Generated waste management in iron melting industry: quantitative and qualitative identification, classification, coding and disposal (Case study: Isfahan iron melting plant)

Aghil Qorbani Shahnajfi [1], Mahdi Jalili Ghazizade[2*]

[1] M.Sc. Student, Environment Sciences Research Institute, Shahid Beheshti University, Tehran, Velenjak, 1983963113, Iran
[2] Assistant Professor, Environment Sciences Research Institute, Shahid Beheshti University, Tehran, Velenjak, 1983963113, Iran

Corresponding author email: ma_jalili@sbu.ac.ir

Abstract

Iran as developing country has different industries. Iron industries had been considerable extended in the recent decades because of existence of several mines. Iron melting process has several environmental aspects. Different industrial waste is one of the most important aspects which can create several environmental problems if there is no proper management. The purpose of this research is presentation of a general mechanism to manage the generated waste in iron melting industry. Therefore Isfahan iron melting plant has been selected as case study and as a first step, industrial waste identification checklist has been provided. Then important generated waste has been sampled in the field and analyzed in the laboratory. The results show that 2892 ton different industrial waste are being generated daily in the Isfahan iron melting in which converter slag, high stove slag, steel making slag, agglomeration sludge, and converter sludge during melting operation, foundry and iron metal and steel alloy roll are the most important ones. The laboratory analysis shows metal oxides such FeO, AL_2O_3 and CaO are the basic components of wastes. In the next step, waste classification has been conducted based on international procedure like Basel Convocation, RCRA, and UNEP. The results of this coding show that the major part of generated waste in iron melting process is classified in hazardous waste group. Finally the disposal options like sanitary landfilling, recycling and incineration were examined based on different economic, technical and environmental indices and the best alternative was proposed for each kind of generated waste.

Keywords: slag, waste industrial, sludge, high stove, Isfahan iron melting

1. Introduction

Industrial waste generation has been dramatically increased by technology growth in the recent century. Generated waste has been become problematic as bi-products in industrial activities and usually are categorized as hazardous waste. The main source of hazardous waste generation in the world is industrial activities (Alqaydi et al. 2006). Based on UNEP definition, hazardous waste are such waste (solid, liquid or sludge) except radioactive waste that have different risks for human and environment health because of their chemical properties, toxicity, explosiveness, corrosive and other properties (LaGnega et al. 2010). Comprehensive and logic management is the basic step in industrial waste risk minimization. However, finding a proper method to hazardous waste disposal is so complicated, (Nema et al. 1999), nowadays efficient management of wide amount of the generated waste is proposed (Geng Y et al.2007).The history of industrial waste management refers to approving the law of recovery and conversation of resources in USA in 1976 (EPA, 2009). Collecting and dispersal of waste in a true way that decreases directly or indirectly the risks of people health and damage to the environment is very important (HICPAC, 2001). At this time, generation, in situ storage, collection, transportation, processing, disposal and its aftercare are the basic components of comprehensive waste management (Maryam et al. 2006).

Iran as a developing country has different industries. Iron melting industry is one of the most important industries of Iran that recently has grown significantly due to existence of various mines. Iron melting process has different environmental aspects. One of the most important aspects is industrial waste generation during agglomeration, coking, high stove, steel making, processes and rolling engineering. The kind of primary material and processes during the production steps are different, so the quality and quantity of generated waste are different. No research about identification and management of iron melting industrial waste has been done up to now in Iran. A few researches had been done about other heavy industries. Musavi and his colleague in 2014 had worked on identification and management of industrial waste in the direct revival unit of the Iranian Ghadir iron and steel company. In their work at first they identified the waste of this industry, then coded and finally introduced the disposal ways based on waste natures (Musavi et al, 2014). The result of researches that had been done in the country shows that mostly the management of generated industrial waste has no appropriate situation and this challenge for singular and straggly industrial is more complicated. Due to the necessity of presenting comprehensive program of waste management for hazardous waste productive industrial units overall mechanism of such management for iron melting industry will be introduced in this research. Therefor Isfahan iron melting plant is selected as case study. Followed by quantitative and qualitative identification of produced industrial waste in iron melting process, categorizing, coding and presenting the disposal ways are done.

