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Survey on the quality of outlet biosolids and sludge heavy metals in the wastewater treatment plants of Mazandaran province

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Abstract

Background: Sewage sludge is rich in fecal coliforms, Salmonella, parasite eggs, and heavy metals that can cause disease in humans. The aim of this study was to evaluate the quality of outlet biosolids and sludge heavy metals in the wastewater treatment plants (WWTP) in Mazandaran province and to compare them with the Environmental Protection Agency (EPA) standards.

Methods: This study was carried out on the sludge of the treatment plants of Sari, Joybar, Babol, Babolsar, Nowshahr, and Nowshahr-Chalus sludge compost plants. In this study, physical, chemical, and biological properties of sludge samples including retention time, pH, total solids (TS), color, heavy metals (copper, zinc, nickel, cadmium, and chromium) as well as the density of fecal coliform, Salmonella and parasite eggs were determined and reported.

Results: Biosolids of Joybar, Babol, Babolsar, and Nowshahr-Chalus WWTP in terms of parasite eggs were in class A. Biosolids of Sari WWTP in summer after drying off naturally were located in Class A, and in summer and spring, were located in Class B based on the US EPA criteria. The average concentration of heavy metals (copper, zinc, nickel, cadmium, and chromium) was lower than the EPA standard.

Conclusion: The results showed that mostly the treated sewage sludge in Mazandaran WWTPs were in Class B of the EPA guideline. The concentration of heavy metals in the biosolids of these WWTPs is lower than the EPA regulation and the use of these biosolids in agriculture is not limited for these metals.

Keywords: Biosolids, *Escherichia coli, Salmonella*, Parasites, Heavy metals

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Introduction

Today, biosolids management in new or existing wastewater treatment plants has become one of the most critical environmental issues. Biosolids are a product of the biological wastewater treatment process. During the biological wastewater treatment process, the liquids are separated from the solids. Those solids are then treated physically and biologically to produce a semisolid, nutrient-rich product known as biosolids. The terms 'biosolids' and 'sewage sludge' are often used interchangeably. The sewage sludge is defined as the solid, semi-solid, or liquid residues produced during the wastewater treatment process (1). The amount of dry solids in the United States is estimated to be 7 million tons, in the European Union, 8 million tons, in Japan, 3.5 million tons, in Taiwan, 0.2 million tons, and in Korea, 2.43 million tons per year (2). Sewage sludge (biosolids) disposal is a major environmental problem in cities. In the past, burning and burying sludge were common methods of disposal. With increasing costs and limited landfills and the prohibition of unacceptable environmental practices such as ocean dumping, there were strong reasons for increasing the use of sludge in agriculture. Sewage sludge also contains organic matter that is rich in nutrients such as nitrogen and phosphorus and micronutrients required by plants (3). The use of sludge to improve soil and agricultural uses, afforestation, green space, tree planting, and playground grass is one of the most important methods of reusing it (2). For each of the above-mentioned uses, the quality of the sludge must be chemically and biologically (heavy metals and pathogens) measured and evaluated to prevent health and environmental problems. Sewage sludge, despite being beneficial nutrients for plants and soil-improving properties, may contain a variety of bacteria and parasites that make its use in agriculture difficult and dangerous to human health (4). For this reason, regulations were enacted by user countries to control biosolids in agricultural use and reuse, including the Code of federal 40 CFR part 503 Regulation, which was enacted by the US Environmental Protection Agency (EPA) and includes various sections. Biological sludges (biosolids) refer to sewage sludge that has been treated for useful use (5).

Biological solids are divided into two classes, Class A and Class B, based on the content of pathogens. In Class A, a higher level of biological solids treatment is done, so that the dewatered sludge can be used in agricultural land without any restrictions. It can also be packaged and sold. In contrast, Class B biosolids are the result of lower levels of treatment. The treated sewage sludge that is only suitable for specific use as fertilizer with site restrictions. It is intended to reduce the pathogens to a level that is not a threat to public health and environment so that the biosolids can be applied to agricultural lands, forests, or reclamation sites (6). This class of biosolids designed to reduce the pathogens to a level that it is not a threat to public health and environment so that the biosolids can be applied to agricultural lands, forests, or reclamation sites (7). Investigations have shown that wastewater treatment plants are mismanaged and sludge escapes without complete stabilization (4,8).

Farzadkia et al estimated that the mean fecal coliform density to be 8.97×10^7 MPN/g (dry solids), which is lower in microbial quality than the USEPA Class B microbial regulations (8). Asadi Ardali et al reported that the mean values of fecal coliforms for the sludge of Shahrekord, Farsan, and Borujen treatment plants are 1.63×10^6, 1.93×10^6, and 1.98×10^6 for winter and 4.51×10^6, 5.75×10^6, and 9.23×10^6 MPN/g (ds) for summer, respectively (9). According to the EPA standard, all three treatment plants were in Class B in winter.

