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Feasibility of Using Dried Sudge from Wastewater Treatment Plant in Yazd for Agricultural Purposes Based on Environmental Protection Agency Standards

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A R T I C L E I N F O

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ABSTRACT

Introduction: One of the methods for disposal of sludge is its usage as fertilizer on agricultural. The purpose of this study was to analyze the possibility in the application of sludge to agricultural, according to environmental standards.
Materials and Methods: This descriptive-analytic study was conducted for 12 months on dried sludge wastewater treatment plant in Yazd. Monthly sampling and tests were performed on samples in all four seasons of winter, spring, summer, and fall, thus, totally 24 samples were collected. The physical, chemical, fertilizer values, microbiological characteristics, and metal of the sludge were measured and their mean were compared with EPA standards.
Results: The results showed that the mean of pH, TS, moisture, and organic material in the sludge were 6.58, 58.31%, 11.37 %, 33.09 % respectively and they were in a normal range. The mean of carbon, nitrogen, phosphorus, sodium and potassium, were 61.5%, 5.47%, 4.34%, 0.43%, 0.42%, respectively which only sodium was in the range and the rest exceeded it. The mean of coliform and fecal coliform were 15062 and 2655 (MPN/g), respectively and the mean of parasite eggs per 4 g/dry sludge in the four seasons was 3. The mean of metals, namely lead, iron, zinc, manganese, and copper were 19.64, 47.57, 864.23, 89.06, and 146.26 mg / kg.dry solid, respectively.
Conclusion: Results of the study showed that the sludge wastewater treatment in Yazd was in the range of EPA standards for Class B.

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Introduction

The sludge from wastewater treatment is the solids obtained from different treatment methods to remove dissolved and suspended contaminants from wastewater by separating solids from liquid, chemical precipitation, or biological activity in a plant. It contains organic matters and microorganisms and it is an important product in the purification process [1,2]. There are several options for final disposal of the sludge which burning, sludge disposal in sanitary landfills, and use of it in agricultural land is the most notable of them [1, 3]. The general attitude of the wastewater treatment process in our country is in such a way that the main attention focused on the quality of effluents and sludge disposal is considered rarely [4]. The main reasons for the lack of monitoring on the quality of the sludge from wastewater treatment in Iran can be the technical complexity in sludge treatment processes, high costs of sludge plant, and the lack of laws and monitoring regulations for the responsible organizations [5, 6]. Nowadays, the sludge management, with the development of wastewater treatment including the construction of new wastewater treatment units or the existing facilities' improvement, has become one of the most critical environmental issues [7]. Due to the increasing development of urban waste water treatment plants in Iran and productions of more sludge, the necessary facilities are essential for using this valuable product. Use of land is one of the methods of sludge usage and the most common method for final disposal in many developed and developing countries[1]. This is so important that during the past decade the use of sewage sludge in agriculture has become a common issue [8]. It is rich in nutrients such as nitrogen and phosphorus for plants and it also can have positive effects on yield, physical, chemical and biological soil properties [9].Therefore, the offer for the use of sewage sludge on agricultural land looks useful. Because it can solve its disposal problem and then can be used as a valuable organic fertilizer [10.] Since the sewage sludge has a lot of germs and disease-causing microorganisms or heavy metals as well as toxic organic compounds [9]. Thus, the use of sewage sludge in agriculture has led to health concerns and threated the public health[11].That is why many countries regulate the use and disposal of sludge. In this regard, American Environmental Protection Agency (EPA) wrote some regulations named (Code of Federal 40CFR Regulations) with the following parts:

A) The designed regulations to control and reduce Pathogens in sludge

The regulations under Part D from article 503 of the mentioned regulations have been divided into two classes of A and B. The main purpose of the provisions in Class A is to reduce the pathogens of sewage sludge below the detectable levels. It means less than 3 MPN Salmonella, PFU intestinal virus, and a fertilized parasite egg per 4 grams of total solids in terms of dry weight sewage from sewage sludge or less than1000 MPN fecal coliform in each gram of total solids according to the dry weight [12].

