Journal of Community Health Research. 2013; 2(2):96-106.
http://jhr.ssu.ac.ir

Original Article

Potential Investigation of Reusing Ardabil Municipal Wastewater Treatment Plant Sludge Based on AHP and TOPSIS Models

Bizhan Maghsoudlou Kamali Ph.D.[1], Mohammad Taghi Ghaneian Ph.D.[2], Taleb Abdollahi M.Sc.[3*]

1. Department of Environment, Islamic Azad University, Meybod Branch, Meybod, Iran
2. Department of Environmental Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
3. M.Sc. Student of Environmental Pollutions, Islamic Azad University, Meybod Branch, Meybod, Iran

Received: 5/14/2013 Accepted: 7/15/2013

Abstract

Introduction: By ever-increasing of population, shortage of water resources and the necessity of wastewater treatment, large amount of sludge that is a byproduct of wastewater treatment, requires being disposed in safe ways, environmentally. The target of specifying strategic preferences of reusing sludge is going to find the safe way of disposing or beneficial use of sludge.

Materials and Methods: In this study, for selecting the best alternatives for reusing wastewater sludge, two systematic methods will be introduced, in which four alternatives in reusing sludge (using in agriculture, in green space, biogas and desert combat) are introduced and they will be compared with four main parameters including: 1-physicochemical 2-biological 3-economic, social and cultural, and 4-environmental pollution situation, where each one contains some criteria.

Results: Sludge of Ardabil municipal wastewater treatment plant, according to standards, and EPA regulations is eligible to class B, and due to the chemical, in terms of heavy metals, got special (excellent) quality and contains considerable quantities of organic substance, nutrients and micronutrients that indicates the fertilized value of the sludge.

Conclusion: The result of these comparisons showed that the application of sludge in green spaces is the most appropriate alternative while using in agriculture, biogas, and desert combat alternatives are placed respectively in second to fourth preferences of reusing sludge that is derived from municipal wastewater treatment plant.

Keywords: Waste water; Sewage; Population; Water Pollutants; Drinking Water; Water Purification

[*] **Corresponding author*: *Tel*:** +989365145210, ***Email*:** abdollahi_67@yahoo.com

Introduction

Today, by population growth and rapid development of technology in different facets of industry, while they are the origin of modern industrial revolution in human society, we can see that the population is as a main factor in destruction of the environmental resources. If we don't pay serious attention to the continuous development in environment, we will confront same tragedy conditions in this domain [1]. Environmental authorities know that having municipal wastewater plant is necessary for preventing the pollution and also in preserving available resources in nature. This main issue was accompanied production in sewage and sludge, and production quality, where inaccessibility to each one is a conflict to general purpose of wastewater plant [2]. The type of treatment system in Ardebil municipal wastewater treatment plant is a created lagoon with perfect integration .In this kind of lagoon, sufficient energy is used to keep all the materials suspended in pool's whole volume, and the air conditioners are provided in all parts of the pool. For depositing suspended materials, the deposit pool is used and the produced sludge is evacuated in energy once every two years. The derived sewage from this pool enters to make pools double clearer for finding treatment and eliminating Parasites and Fecal coliform. The general attitude to the process of wastewater treatment in our country is in a way that, the fundamental attention is mainly on the quality of exited sewage, and unfortunately the quality of disposal sludge has hardly been noticed [1]. The dispose of municipal wastewater is an inseparable necessity in city management and public health. By building the refinery we can see the problems of the dry sludge production and disposal. Since the amount of dry sludge production in plants is generally high and the clear consumption isn't defined for them, the amount of wastewater sludge production in one unit of refinery for every person in a day is reported 35 to 85 grams [3].

Since we always have the problem of accumulated sludge, the disposal of these materials and also the limitation of preservation places, therefore it is necessary to manage the produced sludge correctly in plants. Now because of the lack of well-management on disposal, sludge of wastewater treatment in our country is a serious threat on human health and environmental resources such as water, soil and crops [4].

Sludge management in wastewater treatment plants is divided in two parts, refinery and health disposal. The set of actions in these two fields, cause the purging and disposing or reusing sludge [5].

In recent decades a large number of studies about the using of wastewater sludge in agriculture and in different countries have been done, where this issue, in addition to improve the productivity of soil, can solve some problems of their disposal [6].

