, incidiendo en acciones para la mitigación de impactos ambientales negativos.

Residuos sólidos urbanos, potencial energético, biogás.

Abstract

An analysis was performed in order to determine the availability of Urban Solid Wastes (USW) generated in Mexico during 2005-2014; it was considered the organic fraction viable for an anaerobic conversion. In addition, in order to make a comparison with sustainable scenarios implemented by the United Nations (UN) corresponding to 17 goals focused on sustainable development and social well-being, values of the energy potential were estimated for 2020 and 2030.

The Mexican central states showed the major generation of USW. The cities that contribute at least 200,000 kg of USW per capita belong to the states of Mexico, Ciudad de Mexico, Guanajuato and Jalisco; considering the potential energy, Veracruz state is included.

The results of this work allow to see the possibility for using USW as an alternative source of energy in Mexico and influence on the national development and social well-being, contributing to the mitigation of negative environmental impacts.

Urban solid wastes, energy potential, biogas, sustainability

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Introduction

Mexico is situated among the main countries generators of methane from landfills and is located in the top ten countries producers of Urban Solid Wastes (USW) worldwide (Vera, 2014).

The amount of solid wastes produced in our country increased according to the National Institute of Ecology. The national average wastes generation increased from 0.7 kg per capita per day in 1987 to 0.8 kg in 1998. In addition, the fewer generation corresponds to semi-rural or rural areas, while the bigger generation correspond to the metropolitan areas as Mexico City (INECC,2012).

During years the generated USW were piled in an open place. Both population growth and increasing consumption of manufactured goods has become impractical and irresponsible (CESOP, 2012).

According to the Mexican National Energy Balance (NBS, 2008), the primary energy production is 10,500 PJ, 89% corresponds to hydrocarbons and the rest is distributed as follows, 5.5% for primary electricity, biomass 3.3% and coal 2.2%. From the above statistics, we can deduce that the Mexican economy depends on hydrocarbons. However, various factors such as the decline in national reserves and the recent global financial crisis have motivated to use renewable energy (Romero, 2011).

Therefore, the use of USW to generate alternative energy, would generate a great impact on a country like Mexico.

There are various processes for conversion of wastes. One of them, is the production of biogas from the anaerobic fermentation of biomass, which is based on the transformation of organic matter, through a series of biochemical reactions in presence of microorganisms (Chamy, 2007).

Elango et al (2007) have reported the high potential of municipal solid wastes as feed-stock for anaerobic digestion for biogas production. The levels of organic matter produced per capita vary considerably from developed to developing countries, however, the anaerobic digestion of organic wastes is a highly feasible technology for energy production (Ofori, 2013).

On the other hand, energy scenarios provide a framework for exploring future energy perspectives, including various combinations of technology options and their implications. Many scenarios illustrate how energy system developments will affect the global issues. Some describe energy futures that are compatible with sustainable development goals, such as improved energy efficiencies and the adoption of advanced energy supply technologies. Sustainable development scenarios are also characterised by low environmental impacts and equitable allocations of resources and wealth (WEA, 2000).

In the present paper we considered an organic fraction of 53 percent of USW, according to the national characterization of residues (SEDESOL, 2004), this fraction can be converted to biogas like an alternative source of energy during 2005-2010 and the estimate for the years 2020 and 2030.

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Material and methods

Recollection of historical data

In order to calculate the energy potential of each city in Mexico it was necessary to obtain the population for each year in the lapse of study.

The information was collected from the database of the National Institute of Statics and Geography (INEGI) for 2015; the growth rate per year of the population was estimated.

It was considered a different growth rate for each State according to the study carried out by INEGI from 1990-2010.

Also, the total and projected amount of USW generation per capita was taken by National Population Council (CONAPO) analysis for 2000-2050 and it was considered that this could be linear as population growth. The generation is given as kg/hab/day.

Estimation of energy potential of USW

This estimation was made considering the availability of USW.

It was considered the per capita generation values reported by CONAPO (2003), only the organic fraction was considered.

The energy potential of the USW (EPUSW) was estimated by employing equation 1 (EPA,1996).

$$\text{EPUSW} = \text{CB} * (0.10\frac{\text{cf}}{\text{lb}} * 2000\frac{\text{lb}}{\text{Ton}}) * (500\ \frac{\text{BTU}}{\text{cf}}) * (1/(12{,}000\frac{\text{BTU}}{\text{kWh}})) * (\frac{1\ \text{día}}{24\ \text{h}}) \quad (1)$$

Where

EPUSW= Energy Potential of Urban Solid Wastes (kW)
CB= Urban solid wastes generated per day (Ton)

Results

Estimation of the energy potential

Figure 1 shows the average over the 10 years of the energy potential for each state.

