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Municipal solid waste open dumping, implication for land degradation

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Abstract

Open dumping is the common procedure for final disposal of MSW in Iran. Several environmental pollutions and land degradation have caused because of poor planning, insufficient financial resources, improper organizational chart for MSW management system, and the lack of rules, guidelines and regulations. In Iran standards and regulations of environmental issues are not perfectly attended, evaluation an open dumping can show existing restrictions and troubles in these areas. So recognition of the municipal solid waste landfill state is required to prevent the increase of environmental problems and decrease the negative environmental impacts. The suitability of Tonekabon existing municipal landfill site in the west area of Mazandaran province, located in north of Iran, and the south coast of the Caspian Sea is the significance of the present study as a case study of land degradation. In order to carry out this evaluation, two guidelines are used. After reviewing all the considered criteria in each of the guidelines, the authenticity of the deposit site of the study area and also the entire city was examined; and eventually the appropriate areas were identified. The conclusion of the results indicated the incoherence in appropriateness of the existing landfill site, with two mentioned methods and field work.

1 Introduction

In the developing countries, because of over population and urbanization phenomenon in the past few years, the development of perfect waste management systems is necessary. In spite of developing in waste management in the world, the disposal of solid wastes by land fill still remains the most commonly used method in developing countries (Sumathi et al., 2008). Sanitary landfill is one of the initial methods of municipal solid waste disposal. Although Landfill is the most commonly used method for urban solid waste disposal, it is at the bottom of the hierarchy of options for waste disposal (Mahini and Gholamalifard, 2006). Of course sanitary land-filling is one of the best ways to reducing environmental health problems, and gathering the gas and leachate and in addition, it can decrease the volume of waste quantity (Glynn, 2004; Wang et al., 2009). Nevertheless lack of effective environmental laws and enough land for landfill site sitting in developing countries is a main issue which causes many problems (Hagerrty et al., 1997). Unfortunately, in most Iranian cities, the simplest method of waste disposal is still confined to pile-up and open dumping. An open dump site is a great environmental hazard which causes natural resources degradation and environmental pollutions. A number of literatures have been reported in the past, where leachate had contaminated the underground water (Mor et al., 2006; Dimitrio et al., 2008; Nema et al., 2009), some researches showed soil contamination (Raman and Narayanan, 2008; Shaylor et al., 2009; Hernandez et al., 1997). Another main problem in open dumping is open air burning because of gases emitted from waste degradation process. In some literatures the effect of fire on soil have been studied for example Guenon et al. (2013) and Leon et al. (2014) studied and showed that fire changes the quality of soil. Chemical and microbiological properties of soil may be altered during high temperature. Mohavesh et al. (2015) showed in their research that the major cause of land degradation is insufficient and improper land use management. In this research they examine the effects of land use changes on degradation. One of the other serious threat to soil is salinity, improper land use by human activities such as deforestation, road and the other constructions causes soil salinity. Salinity effects on soil physical and chemical structure, and causes soil degradation and promotes underground water salinization level (Iwai et al., 2013). Our research is an example for improper land use which causes forest degradation. Also Biro et al. (2013) showed in their research that the change of the physical and chemical properties of the soil may have attributed to the changes in the land use and land cover resulting in land degradation, which in turn has led to a decline in soil productivity. Restoration of degraded soil is a difficult and long process in natural ecosystems which includes the return of microbiota activity and establishment of vegetative community (De Suza et al., 2013). Total nitrogen and pH and erosion severity are important factors which soil development is dependent to them. When these factors increased, soil richness decreased (Pallaviciny et al., 2014). So all of the research investigations, emphasize the negative impacts of improper land use management system on our solid earth. One of these unsuitable systems in developing countries is MSW management system. Due to protect the environment and natural resources in the developing countries, a proper solid waste management is becoming a necessity (Rao et al., 2007). In most developing countries, the environmental standards are not completely considered, so the environmental evaluation of landfills is suitable to identify the limitations and problems. As well as, identification of the municipal solid waste landfill condition and showing existing shortages can decrease the environmental pollution (Anzi et al., 2004). Despite the increasing advances in modern methods of locating waste landfills in the world, 49 % of the total solid waste disposal methods in Iran is piled up which is unsafe method (Abdoli, 2005a). The MSW management systems in Iran are not in good condition. These systems have not been adequately progressed in Iran and so the open dumping of solid waste is a prevalent manner. Despite numerous efforts around the world, in order to reuse the municipal solid waste, unfortunately in Iran, wastes are dumped without any consumption. In this time reuse of waste and treated wastewater has increased in all of the world, for example reuse treated wastewater is the best option for agricultural land irrigation, because of water crisis in the world, these practices will be very useful in Iran too. Murogan et al. (2013) assessed the status of agricultural soils irrigated with treated wastewater and showed that only in the case of very low wastewater quality and its long term application, relevant changes in soil properties can be produced and the other samples properties and their quality are not changed. Al-Karaki (2011) showed the utilization of treated sewage wastewater for green forage production in a hydroponic system as a useful method. In the other researches for soil restoration and also increase the biological properties of soil, the organic materials existing in wastes had been used as, Tejada and Benitez (2014) showed effects of crushed maize straw residues on soil biological properties and soil restoration, they considered a benefit environmental strategy for degraded soil. Iwai et al. (2013) studied on the effectiveness of compost and

