UTILIZATION OF THE TREATMENT PLANT'S SLUDGE AS A GLASS

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ABSTRACT

In this study, physical and chemical characteristic of the treatment sludge obtained by Bergama- Ovacık treatment plant and the possibility to evaluate them in glass industry were investigated. In this treatment plant, 277,882 tons of sludge is annually produced. The chemical composition of the waste sludge's is determined by gravimetric method and it is examined by X-Ray diffraction (XRD), X-Ray fluorescence (XRF) and Fourier Transform Infrared Spectrophotometer (FT-IR) equipments. The chemical composition of the treatment sludge showed that it is potential to be used in a glass industry to produce Borosilicate glass and Flat glass with the addition of chemical substances. In order to examine the composition of the samples, their analyses were made by (FT-IR) and (XRF) equipments.

KEYWORDS

Treatment sludge; Flat glass; Borosilicate glass.

1 INTRODUCTION

Recycling and evaluation of wastes obtained from the industrial processes has become a worldwide concern, especially in the last few years and claims for a solution in the near future [1].

Domestic and Industrial wastewater treatment with physical, chemical and biological processes have approximately between 0.25-12% of solid substances, being known as sludge. [2].

This sludge leads to some serious environmental problems because of the presence of pathogen and toxic compounds. Besides, it constitutes significant storage and transport problems. In the treatment plants, the units which are related to the disposal of the sludge that comes out constitute approximately 50% of the total investment cost [3]. Due to the development of industry and the increasing population in Turkey, the studies and researches about this topic are being considered to be significant especially in the last years.
It is clear that the sludge from wastewater treatment plants will reach larger amounts because of the increasing population and the addition of the new treatment plants. On account of the problems of the treatment sludge will reach wider extents in the forthcoming years. For instance; in Turkey approximately 3 million tons of sludge is produced from the industrial wastewater treatment plants in a year [4]. However, these wastes will be decreased in a

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distinctive rate by the evaluation with a proper process and it can be beneficial in both economic and environmental aspects, by the use of raw materials or fuel especially in energy production.

Vitrification is a well-established technique for converting several wastes into materials for possessing is considered to be a remarkable chemical stability. In fact, various inorganic wastes are constituted by glass-forming oxides or may be dissolved in a silicate melt provided by glass-forming additives [5].

In this study, the determination of the characteristics of the sludge obtained by Bergama-Ovacık Gold Mine treatment plant and the use as raw materials in Glass Industry have been investigated.

2 EXPERIMENTAL

2.1 Material

The treatment of sludge that is assured by Bergama-Ovacık Gold Management Plant was used as a basic raw material in experimental studies. During the production, 277,882 tons of treatment sludge is erupted in the treatment plant every year. The sludge contains 89.42% of SiO_2. The chemical composition of the sludge is given in *Table 1*. Moreover, in order to produce glass, sodium carbonate, boric acid, calcium carbonate and magnesium carbonate were used as chemical additives.

Table 1. Chemical composition of Bergama waste.

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	Na_2O (%)	K_2O (%)	Total (%)
89.42	3.85	2.12	0.30	0.1	1.69	100

2.2 Equipment

- High temperature furnace, which can reach to 1600°C in order to melt glass and melting pots which are durable to high temperature were used.
- Chemical characterization of the waste and the obtained glasses were carried out using Spektro X-LabPro X-ray fluorescence (XRF) apparatus.

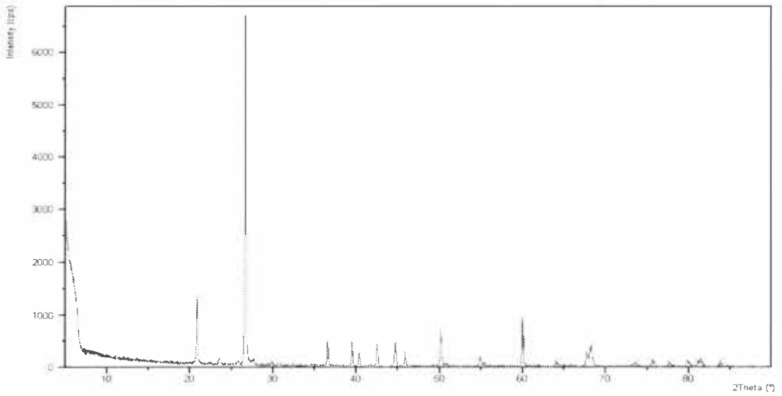


Figure 1. XRD diagram of the waste.