In this case it is possible to observe that Edo. de México, Ciudad de México and Veracruz are the most important states with respect to generation of energy.

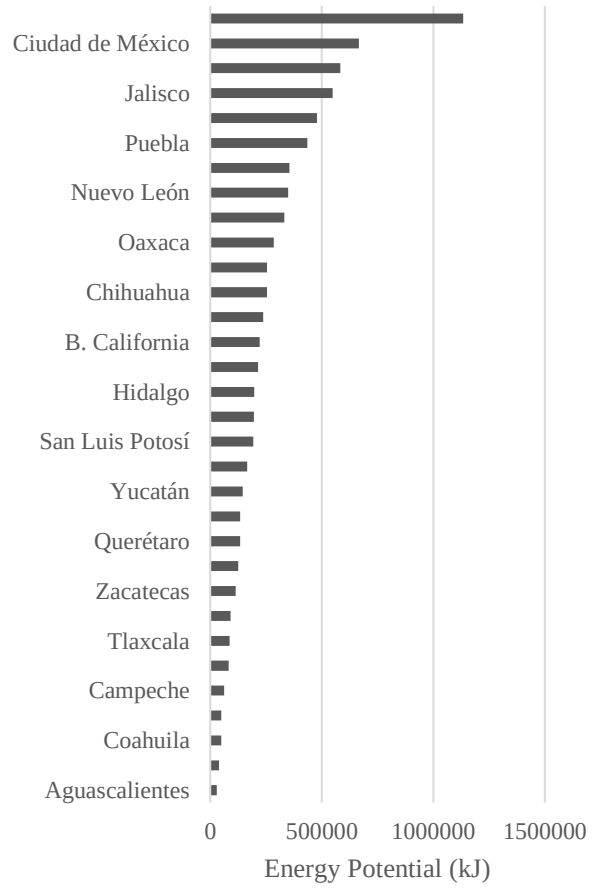

Figure 1 Energy potential averages for each state through ten years.

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On the other hand, Table 1 shows the global energy potential generated for each year. It is possible to observe a positive tendency that increase over the years.

Año	PERSU total (kJ)
2014	10,001,574
2013	9,063,809
2012	8,842,587
2011	8,626,217
2010	8.414.585
2009	8,207,583
2008	8,005,103
2007	7.807,043
2006	7,613,299
2005	7,423,775

Table 1 Global energy potential by using the urban solid *wastes through the ten years.*

Main cities generators of USW

It was identified the main USW generators cities in each Mexican state. The analysis was made regarding on a base amount of 200,000 kg urban solid waste (organic fraction). At the end the following states were identified: Baja California, Coahuila, Chiapas, Chihuahua, Ciudad de México, Durango, Guanajuato, Guerrero, Jalisco, Estado de Mexico, Michoacan, Nuevo Leon, Puebla, Queretaro, Quintana Roo, San Luis Potosi, Sinaloa, Sonora, Tabasco, Tamaulipas, Veracruz and Yucatan.

These states had at least one city with 200,000 kg of wastes generated.

It can be observed in Figure 2, that the main states with four or more cities generators of more than 200,000 kg wastes are Ciudad de Mexico, Estado de Mexico, Guanjuato and Jalisco.

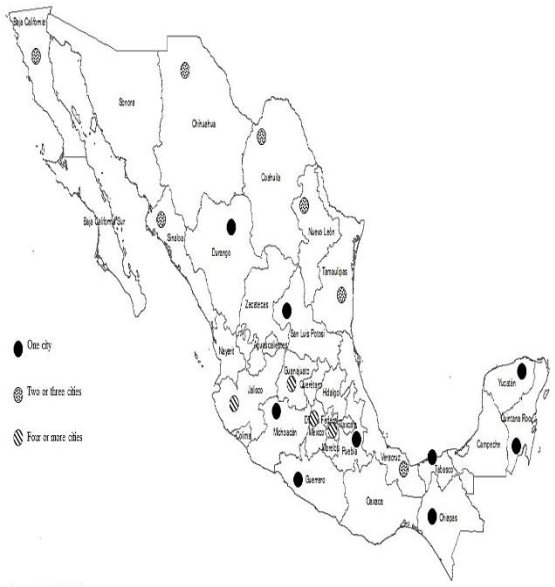

Figure 2 Main states generators of urban solid wastes

Estimation of energy potential. 2020-2030. Comparison with Sustainable Development Goals (SDG)

For this section also it was considered the information obtained from INEGI and CONAPO to calculate the population in this years considered a linear growth rate and after that it was possible to obtain the global generation in each state.