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vermicompost to improve the soil quality. Ros et al. (2005) showed the effectiveness of green compost in increasing the organic matter and nutrient level in soil structure. In Iran the municipalities are responsible for MSW management systems and there were not administrative legislations for landfill site siting. Due to Poor planning, insufficient financial resources, defective collection system, insufficient data and experience, unsuitable disposal convenience, and insufficient rules,guide lines and regulations and totally a lack of knowledge of new municipal solid-waste management options in municipalities, and increasing needs to remove wastes from cities, final disposal way which municipalities select is uncontrolled dumping (Abdoli, 2005b). The Most common way of waste disposal in humid regions as the south coast of the Caspian Sea has been open dumping too (Monavari and Shariat, 2000). The quality and quantity of municipal solid waste crated in the southern coast of the Caspian Sea in Iran has changed in during the previous years, but unfortunately the methods of collection, transportation, and disposal have remained the same. So there are many serious environmental problems. For example, some of the rivers and forests and coastal regions are contaminated and destroyed and have been converted into dumping sites (Diaz, 1997). Therefore, it is both essential and useful to understand the quality of current municipal landfill sites included in this study area too. Some landfill sites evaluation have been done by different methods, for example by Oleckno method (Monavari et al., 2007; Monavari and Arbab, 2005), Drastic method (Wang, 2007), USEPA method (Christensen et al., 1992), Monavari 95–2 method (Ghanbari et al., 2011), and local and Regional Screening (Aliowsati et al., 2013). The first step to improve MSW management system is evaluation of the current landfill sites state in the country. So in this research, in order to evaluate the current Tonekabon landfill site suitability, two methods were chosen: Minnesota pollution control agency and regional screening method. The Tonekabon landfill site in Mazandaran Province is located in the Pordesar forest, 30 km far from the centre of Tonekabon city. In this site wastes are dumped in the forest without applying any environmental and engineering standard. More precipitation of the area provides more humidity, more leaches. The lack of proper waste management systems and humid climate increased environmental problems in this site.

2 Materials and methods

2.1 Area of study

Tonekabon with about 1631.8 km^2 area, is located in the west of Mazandaran province, on the Northern edge of Iran between Ramsar and Abas Abad city, in the south coast of the Caspian Sea (Fig. 1). The MSW landfill of Tonekabon is located at Dohezar road, 30 km from south of this city. This site with an area of over 5 acres, is located between $36^\circ 42'$ N latitudes and $50^\circ 49'$ E longitudes. Its height is equal to 520 m above the sea level. Located between the Alborz mountain range and Caspian Sea, the studied area has temperate and humid climate. The average annual precipitation from the nearest climatological station is equal to 994 mm, and monthly relative humidity is 82 %. The input solid wastes which are collected from 3 municipal districts to this site is 70 to 100 t per day: central district, Nashta, and Khoram Abad districts with 149 010 inhabitants. Application of the methodology is based on the collection of data related to the physical environment, state and characteristics of deposit site. Data collection involved visiting the current deposit point as well as studying the existing information, regarding the point and characteristics of its environment. In this study, input map layers including; surface water (rivers and lakes), flood plain,ground water (springs and wells), distance to airport, land use (agricultural land, forest land, residential area), sources of drinking water, distance to residential areas, road distance to waste production centres, geology (fault, bedrock, seismicity); were considered.