Bina et al determined the geometric mean of fecal coliform in three WWTPs of South, North, and Shahinshahr of Isfahan, respectively, 1.8×10^6, 2.3×10^6, 1.6×10^6 MPN/g (ds) of sewage sludge. According to the results of this study, South and Shahinshahr WWTPs in Isfahan are in Class B of the U.S. EPA regulations (above 1000 and less than 200 000) and Northern WWTP are not even in Class B and their use should be avoided separately (4).

Farzadkia et al showed that the mean values of fecal coliforms in the discharged sludge from Sarkan WWTP were 1.93×10^8 MPN/g (ds) (8). The sources of heavy metals entering urban sewage include direct precipitation from the atmosphere in polluted areas, discharge of industrial and hazardous wastewater into the urban sewage network, runoff entering and infiltrating and leaking into the sewage network (10). Torabian et al determined the density of fecal coliform in the municipal sewage sludge of Qods city WWTP to be at least 120 MPN/g (ds) in the spring sludge sample, which meets the sludge conditions of Class A of the EPA biosolids criteria (less than 1000 MPN/g (ds)). Also, with fecal coliform density with a maximum amount of 1.6×10^4 MPN/g (ds) in the autumn and winter sludge samples, meets the Class B of the EPA biosolids criteria (less than 2 000 000 MPN/g (ds)) (11).

Rahmani et al conducted a study to assess the mean fecal coliform levels in dried sludge from the Shahin Shahr WWTP in Isfahan. The results showed that the mean fecal coliform count was 1.46×10^4 MPN/g in summer, which was the lowest value observed. In contrast, the highest value of 2.4×10^8 MPN/g (ds) was recorded in winter. It is important to note that the dried sludge in winter exceeded the permissible limit for Class B, indicating that it is unsuitable for use on agricultural land. (12). Soil amendment with municipal sewage sludge compost fertilizer containing N, P, and K prevents their excessive leaching in underground water (13).

The fertilizer produced by composting urban sewage sludge causes changes in the biological, chemical, and physical characteristics of the soil, which affects the soil properties in the long term if this fertilizer is applied to agricultural land (14). Ziaei Hezarjaribi et al reviewed the parasite prevalence and removal efficiency in different WWTPs (15). In a research conducted by Yousefi et al in Babolsar-Northern Iran on the identification of parasites in the output sludge of an active sludge treatment plant, the number of worm eggs in the sludge was reported to be more than the recommended value by the EPA standards. Also, the number of Hymenolepis diminuta and Toxocara in the biosolids was high, and the possibility of secondary contamination due to animal movement was also high (16).

One of the causes of parasitic contamination of drinking well water in Mazandaran province is the lack of organizing the sludge of decentralized treatment plants and septages. The lack of sewage treatment plants in the cities of the province or the lack of complete coverage of the urban sewage network and the high level of underground water have provided the basis for the discharge of sludge from toilets and septic tanks, etc. into the environment. Septages in Mazandaran province are collected and discharged into the environment through septage discharge tankers, and eventually, cause surface and underground water pollution that are used as sources of drinking water supply (17,18). In this study, the quality of sludge coming out of wastewater treatment plants in the cities of Mazandaran province was analyzed and compared with the EPA standards. In the research conducted by Aghili et al on the dewatered sludge sample of Sari WWTP, the density of faecal coliform, salmonella and helminth ova were reported as $2.37 \times 10^6 \pm 1.06 \times 10^6$

MPN/1 g d.s weight, 47 ± 12.92 MPN/4 g d.s weight, and 466 ± 61.85 number/4 g d.s weight, respectively, therefore, the DWS of Sari WWTP was categorized in the Class B of the EPA standard (19).

Materials and Methods

Biosolids samples were taken from the sewage biosolids of Sari, Joybar, Babol, Babolsar, and Nowshahr-Chalus WWTPs. Sampling and analysis of samples parameters including fecal coliform, salmonella, helminth ova, pH, total solids (TS), and heavy metals (Cr, Cd, Ni, Cu, and Zn) were performed during three seasons with three replications based on the US EPA Standard (No. 1680) (13).

Before sampling, all biosolids sample containers were washed with distilled water.

The containers of heavy metal samples were protected by 1% nitric acid (HNO_3) and stored in a refrigerator at 4 °C (in ice-filled unolite containers). Sample containers were stored in an ice box at 4 °C and were transferred to the laboratory of the Health Faculty of Mazandaran University of Medical Sciences for analysis. The method used in this research to digest sludge samples for heavy metals was according to the Iran's national standard (No. 5615).