The above considerations were assumed with the objective to compare with the SDG emitted by the ONU (United Nations Organization) which include the perspective and goals to impact on some aspects like poverty, hunger, discrimination, and to promote gender equality, well-being, etc.

The Table 2 presents the result about the estimation of energy potential to both years, 2020 and 2030.

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Year	EPUSW (kJ)
2020	10,744,355
2030	19,982,524

Table 2. Estimation of Energy Potential to 2020 and 2030 in Mexico.

Discussion

Use and management of USW represents a challenge due the amount generated and the environmental impact in soil and water in Mexico and worldwide.

According to the results it was observed that the greater amount of wastesare generated in the central part of Mexico.

Aguilar et al (2009), described a composition of wastes in Vicente Guerrero, Estado de Mexico, the paper concludes that 83% of total wastes generated have potential of exploitation.

Yanez (2005) made a proposal for the improvement of municipal management for handling of household solid waste in metropolitan región in Chile, and considered that this research is a contribution to achieving the goals of reduce, reuse and recycle and save the economy.

Due to the amount of potential energy generated by the use of resiudes, it has an important impact on human activities.

Bitran and Associates in (2003), based on existing theoretical relationships, determine that the potential of generation of biogas from household waste, depends of variables such as: amount of waste deposited regularly in landfills and their accumulation, the conditions of the disposal of USW, general conditions regarding weather variables, age of landfill, percentage of the organic fraction in wastes, etc.

The results show that in this case due the considerations about the population growth and the rate of generation of wastes, the amount of wastes generated, is directly proportional to the energy potential. This can be observed for Ciudad de Mexico, Estado de Mexico, Veracruz, Jalisco and Guanajuato.

To see the importance and benefit to use the energy potential from USW it can be possible make a comparison; a petajoule is a unit of measurement of heat and energy that is used to quantify large amounts of energy. About little more than 277 million kilowatt hours (KWh). And it is reported that in Mexico 2009 the consumption of alternatives energy sources was of 6.9 petajoule (SENER, 2011). Murphy and McKeogh (2006) have reported that in any municipal solid waste incineration system, about 15% of the wastes is available as electricity. Again, municipal solid wastes from 1,000,000 person equivalent could power 12,400 cars; provide electricity for 30,900 houses and heat 15,100 houses in Europe and United States.

In this work it is clear to see that the energy potential of USW is insignificant compared to the consumption in Mexico, but the environmental impact is great.

Sustainable Development Goals

On September 25th 2015, countries adopted a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development (UN, 2016). This compilation of Sustainable Development Goals (SDG) are focused in the human wellness worldwide and they are specified for a period between 2020 and 2030. The UN says that everyone needs to do something to reach the aim about the SDG, which are regard in the follow points:

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1. *No poverty*
2. *Zero hunger*
3. *Good health and well-being*
4. *Quality education*
5. *Gender equality*
6. *Clean water and sanitation*
7. *Affordable and clean energy*
8. *Decent work and economic growth*
9. *Industry, innovation and infrastructure*
10. *Reduced inequalities*
11. *Sustainable cities and communities*
12. *Responsible consumption and production*
13. *Climate action*
14. *Life below water*
15. *Life on land*
16. *Peace, justice and strong institutions*
17. *Partnerships for the goals*

In this work, according to the study and the results obtained for years 2020 and 2030, we focused mainly in the follow SDG:

- Affordable and clean energy
- Sustainable cities and communities
- Climate action

Our work is address to enhance a sustainable change for allowing us a better quality of life with the use of alternative energy. In this case we observed that the quantity of energy potential in 2020 and 2030 from USW is considerable, besides, this is only considering the 53% of organic fraction, if we would have clean technologies to convert easily the rest of wastes, the energy potential would be greater. Also, the use of USW to produce clean energy has colateral benefits, for instance the contamination may decrease and the problematic about the disposal of USW may stop.

Conclusions

The results of this work show the potential for considering the wastes as a non conventional source of energy, impacting not only on the environment but also on the developing of new technologies for improving the generation and use of the energy.

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