2.2 Preparation and investigation of thematic maps and overlaying these maps in GIS

Evaluation of a suitable landfill site is a complex procedure which involves evaluating some factors, such as regulations, environmental, socio-cultural and engineering factors based on a consider method. Using GIS for evaluation and choosing a proper location for the landfill sites is an economical and practical method which had been used in past researches. GIS software is capable of a producing useful, high quality maps for such purpose in a short period of time. So in this research GIS was used too. However, it is important to realise that GIS analysis software is not a substitute for field analysis, using GIS is helpful to distinguish between more suitable and unsuitable or restricted by regulations or constrained locations. Therefore, the combination of findings from GIS software and field work is very useful. The landfill site map layer is prepared by locating the GPS coordinates of Tonekabon landfill site and entering it as latitude and longitude in the GIS software database, and then converting it into the point data. The constraint map layers have been standardized based on Boolean logic. Thus with the reclassified module in Arc GIS software, the restricted area's value was zero and the other area's value was one, as a form of coefficient. Some buffer maps are also generated in which the "areas of constraints" are displayed. Such areas which are usually encompassed from lakes, rivers, water supply sources, protected area, roads and fault lines; indicate these areas are not appropriate for a landfill. Over the last few years, GIS has emerged as a suitable tool for land use analysis (Malczewski, 2004). Most maps and data were obtained from Mazandaran Management and Planning Office of Governor. And its scale is 1 : 100 000. The surface and ground water maps were obtained from the Geographic Information Centre of Mazandaran Regional Water Organization with the scale of 1 : 250 000. In this research, at first the geographical and environmental condition of Tonekabon landfill site is identified then, MPCA and the regional screening methods are applied to evaluation of mentioned landfill site.

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2.3 Investigate the evaluation criteria

To implicate a waste disposal site various aspects should be taken into consideration. For instance, diverse social, economical and environmental fields, such as soil science, hydrology and hydrogeology, land use, geology and etc., should be evaluated for this purpose. Methods of evaluating landfill site measure many spatial criteria for example distance to roads, distance to protected areas, distance to city, and distance to surface water and the soil capacity to contaminate. Consequently, supplying different and proper spatial data, and matching between the suitable parameters and regulations is mandatory. In this research two methods are used, MPCA method and regional screening guideline. Each system, evaluates waste site for some criteria which are mentioned below:

2.3.1 MPCA method

MPCA method, the prevalent method in landfill siting, was presented by the Minnesota Pollution Control Agency (MPCA) in 1983 (Badve, 2001). In this method of landfill siting, 6 determinative factors and 7 conditional factors are allocated. Complete achievement of 6 determinative factors is committed in landfill siting where as other conditional factors should be achieved by engineering considerations. Determinative and conditional factors utilized in MPCA method are illustrated in Table 1.

2.3.2 Regional screening method

In regional screening method, three important parameters such as natural conditions, land use and economic factors are considered (Ball, 2004) each of which include:

- Natural Conditions

  1. The MSW landfill sites should not be sited near the surface water (minimum distance of 61 m should be observed).

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2. Regions with high underground water levels are not compatible for MSW sites, if the hydraulic trap method is used.
3. The MSW landfill site should not be sited in the ravines.
4. The areas with shortage supply of heavy clay and fine grained soil for using coating layers are not suitable for municipal solid waste landfill siting. This soil type should have a permeability coefficient of minimum $10^{-9}\,\mathrm{m\,s^{-1}}$. The layers of clay-silt type soil under the landfill should be with permeability of $10^{-9}\,\mathrm{m\,s^{-1}}$ at least the depth of 15 m and more.
5. The distance from faults must be at least 61 m.
6. The regions with slide risk potential and sensitive clays are not suitable for landfill sites.
7. The regions with high sensitive soils such as limestone and fragile soils are not suitable for landfill sites.

– Land Use

1. At least distance of 150 m from, commercial, educational and residential centers and at least 80 m from industrial applications.
2. At least 3 km distance from the airport.
3. At least 300 m distance from water wells.
4. The agricultural land use can be suitable for solid waste landfill sites.

– Economic Factors

1. A proper distance from the main road should be considered. (Less than one kilometre is ideal.)

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3 Result

After combining of findings from GIS software and field work the current conditions of study area based on mentioned criteria are in the below:

Surface water (hydrology) map: these are important environmental factors due to potential risk of contamination. There is no lake and pool in this area. Because of the specific climate conditions, there are multiple rivers in this area, and the nearest river to this site is located far from 1.8 km. Less than 61 m is unsuitable and more than this distance is suitable.

Infiltration map: an infiltration map displays the various soil types existing in the studied area. The infiltration rate is a key parameter to evaluate the probability risk of underground water pollution, and thus is important factor for landfill site sitting in the study area. This map is used to estimate the ground water level and soil type. The infiltration of this site is high and the soil type is silt clay loam. So the high level of underground water is not suitable.