Samples were collected from each treatment plant during the three seasons of the study and a total of 36 samples were taken from the biosolid output of the treatment plants to determine the concentration of fecal coliform, salmonella and parasite ova. The samples were taken randomly using the method provided by the US EPA standard 1680 and transferred to the laboratory in sterile glass containers at temperatures below 10 °C. To determine the concentration fecal coliforms, microbial tests were performed using MPN multi-tube fermentation method with culture medium of Lauryl tryptose broth and *Escherichia coli* broth (20). The MPN method was used to enumerate Salmonella, with TSB media used for enrichment and MSRV employed to inhibit the growth of non-Salmonella species. Suspicious colonies were isolated on xylose lysine deoxycholate (XLD) agar medium. Subsequently, a biochemical confirmation step was carried out using lysine iron agar(LIA), triple sugar iron(TSI) agar, and urea broth media, and the number of Salmonella was determined and reported as MPN per 4 grams of dry weight of sludge (21). To ensure accuracy, the tests were conducted three times, and the results were reported as averages. Parasitic infestations were assessed using modified Bailenger method, which included direct observation, flotation, and slide McMaster techniques (22). The analysis of heavy metals followed the standard methods outlined in Instruction No. 6515 and 6516 of the Standard Organization of Iran, involving acid digestion. Helminth ova measurements were carried out in accordance with the EPA guideline (21). Statistical analysis of the data was performed using SPSS version 22.0, and graphs were generated using Excel software.

Results

Physical and biological characteristics of sludge samples including retention time, pH, TS, color, fecal coliform density, Salmonella and parasite eggs are listed separately for treatment plants in Table 1.

Table 1. Physical and biological properties of sludge output from treatment plants in the cities of Mazandaran province

City	Season	Detention time (d)	pH	TS %	Color	Fecal coliform MPN/g (ds)	Salmonella MPN/4 g (ds)	Parasite eggs ova/4g (ds)
Sari	Winter	0-40	7.75	12.27	Dark brown	14000	16	2
	Spring	50-90	7.9	11.5	Dark brown	40	14.83	9
	Summer	370-415	6.61	61.9	Dark brown	25	0	1
Joybar	Winter	730	8.7	72.2	Light brown	4	2.4	0
	Spring	840	8.63	83.8	Light brown	20	2	0
	Summer	910	6.26	81	Light brown	150	3	0
Babol	Winter	90-110	7.8	22.47	Dark brown	400	11	1
	Spring	180-215	8.63	23.25	Dark brown	180	7.5	0
	Summer	270	7.38	28	Dark brown	160	7.35	0
Babolsar	Winter	20-120	7.73	18.36	Dark brown	230	11	1
	Spring	10-40	7.24	16.97	Dark brown	2500	4	0
	Summer	95	7.45	22.5	Dark brown	35	35	1
Nowshahr-Chalus	Winter	50	7.36	20.9	Dark brown	15	7	0
	Spring	115-135	7.41	27.82	Dark brown	30	9	0
	Summer	80-200	6.49	35.3	Dark brown	160	2.4	0
Nowshahr-compost	Winter	360	6.92	58.2	Light brown	3	0	1
	Spring	450	7.07	66.7	Light brown	2	0	0
	Summer	490	6.39	75.3	Light brown	3	0	0
	Standard values		6-9	50-70	-	-	-	-

Physical characteristics

Dark brown color in the effluent sludge of Sari, Babol, Babolsar, and Nowshahr-Chalus wastewater treatment plants and light brown color in the effluent of the effluent treatment plants of Joybar city and composted sludge of Nowshahr wastewater treatment plant along with the appearance of Floc odorless indicates that the sludge digestion process was well done and easily dehydrated and dried.

The changes in pH and TS with the retention time or storage of biosolids output from several sewage treatment plants in Mazandaran province for five WWTPs in the cities of Sari, Babol, Babolsar, Joybar, and Nowshahr-Chalus are shown in Figures 1A to 1E. As shown in the figures, generally, with the exception of the Joybar WWTP, with increasing sludge retention or prolonging the retention time of biosolids, the pH decreases. Also, the figures clearly show that as the retention time increases, the TS resistance increases or becomes concentrated.

Biological characteristics

Fecal coliforms

The average density of fecal coliforms in the samples taken from the sludge of the treatment plants of the studied cities in winter, spring, and summer are presented in Figure 2.

As shown in Figure 2, WWTP biosolids in Joybar, Babol, Nowshahr-Chalus, and also, the composted biosolids of Nowshahr-Chalus, in terms of the amount of fecal coliforms in the studied seasons, meets the U.S. EPA standards for agricultural use at Class A levels (less than 1000 MPN/g (ds)).

Salmonella

Figure 3 shows the salmonella density for sludge samples coming out of treatment plants in the cities of Mazandaran province.

