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Projection of Environmental Pollutant Emissions From Different Final Waste Disposal Methods Based on Life Cycle Assessment Studies in Qazvin City

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Abstract

In the current study, the life cycle assessment (LCA) method was used to expect the emissions of different environmental pollutants through qualitative and quantitative analyses of solid wastes of Qazvin city in different final disposal methods. Therefore, four scenarios with the following properties considering physical analysis of Qazvin's solid wastes, the current status of solid waste management in Iran, as well as the future of solid waste management of Qazvin were described. In order to detect the quantity of the solid wastes, the volume-weighted analysis was used and random sampling method was used for physical analysis. Of course, regarding the method of LCA, it contains all stages from solid wastes generation to its disposal. However, since the main aim of this study was final disposal stage, the emissions of pollutants of these stages were ignored. Next, considering the mixture of the solid waste, the amount of pollution stemming from each of final disposal methods from other cities having similar conditions was estimated. The findings of the study showed that weight combination of Qazvin solid wastes is entirely similar to that of other cities. Thus, the results of this study can be applied by decision makers around the country. In scenarios 1 and 2, emission of leachate containing high amounts of COD and BOD is high and also the highest content of nitrate, which can contaminate water and soil resulting in high costs for their management. In scenarios 3 and 4, the amounts of gaseous pollutants, particularly CO_2, as well as nitrogen oxides are very high. In conclusion, the LCA methods can effectively contribute to the management of municipal solid wastes (MSW) to control environmental pollutants with least expenses.

Keywords: LCA, Solids Waste Management, Environmental Pollutants

1. Introduction

In developing countries, the amount of municipal solid wastes (MSW) is affected by life style, economical situation, eating habits and so forth (1), because MSW management, which is considered as one of the main axes of sustainable development, is not proper to growth rate of solid waste generation (1, 2). Landfilling is the most common method of final disposal of solid waste in most parts of the world (3, 4); however, huge value of leachate containing high amount of pollutants is one of the major challenges of this way (5). Surface and ground water pollution is the most important effect of leachate discharge (6). Transformation of municipal to manure or compost is one of the strategies of MSW, which can be used for the mixture of solid wastes. Composting decreases the volume and weight. Odor and leachate emission causes resource recovery (7). Several stages of composting including intake, grinding and fermentation create a lot of environmental pollutants (8). Incineration of solid waste is regarded as an alternative to landfilling. Of course, this method has advantages from a decrease in transportation cost and solid waste volume to energy production, it can be entirely dangerous in terms of emission of various pollutants (9). Final waste disposal methods have different emissions of pollutants. Thus, a way or combined way must be selected that creates the least emission. The life cycle assessment (LCA) method is a tool for helping decision-making about selection of management kind, which can be used in the management of MSW (10, 11). This method can be widely used for assessment of energy consumption and pollutant emission in final waste disposal methods (12, 13). Most countries have the challenge of MSW management and Iran is not exceptional.

This study was conducted via a one-year quantitative-qualitative analysis of solid wastes of Qazvin city and based on recent LCA studies as well as the results of extensive investigations on environmental pollutants emission in different final waste disposal methods to estimate the content of pollutants emission in four suggested scenarios for selecting the best way to reach the amount of pollution from different separate methods as well as in conjunction with together with the aim of comparing different conditions for environmental aspects in this city, considering the current facilities and infrastructures, as well as economical and technical circumstances.

2. Materials and Methods

To detect quality of Qazvin's solid waste, the volume-weighted analysis was used over one year: the whole generated solid waste of Qazvin city was weighted twice on middle days of each week in each month of the year; in the middle days of each week and four times in a month during one year. Next, based on demographic data the amount of daily per capita municipal solid waste generation was determined. Moreover, to detect ingredients of the solid waste, samples were randomly collected manually from fresh solid waste in garbage trucks during the year.