Residential areas map: this map displays the existing cities and villages. There are 4 towns in Tonekabon city, the nearest one of them, Khoram Abad, is located at the distance of 10 km to this site. So the distance of less than 150 m is not suitable for landfill site base on this legislation.

Road network map: the road network map delineates all the major and minor roads of the studied area. The location of the landfill is at the distance of about 3 km from Dohezar main road.

Land use map: it illustrates the land used by human and the natural environment in the area. This map shows good and medium ranges, gardens, agricultural lands, forest and three cities in Tonekabon. The dominant type of land being used in this area is forest. This landfill site is located in Pordesar forest.

Ground water source (hydrogeology) map: this map displays the wells and springs in this area. The nearest well is located at the distance of more than 6 km; and the nearest spring is located far from about 3 km.

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Geology map: this map shows that dark grey medium bedded to massive limestone (Ruteh limestone) is geological unit in the studied area.

Protected area sites map: the map displays the protected areas, under the management of the Department of the Environment of Iran (DOE). Beleskoh protected area, is located at distance of less than 2.5 km to landfill site.

Flood plain map: this map shows that the studied landfill is not at risk of flood.

Faults map: this map displays the existing faults of this area. The areas without faults or the ones which have a safe distance from the faults are suitable for landfill sitting. In this study area we have two kinds of major and minor faults. The nearest fault is located far from 2.5 km.

Airport map: Ramsar airport is located at the distance of about 13 km far from Tonekabon town centre.

Totally the suitability of Tonekabon landfill site based on criteria of the Regional screening and MPCA methods is mentioned in Table 2.

Different criteria are used to obtain GIS data sets of the buffer zone for rivers, roads, water supply sources, fault lines, and protected areas. Maps represent the acceptable distance which should be considered in site sitting for different criteria using the buffer option in ArcGIS. They were produced on the basis of existing standards which are indicated above. The areas within the buffer zones are not suitable for landfill sitting and solid waste disposal. They were produced on the basis of MPCA guideline, and the regional screening method. For example, in order to prepare the buffer for rivers in MPCA guideline, at the first the rivers in our studied area were investigated then around each of them a buffer distance of 92 m was performed. In the same way, buffer zones for the other criteria such as roads, protected areas, water reservoir sources and faults, were created at a distance which is mentioned in 2 above methods. A GIS-based overlay analysis of generated buffer maps was done in order to identify the landfill site suitability. After reviewing all specified criteria in each of the guidelines, the authenticity of deposit site in the study area was identified (see Figs. 2 and 3). After that thematic maps and GIS data maps were prepared base on mentioned parameters for evaluation of landfill site, the thematic maps, overlaid upon one another and the above GIS based analysis was applied based on proposed algorithm. The GIS-based constraint mapping technique was applied to the study area. Also field studies were implemented in terms of providing more information for a suitability evaluation. After reviewing current site with GIS maps and field views (see Table 3); it was found out that Tonekabon landfill site is suitable based on MPCA determinative guideline, but it is unsuitable based on Regional screening method.

4 Discussion

Humid areas are vulnerable and sensitive towards environmental impacts of landfills, due to their special physical and biological conditions. These special conditions include high precipitation, several water currents, high water level, productivity of farms, existence of forest and wetland, agriculture, drinking water consumptions, etc. (Monavari and Shariat, 2000). As it has already been mentioned, basically, municipal solid waste landfills are evaluated by methods such as Oleckno method (Monavari et al., 2007; Monavari and Arbab, 2005), Drastic method (Wang et al., 2007), USEPA method (Christensen et al.,1992) and Monavari 95–2 method (Ghanbari et al., 2011). Local and Regional screening (Aliowsati et al., 2013). Each system evaluates waste sites for one or more hazard migration route(s), namely groundwater, surface water, soil and public health. In Oleckno method, factors such as rainfall, soil characteristics, and ground water table are considered just in order to distinguish the dangers of latex and underground water pollution. Drastic method, presented by EPA, is only considers seven parameters involved in the contamination of underground water to evaluate potential contamination. In MPCA method, surface water resources; such as, river, pool, lake, wetland; and geological conditions are determinative criteria to evaluate municipal landfill site, but in regional screening method, the landfill will be evaluated in 3 sections (Natural, Economic and land use) and with more criteria to be considered. So in this method evaluation is more accurate than MPCA method. Identifying incompatible impacts of different parameters in landfill of Tonekabon and considering different standards will help to control different types of existing landfill problems. Paying more attention to waste management's issues will change the weak points to power points. It is important, that the defined criteria in MPCA method and Regional screening guideline are for Sanitary landfill site evaluation and selection, but the evidences in Tonekabon landfill site suggests open dumping not sanitary landfill site. The evaluation of the current unsanitary landfill sites and the implications of land degradation, can open a new way to start restoration of these regions and convert them to self-sustaining and productive ecosystems in developing countries. So a better management approach can be planned to decrease land degradation. There are many researches which can used to recovery the degraded lands. Since soil recovery is the first step in land restoration process, some previous experiences mentioned: for example Iwai et al. (2013) studied on the effectiveness of compost and vermicompost on saline soil recovery and improving the soil quality. In the other research the effectiveness of buaxite residue with varying rate of compost to increase soil fertility and gypsum to reduce sodicity had been shown (Courtney and Harrington, 2012). Esawy and El-kader (2014) suggests phosphogypsum may be useful for the immobilization of heavy metals in contaminated soils. In other research, Gasco et al. (2014) showed the environmental benefits of biochar, such as increasing in water holding capacity, saline soil remediation, improve soil fertility and soil physical properties. So these methods may be useful to do soil recovery in this site and convert this degraded forest to a productive ecosystem in the future.