Comparison of the Figure 3 data with the U.S. EPA standards shows that the discharge of sludge from Joybar

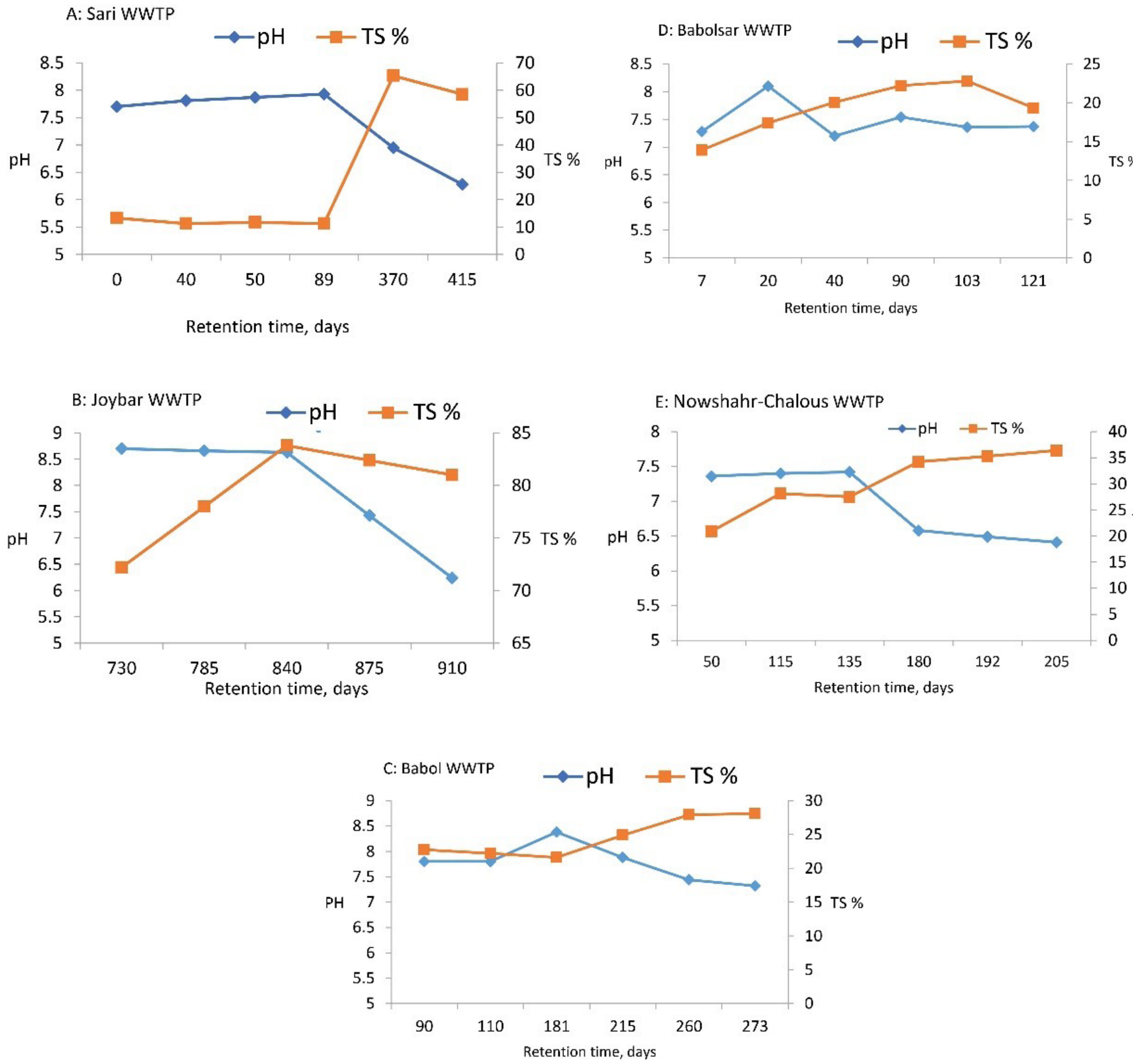
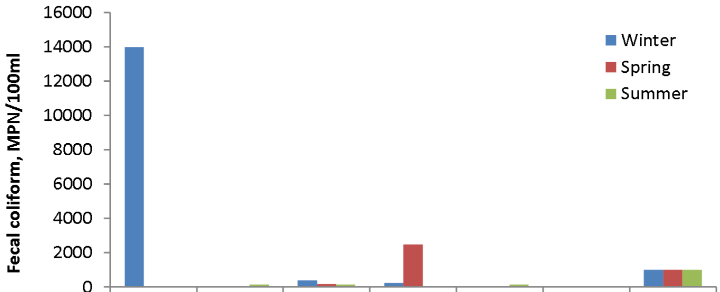