The wastewater sludge contains many ingredients that are necessary for plants, such as, nitrogen, phosphor and less-used ingredients

that using them in agriculture fields are economically very important.

High materials in wastewater sludge cause the improvement of physical characteristics of soil such as, electrical conductivity, stability of soil ventilation, and soil moisture. So by this it causes the improvement in growth and promotion of agricultural production [7].

The general management plan of sludge has been performed for many years in developed countries, so it is better that these plans can be fulfilled in our country by law-makers, and executive and control organizations.

Ardabil province is located in northwest of Iran in 37 degree and 45 minutes to 39 degree and 42 north width, and 37 degree and 30 minutes to 48 degree and 55 minutes of east length .This province is about 17867 square kilometers where it is about 1/1 percent of country.

Ardabil municipal wastewater plant is located in 9 kilometers of city, near Karkaragh village, and it is used for refinery of domestic wastewater of Ardabil city.

Identifying and selecting the effects

For determining the most important and effective criteria in reusing sludge in Ardabil municipal wastewater treatment plant,

We used Delphi method in four Components; physicochemical, biological, economic, and social and cultural and environmental pollution situations.

Delphi is one of the successful and nice methods in classification of decision making. In this method some groups of experts study the problem, so if the weighting is necessary, they will decide [8].The purpose of Delphi is to use the judgment of people for problem solving and decision making [9, 10].

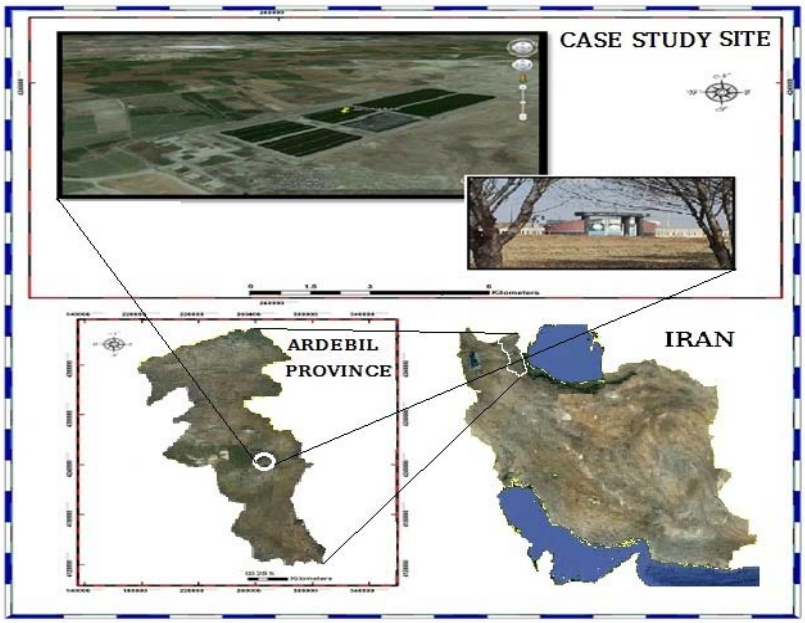


Figure 1. Position of Ardabil municipal wastewater treatment plant

Materials and Methods

First of all, we recognized the process of wastewater refinery in Ardabil municipal wastewater treatment plant and the situation of studied area. By studying that area and collecting the environment data in receptive environment, the information was completed, because the recognition of targeted environment is the operation field of all the human activities.

in the next step we made samples and did experiments; we got the results and compared them with the output standards. The sample was taken from manually evaporated sludge and by combined techniques from mid depth of different parts. The time of sampling was based on the making –hours of laboratory in the morning when the treatment plants were in their optimal condition of beneficiary. The sampling dishes were plastic with screwed lid. The volume and other characteristics of sampling, for water and wastewater experiments were performed by paying attention to experiments that were based on the recommended standard methods. In the next step we prepared Delphi questionnaire. The target groups completed it and according to the answers, we designed the AHP diagram for determining and studying main criteria and sub-criteria in reusing sludge of municipal wastewater treatment.