5 Conclusions

It is already clear that the main problem is due to the non-compliance with landfill site selection standards, engineering frameworks, and design as well as lack of appropriate waste management and sanitary landfill. The problems include open-air waste burning, open-pit dumping, and uncontrolled waste disposal in landfill, which can result in negative impacts on human health and on the environment. Unfortunately hardly any

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of the applicable criteria are applied to most landfill areas. The conclusion of the results indicated the incoherence in appropriateness of the existing landfill site, with two mentioned methods. The study shows the shortage of suitable places in Tonekabon city based on Regional screening method. Although Tonekabon landfill site is accepted according to MPCA method, but in field work, lack of machinery and necessary equipment, destructed and insufficient fences or walls around the site, insufficient guards and lack of office stand, also lack of gas and leach control and open air burning are some of the disadvantages in this landfill site. Based on the evidences in field work this site causes natural resources degradation such as soil contamination and degradation, river pollution, deforestation, underground water pollution and totally land degradation in this forest. According to MPCA method, this site is accepted only because of the lack of enough criteria. Also using GIS for evaluation the suitability of landfill sites is an economical and practical method which had been used in past researches, however, it is important to realise that GIS analysis software is not a substitute for field analysis and the combination of findings from GIS software and field work is very useful.

References

Abdoli, M. A.: Recycling of Municipal Solid Wastes, Tehran University, Tehran, Iran, 384 pp., 2005a.

Abdoli, M. A.: Report of the waste management in Iran, in: Solid Waste Management Issues and Challenges in Asia, Report of the Apo survey on Solid Waste, the Asian Productivity Organization, Mumbai, India, 92–117, 2005b.

Aliowsati, F., Monavari, M., and Omrani, G. A.: The evaluation of Karaj municipal solid waste landfill site with local and regional screening, Environ. Sci. Technol., 15, 86–96, 2013.

Al-Karaki, G. N.: Utilization of treated sewage wastewater for green forage production in hydroponic system, Emir. J. Food Agric., 23, 80–94, 2011.

Anzi, I., Inanc, B., and Nassir Hassan, M.: Overview of waste disposal and landfills dumps in Asian countries, J. Mater. Cycles Waste, 6, 104–110, 2004.