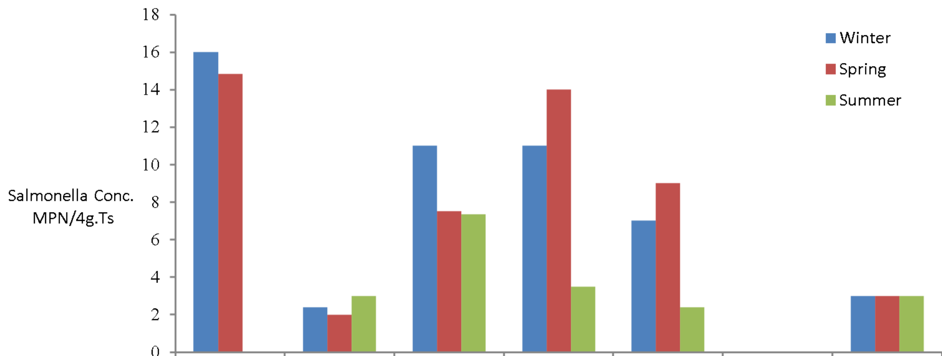
Figure 1. Changes in pH and TS with time in the sludge output from Mazandaran WWTPs



	Sari	Joybar	Babol	Babolsar	Nowshahr	Nowshahr compost	Class A
Winter	14000	4	400	230	15	3	1000
Spring	40	20	180	2500	30	2	1000
Summer	25	150	160	35	160	3	1000

Wastewater Treatment Plants

Figure 2. Geometric mean density of fecal coliforms in different seasons in Mazandaran municipal treatment plants



	Sari	Joybar	Babol	Babolsar	Nowshahr	Nowshahr compost	Class A
Winter	16	2.4	11	11	7	0	3
Spring	14.83	2	7.5	14	9	0	3
Summer	0	3	7.35	3.5	2.4	0	3

Wastewater Treatment Plants

Figure 3. Geometric mean number of Salmonella density in different seasons in Mazandaran municipal treatment plants

wastewater treatment plant and the composted sludge from Nowshahr treatment plant met Class A limitations (less than 3 MPN/4 g (ds)) during the study seasons, for Salmonella density.

Parasite eggs

The results obtained from the number of parasite eggs in the sludge leaving the treatment plants of Sari, Joybar, Babol, Babolsar, Nowshahr-Chalus and composted sludge of Nowshahr in the studied seasons are given in Figure 4.

The average concentration of heavy metals in the sludge output from the treatment plants of cities in Mazandaran province is presented in Table 2.

Discussion

Using SPSS software, Spearman's correlation coefficient showed that there is a significant relationship between pH and retention time ($r=-0.517$, $P=0.007$) and with increasing retention time, pH decreased significantly, except for the limited cases where the pH increased slightly due to the addition of lime water solution to accelerate the destruction of pathogens. According to the study, the pH range in the sludge was in the neutral pH range, which indicates good sludge stabilization (Figure 1).

Sari WWTP in winter and Babolsar WWTP in spring have provided Class B level limits as fecal coliforms (1000 to 2×10^6 MPN/g (ds)). However, these biosolids met the standard requirements of the U.S. EPA for sludge at Class A level after a 2-month retention period for fecal coliforms.

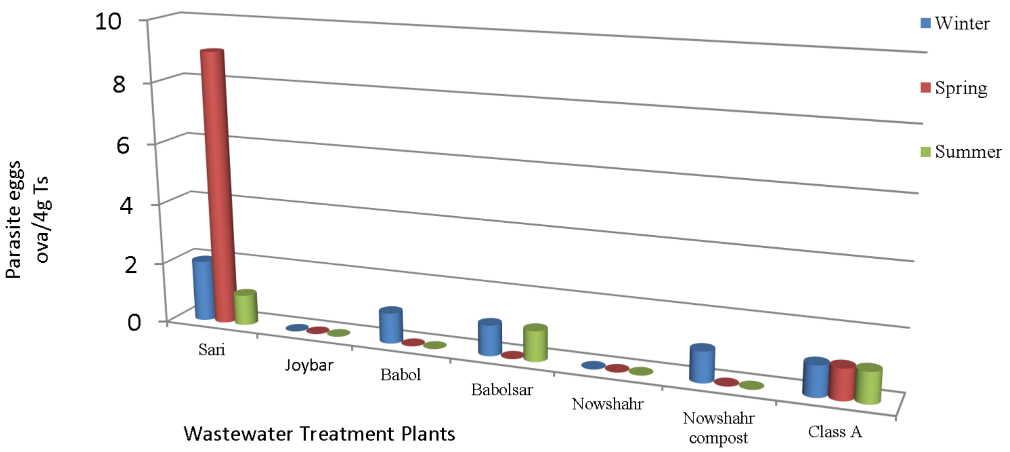
In terms of the presence of faecal coliform, the use of digested and dewatered biosolids from the WWTPs of Joybar, Babol, Nowshahr-Chalus cities and composted biosolids of Nowshahr in the studied seasons is unimpeded in agricultural lands, but samples of digested and dewatered biosolids of Sari sewage treatment plant in winter, and those of Babolsar sewage treatment plant in the spring, have spatial limitations.