After this stage, the peer comparison tables for each of the derived factors were prepared. The results of this comparison, the raw data, were studied by Expert choice software, the final output of which was the weighting of criteria and sub-criteria in reusing sludge in municipal wastewater treatment.

By using the decision-making modeling of TOPSIS, we make the priorities and then the ranking of proposed scenarios (alternatives) in reusing sludge which was derived from the municipal wastewater treatment plant.

Analysis Hierarchy Process method (AHP)

The analysis hierarchy process (AHP) it was developed by Tomas Saaty in 1980. AHP method is one of the well-known multi-criteria decision making methods that is suitable for different practical domains [11].

In general, it can be stated that AHP method includes three main steps: 1- creation of hierarchy structure 2- hierarchy structure two by two elements 3- valuing the criteria. Based on AHP approach, the decision making issue is like a tree which its first level is purpose, the last level is the competitor alternative and the middle level or levels are decision criteria. So in collecting the data, the existed elements in every level should be evaluated systematically from down to up in relation to all the related elements in higher levels. In AHP, if the base of the evaluation is qualitative, the assessment will perform in comparison evenly [12].

In researches that had been done by Saaty and Vargas [13], one scope was proposed for criteria comparison which had the number amount, from 1 to 9 (Table 1).

The quantities related to the two by two comparisons should be determined completely by expertise and the optional numbers shouldn't be considered. But the priorities and style of different people, was mismatched and

so was in an incorrect way, therefore the dependence of this method on the vote of analyses, may cause the disturbance and deviation in accounting. So, Saaty gave a specific index to study the matrix stability of two by two comparisons.

According to the knowledge and experiment of operation of different AHPs, they proposed that if the rate of inconsistency be larger than "0.1" then there is needs to restudy of matrix [1].

Table 1. Saaty's 9 quantities table [14]

Preference (qualitative concept of privileges)	Quantity
Extremely Preferred	9
Very strongly Preferred	7
Strongly Preferred	5
Moderately to strongly	3
Equally Preferred	1
Preferences among above intervals	8,6,4,2

Technique for Order-Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS method was proposed by Howang and Yon in 1981. In this method, alternative (A_1, A_2…, and A_m) by n index (C_1, C_2… and C_n), was evaluated. The basis of this concept is that, the selective alternative should have the least interval with positive ideal solution and the greatest interval with negative ideal solution.

Problem solving with this method needs to take the following steps: [15]

1. un measuring of decision matrix by using the un measuring norm:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}} \qquad j = 1,...,J \qquad i = 1,...,n \tag{1}$$

2. Forming the un measuring coordinated matrix (vij) multiply by un measuring matrix (rij) in diametrical matrix weights (w_i):

$$v_{ij} = w_i \times r_{ij} \qquad j = 1,...,J \qquad i = 1,...,n \tag{2}$$

w_i The weight index is i, total weights of indices equals 1.

3. Determining of positive ideal solution (A^*) and negative one (A^-) is as following:

$$A^* = \{v_1^*,...,v_n^*\} = \{(\max_j v_{ij} \,|\, i \in I'),(\min_j v_{ij} \,|\, i \in I'')\}, \tag{3}$$

$$A^- = \{v_1^-,...,v_n^-\} = \{(\min_j v_{ij} \,|\, i \in I'),(\max_j v_{ij} \,|\, i \in I'')\}, \tag{4}$$

4. We determine the interval rate of each alternative to positive and negative ideal.

The interval of each alternative to positive ideal (D_j^*):

$$D_j^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_j^*)^2}, \qquad j = 1,...,J \tag{5}$$

The interval of each alternative to negative ideal (D_j^-):

$$D_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_j^-)^2}, \qquad j = 1,...,J \tag{6}$$