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Badve, k. : site selection for landfilling of waste, Landfilling of domestic waste, First Environmental Engineering symposium, 3 Jan, Tehran University, Tehran, Iran, 2001.
Ball, J. M.: Aspects of landfill site selection, in: Proceedings of the Institute of Waste Management, South Africa Waste Conference, 11–15 October 2004, Sun City, South Africa, 89–95, 2004.
Biro, K., Pradhan, B., Bochroithner, M., and Makeschin, F.: Land use/land cover change analysis and its impact on soil properties in the northern part of Gadarif region, Sudan, Land Degrad. Dev., 24, 90–102, doi:10.1002/ldr.1116, 2013.
Christensen, T. H., Cossu, R., and Stegmann, R.: Landfilling of Waste: Leachate, 1st edn., Taylor& Francis, London, 1992.
Courtney, R. and Harrington, T.: Growth and nutrition of *Holocus Lantus* in bauxite residue amended with combinations of spent mushroom compost and gypsum, Land Degrad. Dev., 23, 144–149, doi:10.1002/ldr.1062, 2012.
De Souza, R. G., Da Silva, D. K. A., De Mello, C. M. A., Goto, B. T., Da Silva, F. S. B., Sampaio, E. V. S. B., and Maia, L. C.: Arbuscular mycorrhiza fungi in revegetated mind dunes, Land Degrad. Dev., 24, 147–155, doi:10.1002/ldr.1113, 2013.
Diaz, L. F., Savage, G. M. T., and Eggerth, L. L.: Managing solid waste in developing countries, Waste Management, 43–45, 1997.
Dimitriou, F., Karaouzas, I., Saratakos, K., Zacharias, I., Bogdanos, K., and Diapoulis, A.: Ground water risk assessment at a heavily industrialised catchment and management, J. Environ. Manage., 88, 526–538, 2008.
Esawy, M. and El-kader, N. A.: Heavy metal immobilization in contaminated soils using phosphogypsum and rice straw compost, Land Degrad. Dev., doi:10.1002/ldr.2288, 2014.
Ghanbari, F., AminSharee, F., Monavai, M., Zaredar, N.: A new method for environmental site assessment of urban solid waste landfill, Environ. Monit. Assess., 184, 1221–1230, doi:10.1007/s10661-011-2034-6, 2012.
Glynn, H. J.: Environmental Science and Engineering, Prentice-Hall, New Delhi, 2004.
Guenon, R., Vennertier, M., Dupuy, N., Roussos, S., Pailler, A., and Gros, R.: Trends in recovery of mediterraniean soil chemical properties and microbiological activities after infrequent and frequent wildfire, Land Degrad. Dev., 24, 115–128, doi:10.1002/ldr.1109, 2013.
Hagerty, D. J., Pavoni, J. L., and Heer, J. E.: Solid Waste Management, Litton, New York, 1997.
Hernandez, A. J., Adarve Alcazar, M. J., and Pastor, J.: Some impact of urban waste landfills on Mediterranean soils, Land Degrad. Dev.. 9, 21–33, 1998.

Iwai, C. B., Oo, A. N., and Saenjan, P.: Soil properties and maize growth in saline and nonsaline soils using Cassava-industrial waste compost and vermicompost with or without earthworms, Land Degrad. Dev., doi:10.1002/ldr.2208, 2013.

León, J., Seeger, M., Badía, D., Peters, P., and Echeverría, M. T.: Thermal shock and splash effects on burned gypseous soils from the Ebro Basin (NE Spain), Solid Earth, 5, 131–140, doi:10.5194/se-5-131-2014, 2014.

Mahini, S. and Gholamalifard, M.: Siting MSW landfills with a weighted linear combination methodology in a GIS environment, J. Sci. Technol., 3, 435–446, 2006.

Malczewski, J.: GIS-based land-use suitability analysis: a critical overview, Prog. Plann., 62, 3–65, 2004.

Mohawesh, Y., Taimeh, A., and Ziadat, F.: Effects of land use changes and conservation measures on land degradation under a Mediterranean climate, Solid Earth Discuss., 7, 115–145, doi:10.5194/sed-7-115-2015, 2015.

Monavari, M. and Arbab, P.: The environmental evaluation of municipal solid waste landfills of the Tehran province, Environm. Sci., 2, 1–8, 2005.

Monavari, M. and Shariat, M.: Evaluation of landfill site selection standards in Rasht, Environ. Sci. Technol., 1, 27–34, 2000.

Monavari, M., Khorasani, N., Omrani, G. A., and Arbab, P.: The study of municipal solid waste landfills in Tehran using Oleckno method, Environ. Sci. Technol., 1, 37–46, 2007.

Mor, S., Ravindra, K., Dahiya, R. P., Chandra, A.: Leachate characterization and assessment of ground water pollution near municipal solid waste landfill site, Environ. Monit. Assess., 118, 435–456, doi:10.1007/s10661-006-1505-7, 2006.

Morugán-Coronado, A., Arcenegui, V., García-Orenes, F., Mataix-Solera, J., and Mataix-Beneyto, J.: Application of soil quality indices to assess the status of agricultural soils irrigated with treated wastewaters, Solid Earth, 4, 119–127, doi:10.5194/se-4-119-2013, 2013.

Nema, A. K., Datta, M., and Singh, R. K.: A new system for ground water contamination hazard rating of landfills, J. Environ. Manage., 91, 344–357, 2009.