- Perkin Elmer Fourier Transform Infrared Spectrophotometer (FT-IR) was used for investigation of chemical bounds and molecular structure of materials. Experiments were carried out in the variation of wavelengths from 4000 to 450 cm^{-1}. Powdered samples were mixed with KBr and sample pellets were obtained after applying pressure of 100 bar.
- The X-ray diffraction (XRD) measurements of the obtained waste were carried out using a Philips Panalytical X'Pert Pro diffractometer, with a Cu-Kα source, at 45 kV and 40 mA. The samples were mounted on a glass sample holder.

3 RESULTS

3.1 Characterization of the waste

The functional group and micro structural characteristics of the waste were examined by XRD, XRF and FT-IR instrumental analysis device.

3.1.1 XRD diagram of the waste

The XRD diagram was recorded to be diffraction angle which changes between 0-90°. According to the XRD diagram, that is given *Figure 1*, the characteristic peaks of the waste were seemed to be in approximately 20°, 27°, and 60° diffraction angle.

3.1.2 FT-IR spectrum of the waste

The functional group structure of the samples between 4000-650 cm-[1] wavelengths, were examined by FT-IR spectrometric method. The sample made to become a pellet by mixing KBr powder at a proper rate and it is prepared for FT-IR analysis. FT-IR absorption band obtained for waste sludge were centered at 2184, 1039, 795, 777, 693 cm^{-1}. The band at 2184 cm^{-1} shows the absorption bands of the O-H stretching. It can be seen from *Figure 2* that there is a broad band centered at vibration at 1039 cm^{-1} [6]. The band can be attributed to Si-O-Si symmetric stretching in cyclic structure. There is a band centered at 795 cm^{-1} and a sharp vibration at 777 cm^{-1}. Two bands were attributed to the SiO_4 asymmetric Si-O-Si band (SiO_2). The band at 693 cm^{-1} was assigned to the O-Si-O band [7].

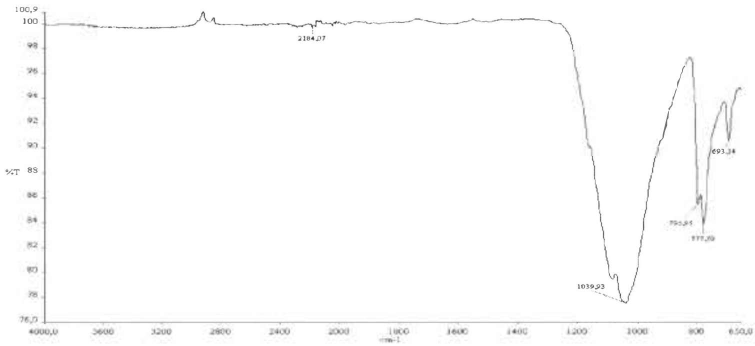


Figure 2. FT-IR spectrum of the waste.

3.1.3 XRF results of the waste

The chemical composition of the waste was examined by X-Ray fluorescence technique. When the XRF results of the sludge were examined, it was observed that the waste has Fe ion in large amounts (*Table 2*).

Table 2. XRF results of the waste.

Element	Concentration	Element	Concentration
Ti	< 0.0069	In	< 0.030
V	< 0.0269	Sn	< 0.050
Cr	< 0.030	Sb	< 0.050
Mn	0.0312	W	< 0.025
Fe	1.48	Ga	< 0.010
Co	< 0.020	Zr	0.050
Ni	< 0.015	Nb	0.1402
Cu	< 0.010	Au	< 0.020
Mo	0.2527	Pb	< 0.020
Pd	0.02360	Rh	< 0.002
Ag	0.002	Zn	0.0100
Cd	< 0.050	Pt	< 0.020

3.2 Glass production

3.2.1 Borosilicate glass production

Three frits were prepared for Borosilicate Glass production, and they were called BG-1, BG-2, and BG-3 glasses (see *Table 3*). Three mixtures were prepared by adding boric acid and sodium carbonate to the treatment sludge obtained from Bergama for Borosilicate Glass (Pyrex) production. The chemical compositions of these mixtures were given in the *Table 4*.

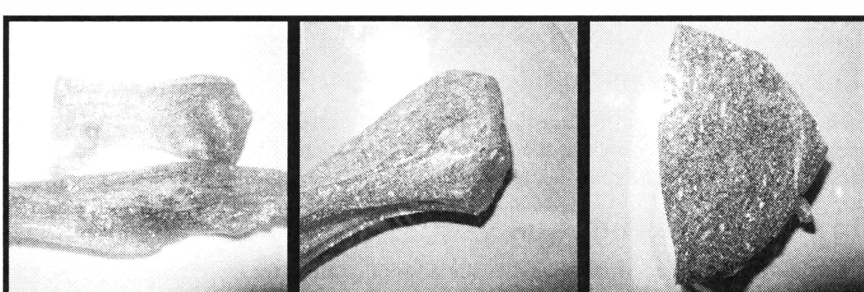
Table 3. The mixtures that were prepared for Borosilicate glasses.