Moreover, the main purpose of the provisions of Class B, is to ensure that pathogens are reduced to levels that cannot be a threat to public health and the environment under certain conditions, i.e. less than 2 million MPN fecal coliform in each gram of total solids in terms of dry weight of sewage sludge for Class B sludge used in land. Class B sludge cannot be packaged in bags or other containers sold for various uses. None of these limits does exist for Class A [12].

B) Regulations established for reducing the vectors' attraction ability

Vectors are organisms that have the ability to transfer pathogens through mechanical and biological methods, such as insects, rodents, and birds that can put a human or an animal in contact with pathogens of sewage sludge and are considered as a risk [12].

C) Limitation of heavy metals and organic compounds

Industrial wastewater and drained rain water from streets and public places are often imported to wastewater canals. So, in addition to the organic material the sewage sludge contains a small amount of pollutants used in modern society [2]. The chemical elements for plants and animals can be both useful and harmful [13] and are the important and determinative factors for the quality of sludge for different purposes.

According to Ozdemir and Ogleni study about the effect of solar drying sludge on reducing pathogens and its application in the soil, the fecal coli-forms in the sludge dried by the sun were reduced from 4.2×10^7 MPN/g to 1.7×10^5 MPN/g and classified in class B[14]. Another study by Mesdaghinia et al. was conducted on Tehran wastewater treatment plant which was entitled as "Comparison of wastewater treatment plant properties with the environmental standards". In this study the following statistics were reported; total coliform (205×10^5MPN/g), fecal coliform (2,016,543), copper (1400.5), lead (247.7), respectively and the sludge was not in any of the standard classes [15]. Takdstan et al. examined the health indicators of digested sludge in Isfahan wastewater treatment plants and compared them with environmental standards for reuse. Their study showed that the sludge under study was in Class B of EPA standard [16]. Farzad kia et al. conducted a research on analyzing the sludge quality in treatment plant in Serkan, Hamadan and compared it with the environmental standards for reuse. Their study showed that the characteristics of the produced sludge were significantly different from Classes B and A of EPA regulations [17]. Since the sludge produced in this plant had no application, this study aimed to investigate the feasibility of Yazd wastewater treatment plant's sewage sludge re-use on agricultural lands and its comparison with the EPA standards.

Materials and Methods

This descriptive and analytical research was performed in 12 months, from october 2013 to september 2014. Yazd wastewater treatment process included an advanced SBR with a capacity of 32,000 cubic meters per day of influent wastewater and 820 cubic meters per day of sludge. In treatment plant, the produced sludge is dried in sludge dryer with the sunlight from an open place. Sampling location in the plant was then determined from the sludge dryer's beds. Composite sampling was performed (samples from four points of the dried sludge masses) in the four seasons, i.e., winter, spring, summer, and fall through a year with one month intervals. 3 samples were collected in each season but since there were two repeated tests, a total number of 24 samples were taken to determine the proposed parameters. According to the conditions listed in references, uniform samples were collected in clean plastic containers for normal tests, and in 400 ml glassy sterile containers for microbiological tests. To avoid change in the sample's condition and maintain the actual conditions, the samples were maintained in Cold box under appropriate conditions in terms of temperature (between 0-4ċ) and then transferred to the laboratory in less than six hours.

In this study, to determine the physical, chemical, fertilizer values, as well as microbiological and heavy metal sludge, some parameters such as pH, moisture, total solids, organic substances, carbon, nitrogen, phosphorus, sodium, potassium, the C/N ratio, fecal coliform (MPN), total coliform, Parasite eggs (total), and heavy metals namely lead, zinc, iron, manganese, and copper were selected. To determine the concentration of heavy metals, the extraction method by nitric acid and hydrochloric acid was used. The applied devices in this study are presented in Table 1. All experiments were conducted based on the guidelines of different authorities like the standard method [18] and others [19, 20]. In the fecal coliform test, the density of the samples in sludge is predicted to be high because they were solid. For the preparation of samples and to have appropriate density, the proposed EPA method was used and then continued with the usual MPN method according to E 9221 instructions [18] of the standard method. Physical parameters and fertilizer values were compared with the standard range in the study of Bina et al. while heavy metals as well as microbiological parameters were compared to EPA standards. In order to enhance the accuracy of the measurements, all tests were performed twice and their average was reported. Data analysis using t-test and $p = 0.05$ was performed using SPSS software (version 16). Further, Excel software was used to plot charts.