5. Determining relative clause (C_j^*) on alternative to ideal solution

$$C_j^* = \frac{D_j^-}{D_j^* + D_j^-}, \qquad j = 1,..., J \tag{7}$$

6. Ranking of alternative based on relative clause (C_j^*); the alternative that its (C_j^*) is greater, is better.

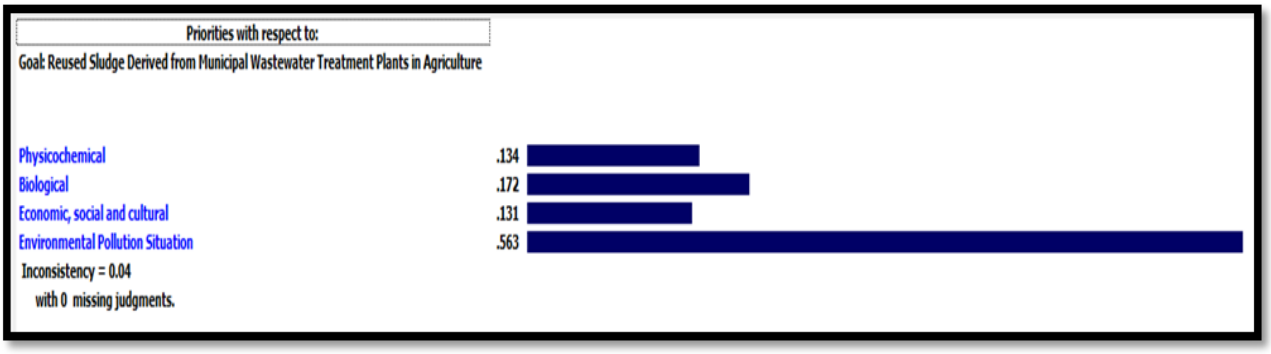
Results

Fecal coliform of sludge in municipal wastewater treatment plant of Ardebil in sampling is 13000 MPN /gr. d .s.

Based on the sampling, there wasn't any parasitism origin in the sludge of municipal wastewater treatment plant of Ardebil.

Table 2. The comparison of heavy metal amount in analysis of targeted sludge study with world standards in (mg/kg)

Allowed amount of exited sewage of refinery (ppm)	**Density 0f specific sludge EPA (mg/kg)**	**Density 0f specific monthly sludge EPA (mg/kg)**	**The amount of experiments**				**Pollutants**
			Sewage 3 (ppm)	Sewage 2 (ppm)	Sewage 1 (ppm)	Sludge (mg/kg)	
0.1	-	41	Not seen	Not seen	Not seen	Not seen	As
0.1	5-15	39	0.003	Not seen	Not seen	0.05	Cd
2	50-200	1200	0.018	0.017	0.017	0.13	Cr
1	500-1500	1500	0.008	0.009	0.009	-	Cu
1	100-300	300	0.08	0.09	0.09	0.11	Pb
0.001	-	17	Not seen	Not seen	Not seen	Not seen	Hg
-	-	-	-	-	-	Not seen	molybdenum
2	25-1000	420	0.012	0.014	0.014	0.08	Ni
1	-	36	Not seen	Not seen	Not seen	-	selenium
2	1000-3000	2800	0.018	0.023	0.024	-	Zn
1	-	-	0.002	0.001	0.001	Not seen	Co



Graph 1. Giving weight and comparing the main dimensions of project, based on main purpose of project