Based on the results of experiments and their comparison with the U.S. EPA standards, the sludge

Table 2. Average concentration of heavy metals in treatment plants sludge of cities of Mazandaran province

WWTP	Cr mg/kg (ds)	Cd mg/kg (ds)	Zn mg/kg (ds)	Cu mg/kg (ds)	Ni mg/kg (ds)
Sari	77.99±50.97	11.6±10.47	401.39±382.57	162.40±175.4	82.02±66.21
Joybar	9.26±80.02	3.81±1.87	35.57±31.07	54.81±6.86	19.38±3.72
Babol	54.55±11.86	7.91±4.89	77.83±92.23	213.56±139.97	70.01±60.08
Babolsar	56.9±42.82	11.32±7.07	307.94±264.13	246.22±138.77	80.01±42.22
Nowshahr-Chalus	32.82±27.54	5.78±5.85	314.98±213.8	202.93±239.82	43.72±41.11
Nowshahr-Chalus compost	21.68±5.97	12.78±13.01	84.8±90.94	41.58±36.45	40.62±7.03
Standard America[a]	1200	39	2800	1500	420

[a](24-26).



	Sari	Joibar	Babol	Babolsar	Nowshahr	Nowshahr compost	Class A
Winter	2	0	1	1	0	1	1
Spring	9	0	0	0	0	0	1
Summer	1	0	0	1	0	0	1

Figure 4. Geometric mean number of parasite eggs in different seasons in Mazandaran municipal treatment plants

from the treatment plants of Joybar, Babol, Babolsar, and Nowshahr-Chalus in the studied seasons in terms of the number of parasite eggs in the range of Class A (<1 ova/4 g (ds)) and their use is allowed in agriculture (Figure 1).

Comparison of the research results with other studies

A comparison of the heavy metal concentrations of the sludges coming out of five WWTPs of Mazandaran province (Table 2) with the standard range of the US EPA (23) showed that the concentration of the investigated heavy metals in these sludges is lower than the standard limit and there are no restrictions for the use of these sludges in agriculture (23-25). The sludge from the treatment plants of Sari, Joybar, Babol, Babolsar, Nowshahr-Chalus and composted sludge from Nowshahr had a brown color and the appearance of clots without odor or with an old smell and were easily dewatered and dried, which shows the sludges has passed the digestion process well.

As shown in Table 3, in the case of fecal coliforms, the obtained value in the present study (five WWTPs of Mazandaran province) except for Sari in the winter and Babolsar in the spring, was lower than both Class A (<1000 MPN/g ds) and Class B (<2×10^6 MPN/g ds) requirement proposed by the US EPA for the land application (23). All the samples in our study met the requirements for use at the Class B limit. However, in a study conducted by Torabian et al in Quds, Tehran, during the spring season, the samples were evaluated at the Class A limit (11). In contrast, other studies were unable to achieve the applicability limit of Class A (8-11). The study of Farzadkia et al., unlike the present study, could not meet any of the needs of sludge application in Classes A and B (8,10). The study of Asadi Ardali et al also did not meet any of the needs of Classes A and B in the three treatment plants investigated in the summer (9), which is not consistent with the present study.

In the case of viable Helminth ova, the obtained value in the present study (five WWTPs of Mazandaran province) except for Sari in the winter (16 ova/4 g DS) and spring seasons (14.83 ova/4 g DS) were in the range of 0-1 ova/4 g DS (Table 1).

Table 3. Comparison of mean fecal coliform density (MPN/g (ds)) in the treatment plants sludge investigated in the present study and other studies