In this study, garbage of this city was divided into 12 general categories and then physical characteristics of solid waste were detected. So as to measure the contents of pollutants emission in case of different final waste disposal methods considering that most solid waste (90%) is landfilling and only 10% is composted in Iran and also since 70% of garbage is compostable and possible problems like pollution emission of incineration method and lack of enough land for landfilling (1) four scenarios were assumed as follows:

1) 90% of the solid waste is landfilled and 10% is composted; 2) 30% of the solid waste is landfilled and 70% is composted; 3) 40% of the solid waste is landfilled and 10% is composted and 50% is incinerated and 4) 70% of the solid waste is incinerated and 30% is landfilled.

Because there is a close resemblance among solid wastes created in Iranian's cities (1), the results and reports of other studies, in which the emission of different pollutants in final waste disposal stages had been investigated, were used. The results obtained by other researchers were used in our study considering that there was a close resemblance between physical conditions of this city and other cities. Moreover, for detecting the amount of pollutant emission in incineration method, existing information in incinerator and current standards were used.

3. Results and Discussion

It was found that the average amount of solid waste generation is 241773 kg/d in Qazvin. Considering the population of the city as 393906, its daily per capita is 614 g, which is very close to the national average amount (640 g/d) (1). Qualitative analysis showed that the main part of solid wastes materials is organic wastes. Figure 1 shows qualitative analysis of Qazvin city in detail.

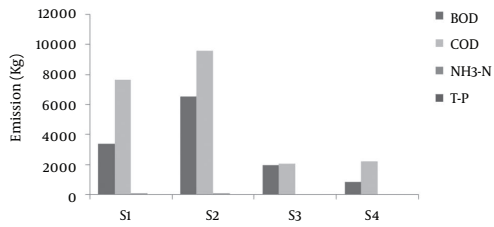

Figure 1. Emission of Different Organic Matters in the Scenarios (kg), S1, scenario 1; S2, scenario 2; S3, scenario 3; S4, scenario 4.

In this study, by investigating final waste disposal methods it was found that the three main ways of landfilling, incineration and composting are not alike for uncontrolled emission of pollutants. The findings illustrated that 9.85 kg CO_2 and 1.83 kg NOX are generated with incinerating each tone of solid wastes in this city with the following characteristics; emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J and a heating value of 10466 J/g. Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10466 J/g. Table 1 shows the emission amount of different pollutants from incinerating each tone of solid waste in this city.

Considering a strong resemblance between weight combination of solid wastes of Qazvin and the whole country, the results and reports of other studies conducted on municipal landfills and composting sites were used to measure the contents of different pollutants emoted in both landfilling and composting methods. Of course, the quality of leachate produced in landfilling and composting depends on some conditions like solid waste quality, weather conditions and site longevity. For example, the concentration of heavy metals decreases in leachate owing to an increase in oxidation-reduction potential in aged landfill sites (14, 15). In this work, the amounts of BOD emitted before controlling methods of landfilling and composting in this city were respectively 25,000 and 75,000 mg/L of leachate, which is discharged. Tables 2 and 3 present the estimated concentrations of different pollutants in each liter of leachate from landfilling and composting.

Table 1. The Amount of Environmental Pollutants Emission From Incineration

Row	Pollutant	Quantity, kg/ton
1	CO_2	9.85
2	CO	2.32
3	SO_2	1.73
4	NOx	1.83
5	Hg	2.8
6	Pb	1.07
7	Cd	5.45
8	As	2.14
9	Cr	4.49
10	Ni	3.93
11	PCDD/DFs	8.35

Table 2. Estimation of Environmental Pollutants per Each Liter of the Leachate From the Landfill

Row	Pollutant	Quantity, mg/L
1	BOD_5	25,000
2	COD	64,000
3	NH_3^-N	500
4	T-P	80
5	Cd	0.45
6	Cu	1
7	Cr	1.1
8	Pb	0.85
9	Zn	5
10	Ni	1.1
11	Hg	0.01
12	Fe	14
13	NO_3^-	100
14	Cl^-	7,000