Table 1: Devices used in this study

Parameters	The used devices
pH	pH meters Portable Model HQ40 - HACH
Total coliform	Incubators Memmert, autoclave made in Iran, Ben Marie with Behdad brand in Iran
Fecal coliform	Incubators Memmert, autoclave made in Iran
Parasite eggs	EBA20- Hettich Centrifuges, microscopes Motic BA310 model
Heavy metals	Atomic Absorption (AA) flaming Varian - spectra AA.20 Plus model, made in Australia

Results

The results achieved from normal objective observations on the samples of fecal sludge in the treatment plant showed that produced sludge in this plant was stinking with dark brown close to black. The pH mean, total solids, moisture, and organic material of the samples as well as comparisons with normal values for different seasons, are presented in Table 2. According to the table, the total mean for all physical parameters is within normal values ($P \leq 0.001$).

Table 2: Mean concentrations of some physical properties of dried sludge in different seasons

Parameter	Winter 2013 Mean ± SD	Spring 2014 Mean ± SD	Summer 2014 Mean ± SD	Autum 2014 Mean ± SD	Total	Typical values	P value
pH	6.9 ± 0.1	6.3 ± 0.26	6.4 ± 0.25	6.7 ± 0.26	6.58	6-9	≤ 0.001
TS (%)	58.51 ± 0.17	58.7 ± 0.27	58.07 ± 0.17	57.94 ± 0.1	58.31	50-70	≤ 0.001
Moisture (%)	14.5 ± 1.3	9.01 ± 0.32	9 ± 0.4	13 ± 0.95	11.37	30-50	≤ 0.001
Organic materials (%)	32.3 ± 0.7	27.4 ± 0.68	34.25 ± 0.52	38.35 ± 0.56	33.09	25-50	≤ 0.001

The mean levels of total coliform, fecal coliform, and parasite eggs have been provided for four seasons in Figure 1-3. According to Figure 1 and 2, the lowest rates for fecal coliform and total coliform were obtained in summer against the highest value in winter. The comparison of the total mean of fecal coliforms with the standard level indicated that there was no significant difference ($p = 0.3$). Moreover, the lowest parasite eggs were obtained in summer and the highest ones in winter (Figure 3). The comparison of the total mean of parasite eggs with the standard level showed that there was no significant difference ($p = 0.9$).

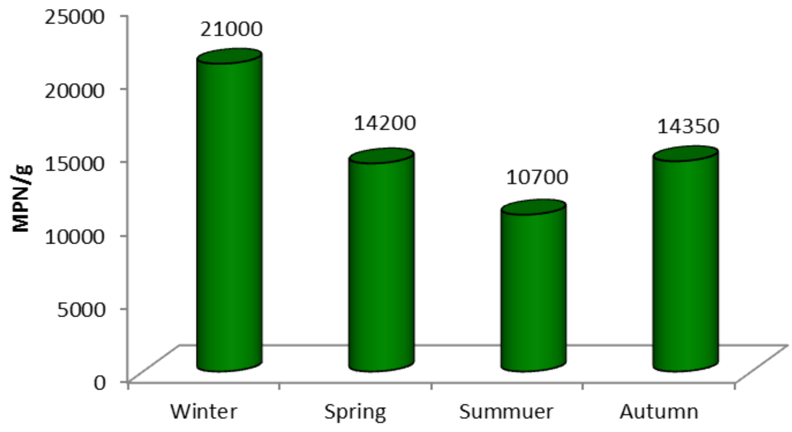

Figure 1: Comparison of the total coliform in different seasons from the dried sludge