2. Material and methods

2.1 Geographical positions

Isfahan iron melting plant is the first and largest productive factory of railway and construction steel in Iran and the biggest long products manufacturer in the Middle East with 3600000 tons produced steel capacity per year. This plant is located at eastern north of Isfahan (Iran), at the road of Lenjan to Zarinshahr with geographical position of N32 .25’.37’’ and E 51.19’.10 (Fig. 1).

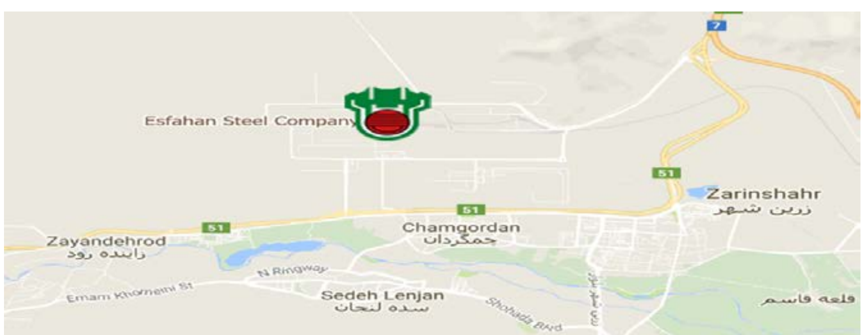

Figure 1: Isfahan iron melting plant position

2.2 Production process

Iron making, steel making, casting, rolling and preparing primary material processes covering agglomeration, pelleting and coking are the steps of iron production process (Figure 2).