In this study, four scenarios were predicted for MSW management of city. Figures 2 - 4 compare the amount of environmental pollutant emissions in all scenarios. Considering obtained data, there are very high amounts of BOD and COD in scenarios 1 and 2 and high contents of environmental pollutants emissions, particularly CO_2, in scenarios 3 and 4. In studied scenarios the least emission of CO_2 was for scenarios 1 and 2. Also, since the increasing application of landfill and composting ways in these scenarios, the emission of this gas can be easily controlled. As can be clearly seen, the amount of this gas in scenario 4 is approximately 40% more than scenario 3. This study illustrated that the most emission of nitrate occurs in scenarios 1 and 2 and the most emission of nitrogen oxides (NOx) in scenarios 3 and 4. The amount of NOx emission is very little in scenarios 1 and 2. In scenario 4, acid precipitations are more likely than other scenarios because of emissions of SO_2 and NOx at high contents. Naturally, these situations are also meaningful in scenario 3. Nonetheless, high emissions of gaseous pollutants are negligible in scenarios 1 and 2. Eutrophication phenomenon should not be ignored if high amounts of nitrogen and phosphors emitted in scenario 2 are discharged into the environment without enough treatment. There would be respectively 84% and

Table 3. Estimation of Environmental Pollutants per Each Liter of the Leachate From Generated Compost

Row	Pollutant	Quantity, mg/L
1	BOD_5	75,000
2	COD	98,000
3	NH_3^-N	900
4	T-P	200
5	Cd	0.8
6	Cu	1.4
7	Cr	0.9
8	Pb	1.03
9	Zn	6
10	Ni	1.2
11	Hg	0.01
12	Fe	155
13	NO_3^-	200
14	Cl^-	5,000

80% drops in nitrogen and phosphors if scenario 4 is selected; this can lead to waterbodies protection and prevention from control pollutants costs.

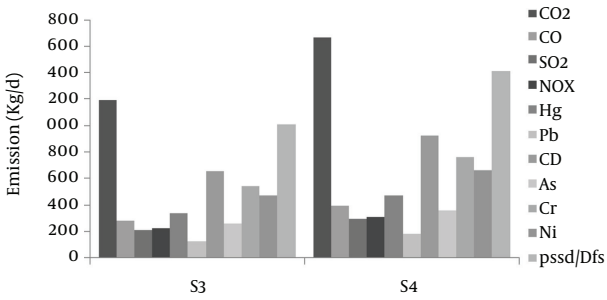

Figure 2. Emission of Different Gases (kg/d) in Two Scenarios, S3, scenario 3; S4, scenario 4.

In this study, it was tried to lessen environmental effects of final waste disposal methods and decrease emissions of different pollutants through scenarios contributing to managers to select methods having the least emissions. If management approaches of these ways are accompanied with using recycling systems and source reduction of solid wastes, it can reduce dramatically the emissions of pollutants; moreover, recycling decreases using raw materials and in turn, protecting the environment (16). The results of a study by Dong et al. (13) showed that using incinerator and energy recovery for electricity generation is the best option for environmental issues and energy consumption and landfilling in conjunction with gas extraction is

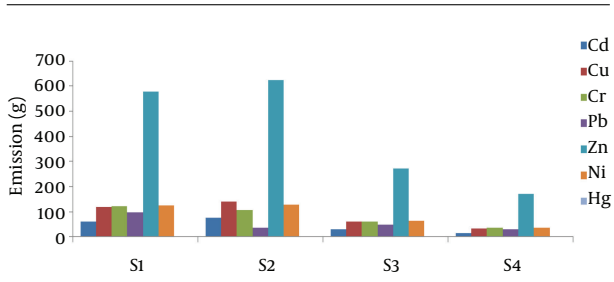

Figure 3. The Emission of Metals in Soil and Water (g) in the Suggested Scenarios, S1, scenario 1; S2, scenario 2; S3, scenario 3; S4, scenario 4.