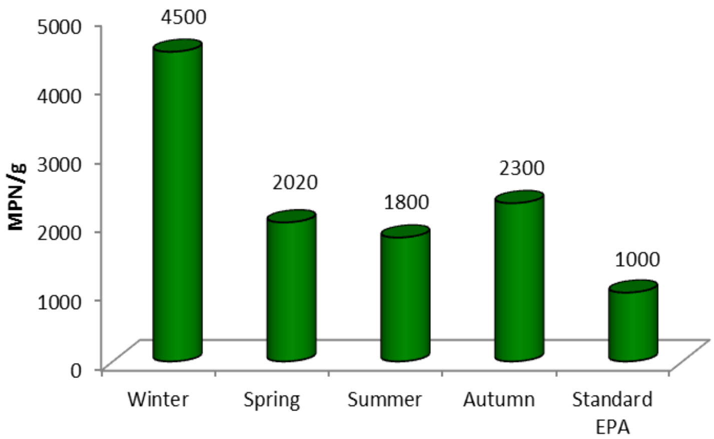

Figure 2: Comparison of fecal coliform in different seasons from the dried sludge with the US. EPA standards

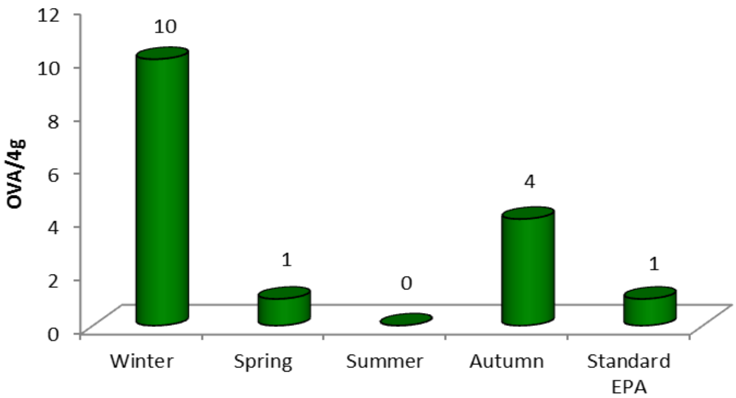

Figure 3: Comparison of parasite eggs in different seasons from the dried sludge with the US. EPA standards

Table 3 shows the measured means of sludge fertilizer value parameters for four seasons compared with normal values. According to that, the mean values of carbon, nitrogen, phosphorus, and potassium in all four seasons are high and out of range while only sodium is in the range. The quality comparison of the sludge fertilizer value parameters showed that the level of carbon, nitrogen, phosphorus, sodium, potassium, and C/N ratio have significant differences with the standard level and the values are higher than the standard.

Table 3: Mean concentrations of some parameters of dried sludge fertilizer values in different seasons

Element	Winter 2013 Mean ± SD	Spring 2014 Mean ± SD	Summer 2014 Mean ± SD	Autumn 2014 Mean ± SD	Total	Typical values	P value
Carbon (%)	62 ± 1	61±1	63 ± 2.6	60 ± 2	61.5	8-50	≤ 0.001
Nitrogen (%)	5.48 ± 0.3	5.42 ± 0.4	5.61 ± 0.26	5.38 ± 0.21	5.47	0.1-3.5	≤ 0.001
Phosphorus (%)	4.51 ± 0.3	4.26 ± 0.33	4.16 ± 0.28	4.46 ± 0.28	4.34	0.3-3.5	≤ 0.001
Sodium (%)	0.45 ± 0.03	0.42 ± 0.02	0.48 ± 0.03	0.39 ± 0.02	0.43	0.2-0.5	≤ 0.001
Potassium (%)	0.39 ± 0.03	0.42 ± 0.03	0.45 ± 0.02	0.4 ± 0.03	0.42	0.1-2.8	≤ 0.001
C/N Ratio	11.31	11.25	11.22	11.15	11.23	20	≤ 0.001

Table 4 presents the mean concentration of heavy metals compared to standards in different seasons of the year. According to the Table, the minimum mean concentrations of heavy metals for lead and copper were in the summer, for Zinc was in the spring, and of iron and manganese were in winter from the sludge samples. In contrast, the highest mean concentration of lead was in the spring, for zinc and copper were in the winter and of iron and manganese were in the summer. Comparing the mean concentration of the data with EPA limit showed that mean scores of the studied heavy metals in the sludge have been significantly below the permissible limit of concentrations ($p < 0.001$).