Glass identity	BG-1	BG-2	BG-3
Waste Loading (%)	83	85	80
SiO_2 (%)	-	-	-
B_2O_3 (%)	13	12	15
Al_2O_3 (%)	-	-	-
MgO (%)	-	-	-
CaO (%)	-	-	-
Na_2O (%)	4	3	5
K_2O (%)	-	-	-
Total (%)	100	100	100
Melting Temperatures (°C)	1350	1350	1325

Table 4. Chemical composition of the samples after the mixture in Borosilicate glasses production.

Glass identity	SiO_2 (%)	B_2O_3 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	Na_2O (%)	K_2O (%)	Total (%)
BG-1	75.2	11.9	3.2	1.78	0.25	4.2	1.42	100
BG-2	76	12	3.27	1.8	0.225	3	1.437	100
BG-3	71.5	15	3.08	1.7	0.24	5	1.35	100

The mixtures were mixed in a grinder for two hours. The mixtures which are prepared for Borosilicate Glass Production were put into the melting pot and they were melted in high temperature furnace. The BG-1 glass was melted at 1350°C, BG-2 glass was melted at 1350°C and the last glass BG-3 was melted at 1325°C by controlling during definite time periods. The aspects of the melted glasses after cooling are shown in *Figure 3a-c*.



(a) (b) (c)

Figure 3. Aspect of the: (a) BG-1, (b)BG-2 and (c)BG-3 glasses at room temperature

Table 5. XRF results of BG–1, BG–2 and BG–3 glasses.

	XRF results of BG-1	XRF results of BG-2	XRF results of BG-3
Element	*Concentration*	*Concentration*	*Concentration*
Ti	< 0.0077	< 0.0068	< 0.0074
V	0.0172	< 0.035	0.0152
Cr	< 0.030	< 0.030	< 0.030
Mn	0.0352	0.0242	0.0326
Fe	1.246	1.26	1.19
Co	< 0.020	< 0.020	< 0.020
Ni	< 0.015	< 0.015	< 0.015
Cu	< 0.010	< 0.010	< 0.010
Mo	0.2687	0.2275	0.2617
Pd	0.02071	0.01861	0.02071
Ag	0.01812	0.01850	0.01945
Cd	< 0.050	< 0.050	< 0.050
In	< 0.030	< 0.030	< 0.030
Sn	< 0.050	< 0.050	< 0.050
Sb	< 0.050	< 0.050	< 0.050
W	< 0.025	< 0.025	< 0.025
Ga	< 0.010	< 0.010	< 0.010
Zr	0.0555	0.05017	0.05658
Nb	0.1590	0.1125	0.1473
Au	< 0.020	< 0.020	< 0.020
Pb	0.0256	0.01842	0.0222
Rh	< 0.002	< 0.002	< 0.002
Zn	<0.010	<0.010	<0.010
Pt	< 0.020	< 0.020	< 0.020

3.2.1.1 Borosilicate glass XRF results

The chemical compositions of Borosilicate Glass were examined with X-Ray fluorescence technique. When the XRF result of the sample that is given in *Table 5* was examined, it was observed that the glass has Fe ion in large amounts.

3.2.1.2 Borosilicate glass FT-IR results

In our study we made use of the characteristic absorption lines for the crystalline SiO_2. The FT-IR spectrums of Borosilicate Glass were shown in *Figures 4, 5 and 6.*

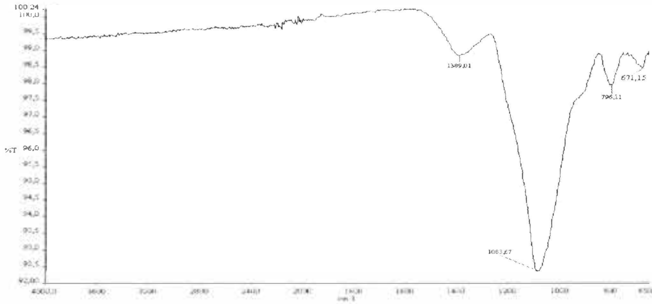


Figure 4. FT-IR spectrum of the BG-1 glass.