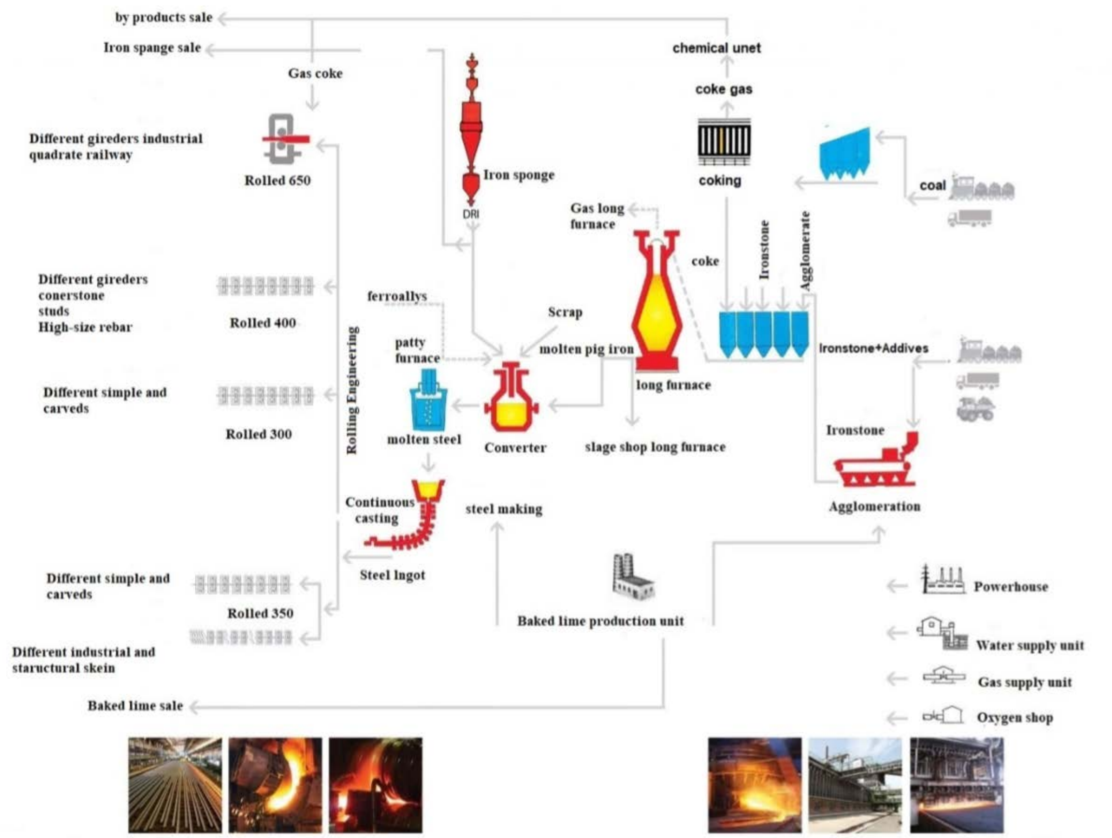

Figure 2: Schematic perspective of Isfahan iron melting production line

Major methods of the steel production in the world are divided into two high stove - converter and direct revival - electrical bow stoves ways and Isfahan iron melting plant uses the high stove-converter procedure. Coke revival material is used in the high stove in this method. There are lateral processes that prepare the feed of fundamental processes which are coking to provide primary material for revival operation and agglomeration for preparing the iron mine stone. This technology is the most important method of raw steel production in the world and approximated 60 percent of the raw steel of the world is produced using this method. Summary of any part operation of the Isfahan iron melting plant is presented in the table (1).

Table 1: Processes of production and input and output of the plant

Application and product	**Product output**	**Main material input**	**Part name**
Use in a high stove to enhance 25-30% efficiency and decrease the consumption of coke by 20%	Agglomerate	Ironstone, dolomite, cooked lime, coke, limestone, manganese rock	Agglomeration
The source of energy and the main redox in the high stove	Coke	Coal	Coking
Production due to use in the steel industry	Molten pig iron	Ironstone, agglomerate, coke,	High stove
Produced ingots in the sizes required for rolled engineering	Steel	Molten pig iron	Steel making
Rebar, Girder, railroad track	Reinforced buildings	Steel ingots	Rolling engineering

2.3 Study method

Regarding the necessity of industrial waste identification a primary checklist was designed as a first step (Table 2). This checklist was filled trough a field visit of different process unit as well as interviewing to relevant experts of Isfahan iron melting plant..

Table 2: Raw checklist for identification industrial wastes generated in Isfahan iron melting plant

Industrial waste name	Waste production unit	Rate and frequency of generation	Composition of raw material	Probable Pollutants	Current management strategy
Waste type 1					
Waste type 2					
Waste type 3					
…					

In the second step, important industrial wastes were identified based on weight of different type of generated waste and sampled based on valid ASTM5283 and ASTM4684 procedures in a field way. Then sampled wastes were transferred to the laboratory and analyzed to distinguish their components.

In the third step, industrial waste coding and categorizing was done based on EPA, UNEP and BAZELL procedures. UNEP categorizing is set based on the kind of extra material, industry or the process that hazardous extra material is produced during. UNEP method categorizes the materials into 6 groups. Managers are informed about the kind of the industries and processes that should be controlled گندله سازی by using this method. In the EPA method the hazardous waste are divided into 4 classes. The first class is named as hazardous waste without defined origin and is known as F class. Any waste has other code that shows the essence of it (I= flammable waste, C= corrosive waste, R= intense combinatory tendency waste, T=toxic waste). The second class which is named as K class contains hazardous wastes with defined origin. This method categorizes the wastes based on the industrial or the desired factory. The BAZELL convention includes 29 clauses and 10 attachments. The attachment number 1 which is showed by Y letter, introduces the kinds of wastes, the number 8by H mark shows the properties of hazardous waste and the attachment number 8 indicates the waste codes by A and B letters.

At the last step, different disposal methods like stabilization-solidification, recovery, waste incinerator and sanitary landfill have been discussed according to three economical, technical and environmental scales. Suitable disposal methods were determined for any waste and appropriate management strategies were presented.