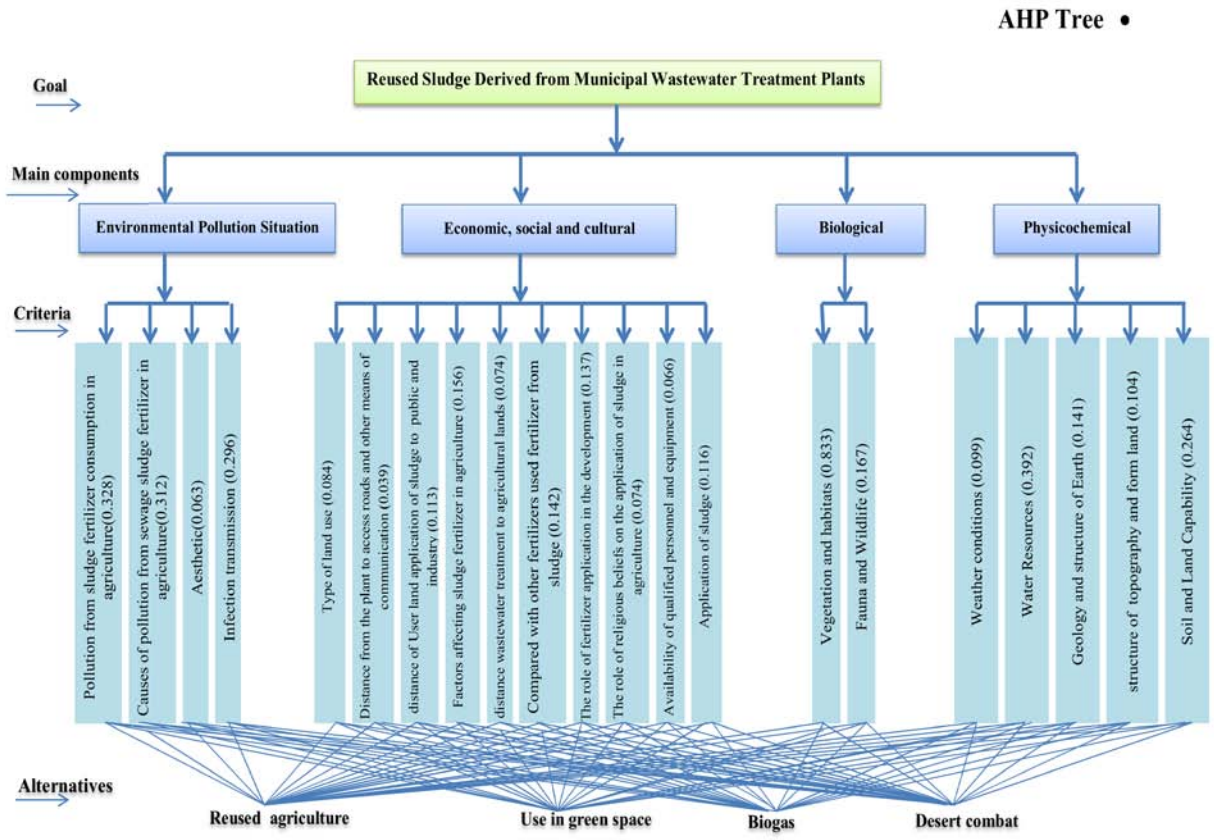
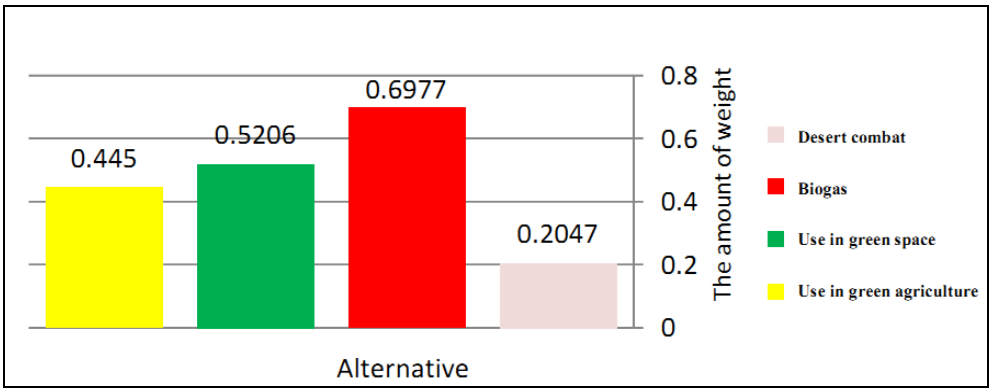


Figure 2. Hierarchy structure of reusing the municipal wastewater treatment plant sludge

Weighting and the priority of alternatives in reusing municipal wastewater treatment sludge and selecting of the best alternative by using the TOPSIS model

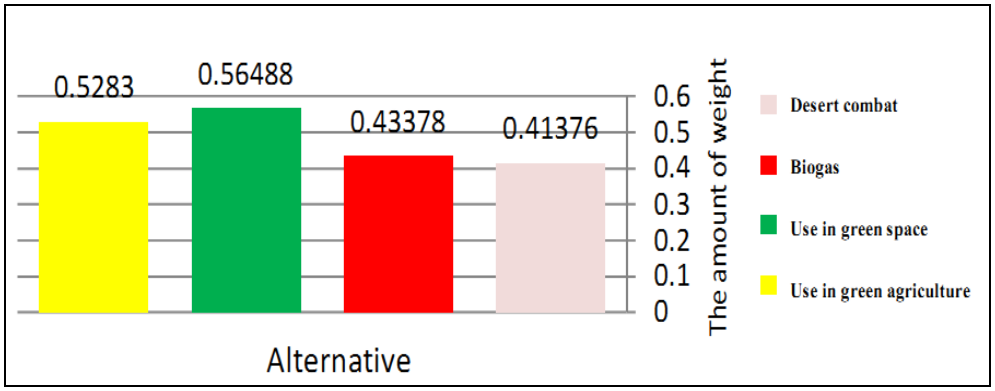
In this stage based on the output of AHP model, the weighted main criteria and the weighted sub-criteria that are related to target of project are used as input of TOPSIS model, and finally the research alternatives are defined, ranked and weighted.