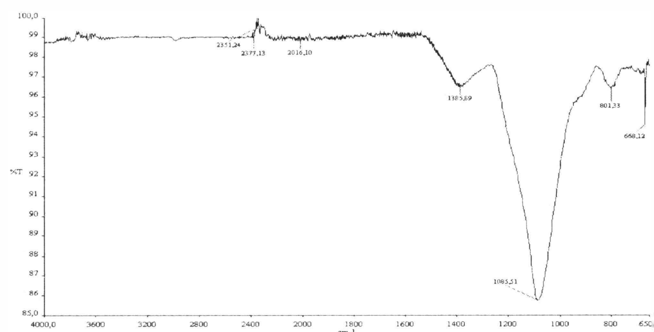


Figure 5. FT-IR spectrum of the BG-2 glass.

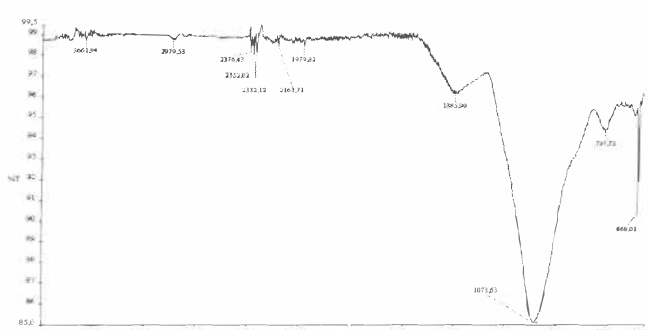


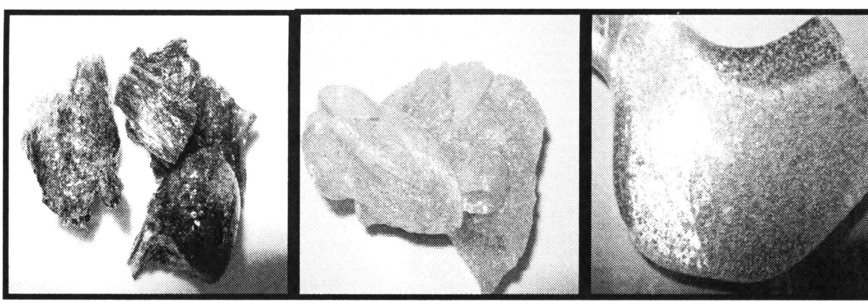
Figure 6. FT-IR spectrum of the BG-3 glass.

3.2.2 Flat glass production

Three frits called FG-1, FG-2 and FG-3 glasses were prepared for Flat Glass production. Mixtures were prepared by adding sodium carbonate; calcium carbonate and magnesium sulfate to the waste sludge obtained from Bergama for the flat glass production (see *Table 6*). The melting temperatures were determined respectively as 1282°C, 1250°C and 1250°C. The aspect of the melted glasses at room temperature was shown in *Figure 7a-c.*

Table 6. The mixtures that were prepared for Flat glasses.

Glass identity	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	Total (%)
FG-1	68.0	2.927	1.61	3.6	0.25	14.06	1.28	100
FG-2	76.0	3.25	1.80	-	0.255	15.085	1.436	100
FG-3	70	3	1.65	-	7	15	1.31	100



(a) (b) (c)

Figure 7. ,Aspect of: (a) FG-1, (b) FG-2 and (c) FG-3 glass at room temperature.

3.2.2.1 XRF result of flat glass

The chemical compositions of Flat Glass were examined with X-Ray fluorescence technique and it was observed that the glass has Fe ion in large amounts (see *Table 7*).

3.2.2.2 FT-IR results of flat glass

The FT-IR spectrums of Flat Glass were shown in *Figures 8, 9 and 10.*

Table 7. XRF results of FG-1, FG-2 and FG-3 glasses.