Results and Discussion

In waste characterization step, waste generation rate, primary compounds of material, current waste management and the probable existing pollutants in waste were identified based on primary check list (Table 3).

Table 3: Classification of industrial wastes based on the frequency and current disposal methods in Isfahan iron melting factory

row	waste name	physical status	frequency of generation	Amount	unit	Store tank	Current disposal

							method
1	Converter slag	solid	Yearly	50000	ton	Storage reservoir	Storage and recovery
2	high stove slag	solid	Yearly	700000	ton	Storage reservoir	Storage and sale
3	Steel making slag	solid	Yearly	286155	ton	Storage reservoir	storage
4	agglomeration sludge	Liquid	Monthly	3500	ton	Evaporation pond	Storage and consumption
5	chemical treatment sludge	liquid	Monthly	900000	litter	Evaporation pond	landfill
6	pump room sludge	liquid	Monthly	14000	M^3	Evaporation pond	storage
7	Sediments slag	solid	Monthly	250	ton	Storage reservoir	landfill
8	Slag wool	solid	Monthly	5	ton	depot	landfill
9	Converter sludge	Liquid	Monthly	70	ton	Evaporation pond	Storage
10	Lime dust	particles	Monthly	100	M^3	depot	storage
11	Converter dust	particles	Monthly	600	ton	depot	Storage in trench

According to the table (4) results show that 2892 tons different industrial wastes are produced per day (1055580 tons per year). Converter slag, high stove slag, steel making slag, agglomeration sludge and converter sludge during melting operation, casting iron metals and steel allays rolling are the most important wastes in which cover the 98% of the produced wastes by weight. Sediment slag, slag wool, lime dust, high stove and converter dust, pump room refinery sludge are the rest of the wastes that include 2% of the waste weight. Important industrial waste of the iron melting plant which had the most weight percentage were sampled based on valid ASTM 5283 and ASTM 4687 procedures in the next step and were transferred to the library. Sampled wastes were analyzed by using the XRF method. The results are shown in the table (4).

Table 4: Chemical composition of identified industrial waste (%)

compound	SiO2	CaO	Al2O3	MgO	FeO	S	TiO2	MnO	ZnO	T.Fe	K2O	V2O5
steel making slag	15	28	40	10.5	40	0.5	1.5	2	-	-	-	-
converter slag	10.6	55.1	1	3.9	11-36	0.4 5	2.4	5.59	-	-	-	2.1
high stove slag	36.4	37.8	10.7	10.7	0.55	1.5	2.18	-	-	12.5	0.70	0.04
agglomeration sludge	7-11	12-18	2-3	4-5	3-4	1	0.6-0.8	0.7-11	0.5-1.6	20-25	0.4-0.8	-
converter sludge	1.78	6.7	.17	.26	7-6	1.8	-	3.59	.13	58.3	0.9	-

The results of wastes experimental analyses of table (4) shows that metal oxides like FeO, Al2O3, CaO, MgO and SiO2, are the basic components of 90% of this plants industrial wastes. ZnO, MnO, K2O, S and the rest of the components of the table (4) are 10% of the plants wastes. Industrial wast of Isfahan iron melting plant were categorized and then coded based on international procedures like Basel convention, RCRA and UNEP table (5).

Table 5: The classification of industrial wastes in iron melting Isfahan based on the method, EPA, UNEP and Basel

row	Name waste	Categorizing based on list													
		EPA				UNEP	UNEP						BASEL		
		F	K	nature	EPA2015	industrial	F	E	D	C	B	A	P1	P3	P8
1	Converter slag	-		C	100201	D-G		*					Y17 Y18	H12	B1200 B1210
2	High stove slag	-		C	100201	D-G		*					Y17 Y18	H12	B1200 B1210
3	Steel making slag	-		C	100304A*	D-G		*					Y17 Y18	H6.1 H12	B1200 B1210
4	Agglomeration sludge	-	K061	T	100213	D						*	Y17 Y18	H6.1 H12	
5	Chemical treatment sludge	-	K062	C T	100213	D						*	Y17 Y18	H6.1 H12	
6	Pump room sludge	-	K061	T	100213	D						*	Y17 Y18	H6.1 H12	
7	Sediments slag	-	K061	T	100207	D-G							Y17 Y18	H6.1 H12	
8	Slag wool					f						*	Y17 Y18	H6.1 H12	
9	Converter sludge	-	K061	T	100213	D						*	Y17 Y18	H6.1 H12	
10	Lime dust	-	K061	T	100207	D							Y17 Y18	H6.1 H12	
11	Converter dust	-	K061	T	100207	D							Y17 Y18	H6.1 H12	