Studies	WWTP	Mean Fecal Coliform Density, MPN/g (ds)	Class B $<2\times10^6$	Class A <1000	Ref
Farzadkia et al	Serkan*	1.93×10^8	Not ok	Not ok	10
Farzadkia et	Serkan*	8.97×10^7	Not ok	Not ok	8
Asadi Ardali et al	Shahrekord*	$1.63\times10^{6(w)}$	Ok	Not ok	9
	Farsan*	$1.93\times10^{6(w)}$	Ok	Not ok	9
	Borujen*	$1.98\times10^{6(w)}$	Ok	Not ok	9
	Shahrekord*	$4.51\times10^{6(su)}$	Not ok	Not ok	9
	Farsan*	$5.75\times10^{6(su)}$	Not ok	Not ok	9
	Borujen*	$9.23\times10^{6(su)}$	Not ok	Not ok	9
Bina et al	Isfahan-South *	1.8×10^6	Ok	Not ok	4
	Isfahan-North*	2.3×10^6	Not ok	Not ok	4
	Shahinshahr*	1.6×10^6	Ok	Not ok	4
Torabian et al	Qods city*	$120^{(s)}$	Ok	Ok	11
	Qods city*	$1.6\times10^{4(A\text{-}W)}$	Ok	Not ok	11
Rahmani et al	Shahinshahr*	$1.46\times10^{4(s)}$	Ok	Not ok	12
	Shahinshahr*	$2.4\times10^{8(w)}$	Not ok	Not ok	12
Aghili et al	Sari	$2.37\times10^6\pm1.06\times10^6$	Not ok	Not ok	19
Present study	Sari*	$14000^{(w)}$	Ok	Not ok	-
		$40^{(s)}$	Ok	Ok	-
		$25^{(su)}$	Ok	Ok	-
	Joybar*	$4^{(w)}$	Ok	Ok	-
		$20^{(s)}$	Ok	Ok	-
		$150^{(su)}$	Ok	Ok	-
	Babol*	$400^{(w)}$	Ok	Ok	-
		$180^{(s)}$	Ok	Ok	-
		$160^{(su)}$	Ok	Ok	-
	Babolsar*	$230^{(w)}$	Ok	Ok	-
		$2500^{(s)}$	Ok	Not ok	-
		$35^{(su)}$	Ok	Ok	-
	Noshahr-Chalus*	$15^{(w)}$	Ok	Ok	-
		$30^{(s)}$	Ok	Ok	-
		$160^{(su)}$	Ok	Ok	-
	Noshahr-Chalus**	$3^{(w)}$	Ok	Ok	-
		$2^{(s)}$	Ok	Ok	-
		$3^{(su)}$	Ok	Ok	-

(w) = Winter; (su) = Summer; (s) = Spring; (A-W) = Autumn and winter.
*Dewatered digested sludge.
**Composted sludge.

In the case of *Salmonella*, the obtained value in the present study (Table 1) except for Sari in the summer (0/4 g DS) and Joybar in winter and spring (2.4 and 2 *Salmonella*/4 g DS) were lower than the requirement proposed by the US EPA (*Salmonella* sp. < 3 MPN/4 g DS) for land application (23).

The density of Salmonella in the digested and dewatered sludge of all WWTPs and live parasite eggs in Sari WWTP has a significant difference in different seasons. Therefore, some operation and maintenance factors, including the adjustment of sludge loads, temperature and pH settings, proper mixing in digesters, and polymer concentration settings in the filter press, etc., can affect the density of parasite eggs (26-28). Therefore, the regular measurement of these parameters in sludge treatment processes and the measurement of the density of live parasite eggs in the outgoing sludge in different seasons of the year are necessary for the safe use of digested and dewatered sludge.

Composted sludge samples of Nowshahr-Chalus wastewater treatment plant achieved all the requirements of sludge application for Class A in terms of faecal coliform and parasite eggs, Salmonella and heavy metals, according to the regulations of the United States Environmental Protection Agency (Tables 1 and 3).

In Table 4, the results of this study on the output sludge of Mazandaran wastewater treatment plants in terms of the number of salmonella and the number of parasite eggs were compared with the results of other studies.

As shown in Table 4, the results of the analysis of the number of parasite eggs in the output sludge of the Sari treatment plant in spring and winter are consistent with the results of other studies (4,8,26-30), but in other treatment plants, the quality of the sludge is at the level of Class A, which is not consistent with the results of other studies.

In addition, the results of the analysis of the number of Salmonella in the sewage treatment plants of Mazandaran province, except for the composted sludge of Nowshahr-Chalus sewage treatment plant, are consistent with the results of the study by Forster-Carneiro et al (29). The composted sludge of Nowshahr-Chalus sewage treatment plant is within Class A, which is not consistent with the results of other studies.

The results of this study showed that Cr among the investigated heavy metals has the lowest concentration, which is consistent with the results of the study conducted by Khan et al (32) on heavy metals in the soil of industrial areas, but inconsistent with the results of the study conducted by Lorestani et al (33) on the concentration of heavy metals in the waters adjacent to the industrial area.

Due to the effective reduction of pathogens after a

Table 4. Comparison of density of Salmonella and Parasite eggs Ova in the treatment plants sludge studied in the present study and other studies