XRF results of FG-1		XRF results of FG-2		XRF results of FG-3	
Element	*Concentration*	Element	Concentration	Element	*Concentration*
Ti	< *0.0073*	Ti	< 0.0067	Ti	< *0.0052*
V	*0.0173*	V	< 0.035	V	< *0.035*
Cr	< *0.030*	Cr	< 0.030	Cr	< *0.030*
Mn	*0.0289*	Mn	< 0.025	Mn	< *0.025*
Fe	*1.127*	Fe	1.26	Fe	*1.155*
Co	< *0.020*	Co	< 0.020	Co	< *0.020*
Ni	< *0.015*	Ni	< 0.015	Ni	< *0.015*
Cu	< *0.010*	Cu	< 0.010	Cu	< *0.010*
Mo	*0.2507*	Mo	0.1748	Mo	*0.1692*
Pd	*0.01993*	Pd	< 0.020	Pd	< *0.020*
Ag	*0.01898*	Ag	< 0.020	Ag	< *0.020*
Cd	< 0.050	Cd	< 0.050	*Cd*	< 0.050
In	< 0.030	In	< 0.030	In	< 0.030
Sn	< 0.050	Sn	< 0.050	Sn	< 0.050
Sb	< 0.050	Sb	< 0.050	Sb	< 0.050
W	< 0.025	W	< 0.025	W	< 0.025
Ga	< 0.010	Ga	< 0.010	Ga	< 0.010
Zr	0.05116	Zr	0.1643	Zr	< 0.050
Nb	0.1265	Nb	< 0.020	Nb	0.09989
Au	< 0.020	Au	< 0.020	Au	< 0.020
Pb	0.02443	Pb	0.0256	Pb	0.020
Rh	< 0.002	Rh	< 0.002	Rh	< 0.002
Zn	<0.010	Zn	<0.010	Zn	<0.010
Pt	< 0.020	Pt	< 0.020	Pt	< 0.020

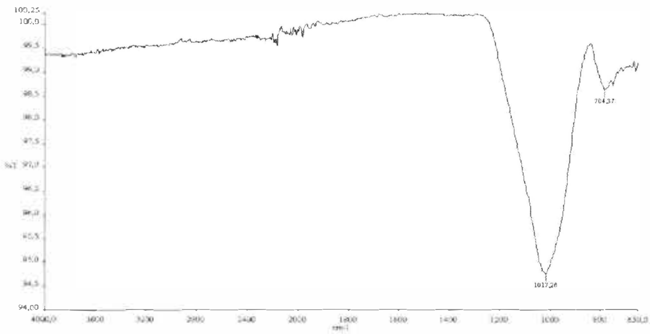


Figure 8. FT-IR spectrum of the FG-1 glass.

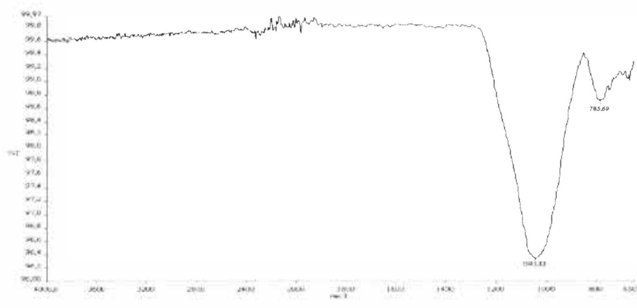


Figure 9. FT-IR spectrum of the FG-2 glass.

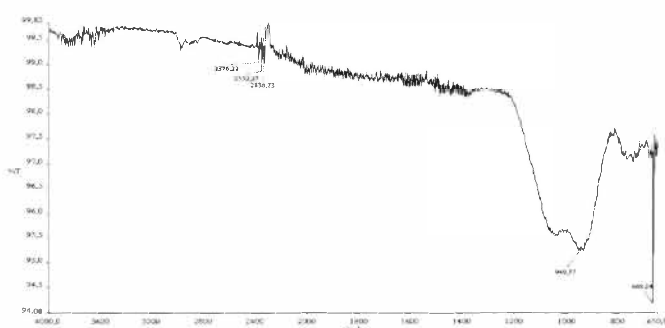


Figure 10. FT-IR spectrum of the FG-3 glass.

4 CONCLUSIONS

The waste contains 89.42% SiO_2, and this is a proof that the waste can be used in the glass industry. Two different samples and two types of glass were obtained by adding different kinds of additives. There were remarkable color differences in the samples. These differences were occurred by 2.12% of Fe_2O_3 which exists in the waste. The iron causes BG-1 glass to be light green-grey, BG-2 glass to be green-grey, BG-3 glass to be dark green-grey and also FG-1 glass sample to be dark green, FG-2 glass to be green, FG-3 glass to be light green. The melting was completed in Borosilicate glass at an average of 1350-1325°C, in Flat glass sample at average 1282-1250°C. The purpose of this study is the disposal of the treatment sludge and the usage of the glasses for a decorative purpose; we can provide the disposal of glasses. In conclusion, 277,882 tons of sludge was generated as a waste sludge in Bergama-Ovacık Gold Mine every year. From this result, the firm will not have the disposal cost of the waste, which is used as raw material; it will form a new source of income. The vital point of the waste is not only just the specific section of the waste but also the whole waste was used as the raw material.

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