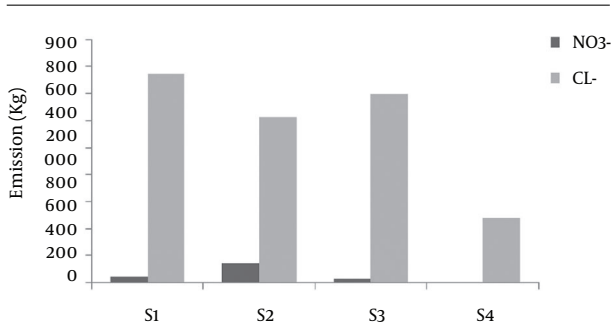

Figure 4. Emission of Nitrate and Chloride (kg) in the Suggested Scenarios, S1, scenario 1; S2, scenario 2; S3, scenario 3; S4, scenario 4.

the most economical final waste disposal method. In scenarios 3 and 4, because of using incineration emissions of toxic gases like lead, sulfur, nitrogen and cadmium creating environmental problems such as acid rain, poisoning and ecosystem pollution are higher.

Also, in these scenarios there are some problems like global warming and ozone depletion due to high amounts of greenhouse gases emissions such as CO and CO_2. This study showed that LCA method in management of MSW can help decision-makers to choose the best way of MSW management; of course, local economical and technical aspects should be taken into account. In addition, knowing the potential of environmental pollutant emissions in each measure would distinguish economic and technical requirements of controlling the method, which influences helpfully in selecting a suitable method for each city. Landfilling and composting produce high content of leachate containing various pollutants (Tables 1 - 3), which can contaminant surface and ground waters. Thus, this issue should be considered in the case of scenarios 1 and 2. Furthermore, when leachate is discharged to water can have negative effect on plants growth like whet (17). In scenarios 1 and 2, there is the problem of accumulation of heavy metals like lead, nickel and cadmium in food chain because of water pollution through leachate. The results of this survey illustrated that selection of each scenario has a significant impact on emitting heavy metals into the environment. For instance, emission of cadmium and chromium in scenario 1 is higher than other scenarios and zinc is significant in scenario 2. Scenarios, in which composting and landfilling are used, can attract insects and vermins, which can spread pathogens from landfill sites to the outside environments (18, 19).

In scenario 1, because the longevity of landfill site is more, acidic phase changes to basic phase decrease concentrations of COD, BOD and heavy metals in created leachate (20, 21). Thus, emission of organic matters to environment is more in the first years of using landfill site. It was found that the amount of pollution in leachate from landfills in Iranian cities is more than cities of industrial countries; it can be attributed to high humidity and perishable materials of solid waste and also weather status (low rainfall and high evaporation) compared to industrial countries (22). To decrease the amount of pollution in unit volume of leachate, source reduction, wet garbage and separation and recycle programs can be used (23). In scenarios 1 and 2, high volume of leachate is generated; there is a decrease in BOD/COD ratio during the longevity of landfill and this decreases the biodegradability of leachate. This decrease in leachate biodegradability over time influences highly biological treatment methods used for leachate (23). Entrance of leachate to soil changes its characteristics such as an increase in salinity, conductivity, nitrogen and phosphorus and a decrease in pH (24). There is potential pollution of area's soil in scenarios 1 and 2.

4. Conclusion

Considering the high amount of emission of environmental pollutants in final waste disposal methods, selection of a suitable option with least emission and expenses considering the conditions of area, is extremely vital. Compared to other studies, we used LCA (four scenarios) method to estimate the emission of pollutants from different methods of final waste disposal in Qazvin city. The findings showed that this study can be helpfully applied for decision-makers for both economic and technical aspects and pollutant emission. Thus, projection of pollutant emission and soil, air and water pollution can help selecting an appropriate method with least amount of emission and expenditure. Since there is a close resemblance between quality and quantity of Qazvin city's and other cities, the results of this study can be used around the country.

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