Pallavicini, Y., Alday, J. G., Martínez-Ruiz, C. F.: Factors affecting herbaceous richness and biomass accumulation patterns of reclaimed coal mines, Land Degrad. Dev., doi:10.1002/ldr.2198, 2014.

Paz-Ferreiro, J., Mendez, J., Tarquis, A. M., Cerda, A., and Gasco, G.: Preface: environmental benefits of biochar, Solid Earth, 5, 1301–1303, doi:10.5194/se-5-1301-2014, 2014.

Raman, N. and Sathiana, R.: Impact of solid waste effects on ground water and soil quality nearer to Pallavaram solid waste landfill site in Chennai, Rasayan J., 1, 828–836, 2008.
Rao, P. J., Brinda, V., Rao, B. S., and Harikrihna, P.: Selection of landfill sites for solid waste management in and around Visakhapatnam City – a GIS approach, Asian J. Geo Inf., 7, 5–41, 2007.
Ros, M., Hernandez, M. T., Bernal, A., and Pascual, J. A.: Biopesticide effect of green compost against fusarium wilt on melon plants, J. Appl. Microbiol., 98, 845–854, doi:10.1111/j.1365-2672.2004.02508.x, 2005.
Shaylor, H., McBride, M., and Harrison, E.: Sources and Impacts of contaminants in Soil, Cornell University , available at: http://cwmi.css.cornell.edu, 2009.
Sumathi, V. R., Natesan, U., and Chinmoy, S.: GIS-based approach for optimized siting of municipal solid waste landfill, Waste Manage., 28, 2146–2160, doi:10.1177/0734242X0302100310, 2008.
Tejada, M. and Benitez, C.: Effects of crushed maize straw residues on soil biological properties and soil restoration, Land Degrad. Dev., 25, 501–509, doi:10.1002/ldr.2316, 2014.
Wang, G., Qin, L., Li, G., and Chen, L.: Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China. J. Environ. Manage., 90, 2414–2421, doi:10.1016/j.jenvman.2008.12.008, 2009.
Wang, L.: Assessment of groundwater vulnerability to landfill leachate induced arsenic contamination in Maine, US, Intro GIS Term Project Final Report, Dept. of Civil and Environmental Engineering,USA, 2007.

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Table 1. Six determinative and seven conditional factors of MPCA method (Badve, 2001).

Number	Determinative Criteria	Conditional Criteria
1	Minimum 305 m distance from any lake or pool	Minimum 305 m distance from road, parks and residential area
2	Minimum 92 m distance from any river or channel	No threat to any water resources pollution
3	Distance from area with 100 retention period flood	Avoiding from area with high erosion and drainage
4	Avoiding from wetlands	No threat to drinking water storage
5	Do not cumulate birds in sensitive area around airport	No threat to groundwater resources contamination
6	Distance from area with limestone caves	Constructed with enough precaution consideration
7	–	Feasibility of monitoring and sampling of ground water

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Table 2. The suitability of Tonekabon MSW landfill site based on two mentioned methods.

Criteria	Suitability
Distance from surface water	Suitable
Distance from underground water resources	Suitable
Land use	Unsuitable
Distance from population centres	Suitable
Distance from faults	Suitable
Distance to landslide	Suitable
Geology	Unsuitable
Distance to roads (economic)	Unsuitable
Distance to airport	Suitable
Soil depth	Suitable
Soil type	Suitable
Distance to flood plain	Suitable

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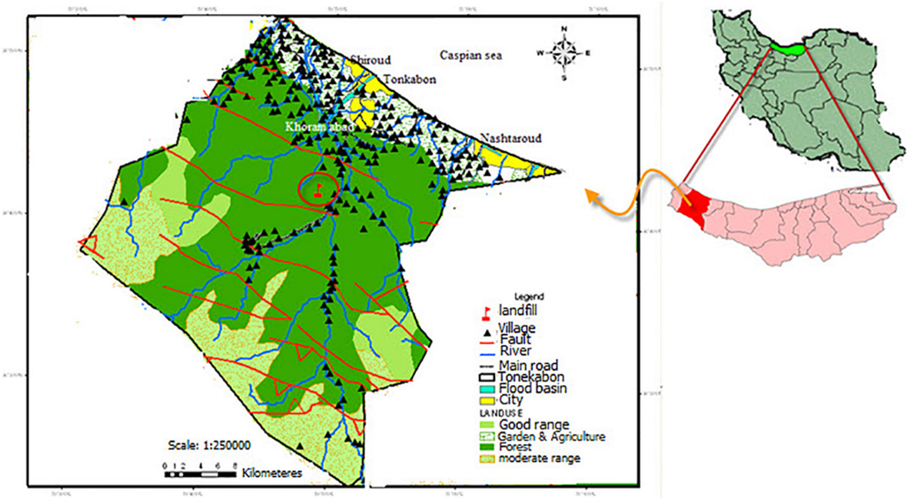

Figure 1. Location of Tonekabon in Mazandaran province, Iran.