Researches	Sludge Treatment	Salmonella MPN/4 g (ds)	Parasite Eggs ova/4 g (ds)	Ref
Aghili et al	Aerated digestion, filter press	47±12.92	466±61.85	19
Lloret et al	Anaerobic two-stage mesophilic, thermophilic digestion	0	-	26,27
Forster-Carneiro et al	Mesophilic anaerobic digestion	9.48	>Class B	29
Sharafi et al	Con-wet & oxi-pond*	-	0	30
Sharafi et al	Con & Ext AS**- dry sludge	-	>Class B	30
Farzadkia et al, Sarkan	Con AS**- dry sludge	-	251	8
Bina et al, Isfahan	Con AS**- dry sludge	-	44-228	4
Mirhosseini et al	ext AS**- dry sludge	-	3-19	31
current study				
Sari***	Con AS**- dry sludge	16(w)	2(w)	-
		14.83(s)	9(s)	-
		0(su)	1(su)	-
Joybar***	Aerated lagoon - dry sludge	2.4(w)	0(w)	-
		2(s)	0(s)	-
		3(su)	0(su)	-
Babol***	Con AS**- dry sludge	11(w)	1(w)	-
		7.5(s)	0(s)	-
		7.35(su)	0(su)	-
Babolsar***	Ext AS**- dry sludge	11(w)	1(w)	-
		4(s)	0(s)	-
		35(su)	1(su)	-
Nowshahr-Chalus***	Ext AS**- dry sludge	7(w)	0(w)	-
		9(s)	0(s)	-
		2.4(su)	0(su)	-
Nowshahr-Chalus***	Ext AS**- composted sludge	0(w)	1(w)	-
		0(s)	0(s)	-
		0(su)	0(su)	-

AS, activated sludge
*Constructed wetland and oxidation pond.
**Conventional and extended aeration AS.
***Dewatered digested sludge.
(w)=Winter; (su)=Summer; (s)=Spring; (A-W)=Autumn and winter.

residence time of two months, in order to achieve Class A levels, it is necessary to keep the dehydrated biosolids in the drying sludge beds for two months, after leaving the Belt filter. In order to ensure the efficiency of the purification processes and the proper quality of the output biosolids, it is necessary to equip laboratories and periodically monitor the output biosolids from each treatment plant.

Due to the lack of national standards regarding the quality of biosolids leaving the treatment plants in Iran, it is necessary to develop the necessary standards in accordance with the geographical and climatic conditions of the country.

Conclusion

The examination of pH of samples showed that the pH range in the biosolids was in the neutral pH range, which indicates good sludge stabilization.

The use of sludge from four WWTPs in agricultural lands has no restrictions in terms of faecal coliform, but the use of biosolids from Sari and Babolsar treatment plants in winter and spring, respectively, has restrictions and mandatory criteria.

According to the results of this study, the output biosolids of treatment plants in Mazandaran province, which have passed the stages of digestion and dewatering of biosolids in the sludge treatment process, based on the guidelines of the US EPA, are classified at least at the level of Class B. It can only be used for special purposes such as fertilizer to strengthen agricultural lands, forest areas and recycling sites, and these uses will be associated with the restrictions of the place of use.

Therefore, the sewage treatment plant sludge in the province, with the exception of the sludge from the Sari treatment plant during the winter and spring seasons, is classified as Class A based on the number of fecal coliforms and parasite eggs. However, it fails to meet the requirements of Class A due to the presence of a dangerous level of salmonella in 4 grams of dry sludge. Consequently, it poses risks to public health and the environment. As a result, it is not suitable for use in agricultural fields, kindergartens, parks, golf courses, gardens, home lawns, or for sale or assignment in bags or containers. Furthermore, it should not be used for land use without restrictions.

The average concentration of nickel in Sari and Babolsar was the highest one compared to that in other treatment plants in the province, and the average concentration of nickel in the biosolids output from the Joybar treatment plant was the lowest one compared to that reported in other cities. Also, the concentration of heavy metals (chromium, cadmium, nickel, copper, and zinc) in the output sludge of these treatment plants were lower than the standard of the US EPA, so the sludge can be used for agriculture.

But the analyzes on the composted sludge of Nowshahr-Chalus treatment plant showed that the quality of the sludge metals met the requirements of Class A, and this result is a good achievement, therefore it can be used as a suitable and cheap solution in all sewage treatment plants of the province and the country. Certainly, with the use of this method, the production product will be usable for Class A purposes without any restrictions. With composting and especially vermicomposting of sludge from sewage treatment plants, we will turn the threats to the health and hygiene of the environment into a useful opportunity. We can take advantage of its financial and environmental benefits by recovering biosolids as a valuable fertilizer.

Based on the results of this study, the best confident and sustainable solution for the safe use of sewage treatment plant biosolids is the use of biosolids composting process, especially vermicomposting of biosolids to meet the needs of Class A sludge application.

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Competing interests

The authors declare that there is no conflicts of interests.

Ethical issues

In this article, the authors considered all the ethical points in collecting data and confidently state that this information has not been previously published in any publication or book. This article is a research project and simultaneous thesis of Ms. Reza Batebi, approved by the Vice-Chancellor for Research and Technology of Mazandaran University of Medical Sciences. (Approval code and the ethical code of the Ethics Committee is 2140 and IR.mazums.rec 95.2140, respectively.

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