Graph 2. The alternatives ranking in relation to the main categories of TOPSIS software output

Table 3. The alternatives ranking in relation to the target of the project

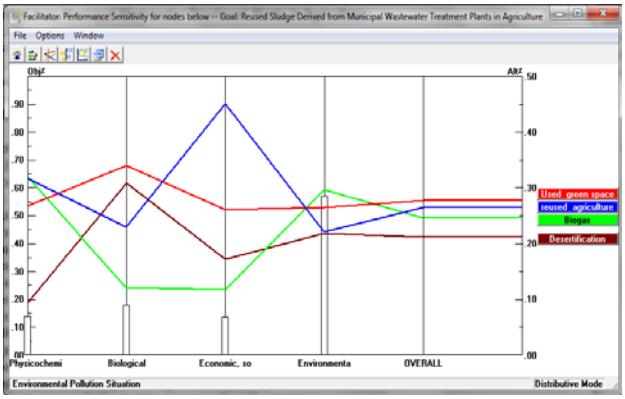
	Alternatives			
	Use in Agriculture	Use in green space	Biogas	Desert combat
Main categories	0.9269	0.5013	0.1494	0.111
Physicochemical	0.445	0.5206	0.6977	0.2047
Biological	0.4914	0.9394	0.1145	0.7446
Economic, social and cultural	0.7507	0.4817	0.2856	0.3864
Environmental pollution situation	0.0275	0.3814	0.9217	0.6221
The target of project	0.5283	0.56488	0.43378	0.41376



Graph 3. The alternatives ranking in relation to the target of the project in TOPSIS software output

Sensitivity Analysis

In general, the analysis of sensitivity shows the results of changes in the amount of main and sub-criteria priorities. In this study, the performance Analysis was used. This analysis shows the important alternatives in each parameter. Here is a point that by considering the weight of each parameter, the set of this priorities causes to get the final result. In fact by paying attention to criteria, this analysis shows how the alternatives have been ranked in relation to each other. In this part, the sensitivity of alternatives are studied in relation to the criteria weight changes. The drawn hierarchy for selecting alternatives has three levels. The sensitivity analysis of target group shows the sensitivity of alternatives in relation to the existed criteria. The criteria are in horizontal axis and alternatives are in vertical. The alternatives interceptor lines are shown by vertical lines, the overall weight of each alternative on vertical axis can be seen in right part of the graph.



Graph 4. The graph of AHP output Sensitivity Analysis in relation to the related alternatives of reused sludge

Discussion

According to the results of heavy metals of the municipal wastewater sludge experiment and the history of sewage of Ardebil municipal wastewater in Table 2 and their comparison with the current standards, especially EPA standards, the density of polluters wasn't over the standard. But it was lower than standard level.

According to Graph 1 and output of expert choice software, comparing main dimensions with reusing municipal wastewater sludge, the index of environment pollution situation with the weight of 0.563 is the greatest priority. After that, the biological index with weight of 0.172 and physicochemical with weight of 0.134 and economic, social and cultural ones with 0.131 are systematically in the next priorities. The inconsistency index amount is 0.04 too, which is less than 0.1 and can be accepted.

According to Graph 2 and output of TOPSIS software, comparing the main categories with decision making alternatives in relation to reusing municipal wastewater sludge, the alternative of using in agriculture with 0.9269 is the best alternative. So using in green space with 0.5013, biogas with 0.1494 and desert combat with 0.111 are in the next priorities.