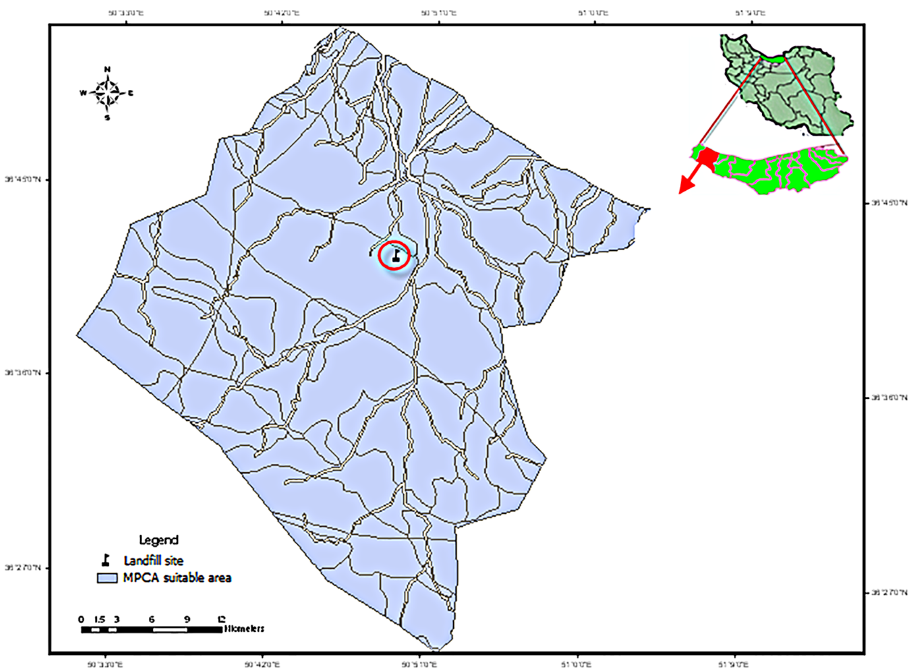

Figure 2. The suitability of the studied area based on MPCA determinative criteria.

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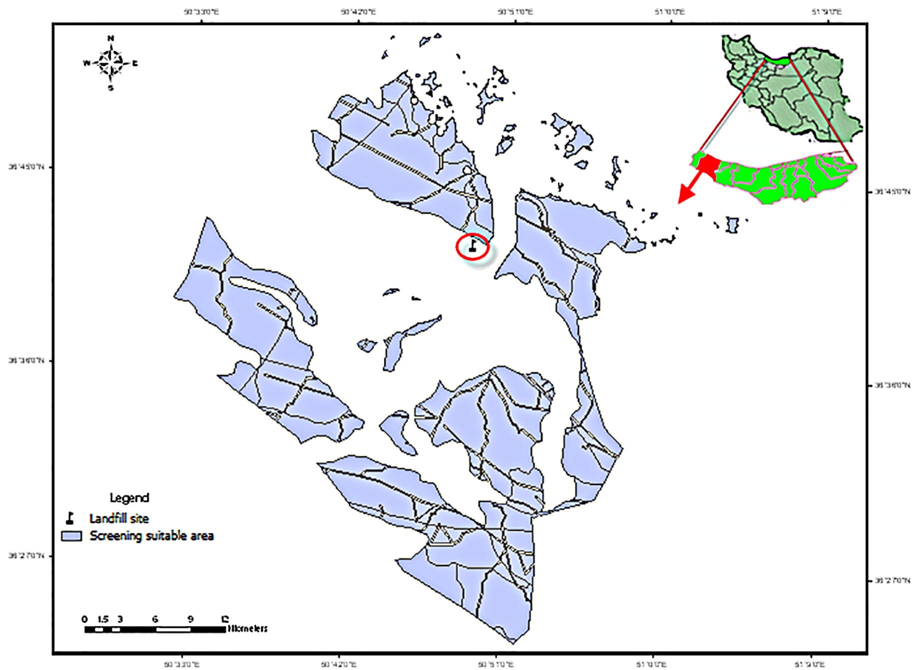

Figure 3. The suitability of the studied area based on regional screening method.

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