Table 4: Mean concentrations of heavy metals in the sludge dry) in terms of (mg / kg.dry solid) and compared to the EPA standard

	Winter 2013	Spring 2014	Summer 2014	Autumn 2014	Total concentration	Standard concentration	P value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD			
Lead	16.91 ± 0.6	23.85 ± 0.31	16.65 ± 0.25	21.17 ± 0.2	19.64	300	≤ 0.001
Iron	40.57 ± 0.3	44.57 ± 0.47	54.57 ± 0.44	50.57 ± 0.24	47.57	-	-
Zinc	938 ± 0.57	801.88 ± 0.35	831.88 ± 0.31	885.18 ± 0.22	864.23	2800	≤ 0.001
Manganese	45.81± 0.19	125.81 ± 0.19	135.81 ± 0.27	48.83 ± 0.23	89.06	-	-
Copper	188 ± 0.39	141.33 ± 0.33	118.35 ± 0.41	137.33 ± 0.36	146.26	1500	≤ 0.001

Discussion

To analyze the quality of the produced dried sludge by the plant and compare it with the standard for different applications, the results will be discussed from four viewpoints.

Physical quality analysis of the sewage sludge

Physical experiments are usually conducted to determine the vectors' attraction rate including insects and rodents [21]. Comparison of data in Table 2 with the typical values show that the mean values of these parameters were all in the normal range and therefore the application of sludge is permitted for different applications especially for agricultural purposes. Comparing the achieved results with those of Bina et al. on the quality of the dried sludge in Isfahan treatment plants showed that physical parameters' mean is less in the present study [10]. PH of sludge or wastewater could be important either from discharge to the environment view point or its usage for different purposes. PH of sludge influences soil pH and is effective in soil, plants, as well as the microbial population absorption. pH less than 6.5 is effective in leaching of heavy metals and their absorption by the plant [22]. According to the results, the examined sludge pH is in the usual range and will not have a significant effect on soil or the recipient environments. In Rahmani et al. research, the pH mean was 6.6. The comparison of the results from the current study with the results of Rahmani et al. showed that both of them are close to each other in terms of the pH parameter [8]. The number of solids in sludge could be important from different aspects including use as fertilizer, sludge dewatering systems design, design and operation of sludge dryer beds, and etc. Therefore, the values would be essential [23]. According to the results of the current study, the highest mean value of the total solids (TS) is in the spring and the lowest values were measured in autumn. According to the data, it can be concluded that the high total solids in spring are due to fluctuations in rainfall and the increase of storms and floods at this time of year. This can result in a greater volume of runoff into the treatment plant which brings and deposits many suspended solids, sediments, and most of the pollutants.

Analyzing the microbiological quality of sewage sludge

A) Fecal coliform and total coliform

Nowadays, the rules and criteria about the features of fecal sludge from sewage treatment have not been provided by the responsible organizations and institutions such as the EPA. So, for microbial quality control of the output sludge from wastewater treatment plants, some reliable laws and regulations from other countries, such as U.S. EPA standards, could be used [24]. EPA standards indicate that for sludge usage on agricultural lands, if the number of fecal coliform per a gram of total dry sludge solids is below 1000, the sludge is classified in Class A, and thus its usage is without any restriction. If the number of Coliform is between 1000 MPN/g to 2x 10^6 MPN/g, the sludge is in Class B and its application has some limitations [25]. Comparing the achieved results with EPA limits, as it can be seen from Figure 2 the sludge in all four seasons of the year is more than 1000 MPN/g and less than 2x 10^6 MPN/g in terms of the number of fecal coliforms, thus it is classifed in class B of EPA standard. As a result, this sludge by taking into account some restrictions can be used in agricultural lands. One of the most important factors in eliminating microorganisms in the summer is solar radiation with sufficient heat during the day and the duration of exposure to sunlight. Ogleni and Ozdemirindicated that reducing fecal coliforms in the sludge significantly depends on sunlight [14]. Results of Ardalan et al. [25] showed that while the produced biological sludge in Shahrekord, Farsan, and Borujen treatment plants, is only classifed in Class B standard in winter in terms of fecal coliform, in this study the means of all four seasons are in the range of class B standard.