According to Table 3 and output of TOPSIS software, comparing physicochemical dimension criteria with decision making alternatives in relation to reusing municipal wastewater sludge, the alternative of biogas with 0.6977 is the best alternative. Then using in green space with 0.5206, using in agriculture with 0.445 and desert combat with 0.2047 are in the next priorities.

According to Table 3 and output of TOPSIS software, comparing biological dimension criteria with decision making alternatives in relation to reusing municipal wastewater sludge, the green space alternative with 0.9394 is the best alternative. Then using in desert combat with 0.7446, in agriculture with 0.4919 and in biogas with 0.1145 are in the next priorities.

According to Table 3 and output of TOPSIS software, comparing economic, social and cultural dimensions criteria with decision making alternatives in relation to reusing municipal wastewater sludge, the alternative of using in agriculture with 0.7507 is the best alternative. Then using in green space with 0.4817, desert combat with 0.3864 and biogas with 0.2856 are in the next priorities.

According to Table 3 and output of TOPSIS software, comparing environmental pollution situation dimension criteria with decision making alternatives in relation to reusing municipal wastewater sludge, the biogas alternative with 0.9217 is the best alternative. Using in desert combat with 0.6221, using in green space with 0.3714 and using in agriculture with 0.0275 are in the next priorities. According to the purpose of the project (Table 3), comparing alternatives derived from the output of TOPSIS software, using in green space with 0.56488 is the best alternative. Then using in agriculture with 0.5283, biogas alternative with 0.43378, and desert combat with 0.41376 are systematically

in second to fourth priorities. Paying attention to the capabilities of AHP model, giving weights to main and sub-criteria of reusing the derived sludge of Ardabil municipal wastewater treatment plant, is a suitable method and giving weights and priorities to main and sub-criteria has been done correctly and carefully. The capabilities of TOPSIS model showed this too. Because of the nature of contemporary comparison of the two intervals based on the positive ideal and negative ideal alternative, it will be a nice method for having priorities of related alternatives to the target of the project.

Noticing the integration of two AHP & TOPSIS models, we can consider the power of giving weights to the criteria. Also by considering the least interval from positive ideal to the most negative interval, we can select the best alternative, which is happened in current study, as reusing Ardabil municipal wastewater treatment plant sludge.

Unsuitable managing in reusing municipal wastewater treatment plant sludge caused many environmental problems and healthy dangers, So, there is a need to serious policies and decisions about this, According to two decision making Approaches, the purpose of this project is an integrated method, i.e. solving these problems whether by decreasing the effects of unsuitable keeping of sludge or correct management and better use of the large amount of produced sludge.

Conclusion

In Iran, by increasing the number of the wastewater treatment plants in coming years, and unavailability of rules and standards about using the sludge, making rules and standards that are specific for Iran climate conditions, in national or international level, is very essential.

The results of the experiments about the sludge and sewage of municipal waste water treatment plant and their comparison with standards, specially the standard of Environmental Protection Agency of United States (EPA) show the density of heavy metals in reusing sludge is in the lowest level and in the bacteriological point of view, the fecal coliform is 13000 MPN/gr.ds lower than the known level in reducing pathogen in class B (less than 2 million MPN/gr.ds). So it will be in class B, due to the sludge classification. According to the sampling about the parasitical origins of sludge in Ardabil municipal wastewater treatment plant, there was no parasitical origin.

After identifying and admitting the criteria and sub-criteria by target group, the questionnaires distributed among the target group, the data of the study were collected and analyzed, and as raw data, placed on Expert choice software to analyze AHP model.

Finally in the output of the software, giving weights, the priorities of main and sub-criteria in mentioned environments were determined. The environmental pollution situation with 0.563 was in first priority. But other environments, like biological with 0.172, physicochemical with 0.134, and economic, social and cultural with 0.131, were the following priorities. we use the output of this software as the input of TOPSIS software, and

the weighted criteria with the optional alternatives, were in low among them, using in green space alternative with 0.56488 was the first priority, and then using in agriculture alternative with 0.5283, biogas alternative with 0.43378, and desert combat with 0.41376 were systematically in the next priorities.

These weighted numbers of defined alternatives in the model were based on the measured criteria, and in relation to the greatness of the prior alternative in the model, they were great in number.

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