B) The number of eggs

EPA standards determine that for sludge usage on agricultural lands, if the number of parasite eggs in 4 grams of sludge dry solids is one, the sludge is placed in Class A. For Class B sludge only fecal coliform testing is sufficient and there is no need for other tests to determine the microbiological quality such as virus, salmonella, and parasite eggs [10]. Due to the importance of parasite eggs, the parasite counting test was performed for all the samples. As it is seen in Figure 3, the sludge in spring and summer are within the limits of Class A and without limitations. Moreover, the sludge in winter and autumn is in class B of the standard.

The quality analysis of sewage sludge for fertilizer values

The main cause of high carbon can be incomplete digestion and condensation of the sludge in earlier stages of sludge treatment [10]. Because of the relation between carbon and nitrogen, carbon comparison with the standard alone is not very valuable [10], so the carbon to nitrogen (C/N) ratio is a better parameter to compare. According to Table 3, C/N ratio is within the standard range for all seasons in the plant. Finally, according to the survey results, the lowest ratio C/N and the largest utility in terms of its fertilizer value for a plant is in the fall. Totally, the value of this sludge fertilizer is relatively high and contains significant amounts of nutrients for plant growth and its products. Therefore, the application of these fertilizers is permitted and useful. Moreover, if the management is correct, the soil will be fertile.

The quality analysis of wastewater from the heavy metals perspective

Heavy metals as the most toxic chemicals in the sludge can have harmful effects on humans, plants, and animals [10]. The majority part of heavy metals settles during wastewater treatment in the form of oxide or hydroxide in the sludge. Then, if the resulting sludge is used to strengthen and amend the soil, some heavy metals may release and absorbed by plants, especially in soils which their pH are acidic and less than 6.5. Comparison of the measured values of heavy metals with the standard values of EPA (maximum) showed that metal amounts do not exceed the standard. Therefore, the application of the sludge in terms of these elements for the sludge usage discussed before is permitted. It should be noted that, although no standards have been determined for agricultural use or disposal of iron and manganese in the sludge, due to the low concentration of these elements in comparison with other metals, there will be nothing to worry about. But attending to these two issues should not be down played. First, the elements have accumulative property and so more care should be taken into account in the amount of sludge application in a particular soil, at any time during a year. The amount of sludge application is considered as one of the important design parameters, i.e., more attention should be paid to the amount of these elements in the soil compared to the sludge [10]. Second, the researchers believe that in setting EPA standards, issues such as chemical differences in soil and sludge as well as the effects of inorganic and organic materials on keeping the solution of toxic metals have not been attended. Therefore, the long-term effects of the sludge containing heavy metals in designated loadings by the EPA regulations is unclear and does not have the necessary protective effects, this means that the amount of these elements in the soil should be considered [10]. Several studies have been conducted in different parts of the world about the measurement of heavy metal contents in the sludge, for example, Rahmani et al. in 2013 studied about the evaluation of some quality characteristics and concentrations of heavy metals in drying sludge of the sewage treatment plant in ShahinShahr, Isfahan. The results of the mentioned study showed that heavy metal concentrations measured in this study were much higher than the values of the present study [8].

Conclusion

Reuse of disposal sludge from wastewater treatment plants, in the case of their compliance with the quality standards, can largely fulfill the agricultural soils, water and fertilizer's needs in Iran. This disposal method will also compensate for a part of the treatment plant's cost by the waste sludge's sale. The results showed that microbial quality of sludge from wastewater treatment in Yazd was within EPA standards for Class B. So, this sludge can be used for agricultural purposes with observing the right precautions and cares. It is suggested that following this research, the mentioned parameters in addition to output fertilizer samples of the water treatment plant be studied to examine the products of the fields in which the sludge is used as fertilizer and thus the actual effects of the sludge are determined.

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Conflict of interest

We have no competing interests.

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