F: Hazardous waste with non-point source   T: Toxic waste   C: corrosive waste

K: Hazardous waste with point source   D: Waste from factories   G: Metal Industry Waste

F: Chemical wastes of factories   A: Hazardous Utterly waste   B: Metal wastes

H: The risk characteristics of the waste   Y: Remaining in contact with air pollution

The results of coding show that the major part of the produced waste took place in the non-hazardous wastes. In this research 11 waste of the Isfahan iron melting plant were identified. After comparison of these wastes to the wastes that are introduced in the united nation environment plant method it was found that among them , 4 cases are non-hazardous and 7 are hazardous. Hazardous wastes are considered as hazardous because of their properties and having same qualities like flammability corrosiveness, toxicity, and intense combinatory tendency. As the table (5) shows 70% (by weight) of the produced waste of this plant stay on non-hazardous waste group and the rest 30% take place in hazardous one. This issue is displayed according to the three different categorization in the figure (3).

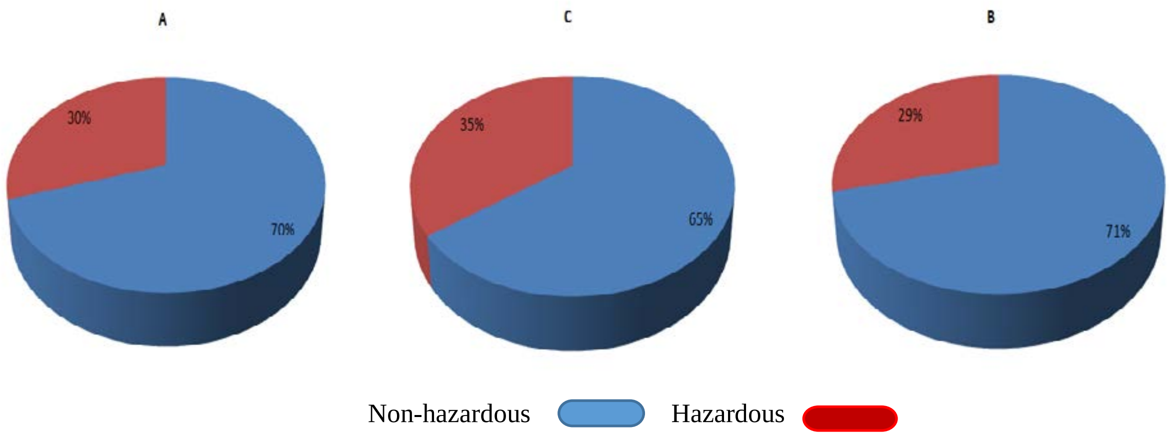

Figure 3: Chart classification of industrial wastes iron melting: A- according to EPA; B- according to UNEP

C- according to Basel

At the end, wide range of disposal methods such as landfill, sale and recovering, waste incineration and stabilization/ solidification of waste were assessed , according to the nature of the hazardous industrial wastes of the Isfahan iron melting plant and its amounts, and the appropriate method was introduced for each waste group. The first method is the Stabilization/ solidification of slag in production units of this waste. Using of slag has spread range of usage; the production of slag cement, iron subsoil building, anti-wear tile, using of it as a filler in the concrete, agricultural land reform, glass production, glass wool production, roof coating, color asphalt production and slip control from snow and ice on the roads. Slag stabilization/ solidification processes were used mostly for eliminating the toxicity of that kind of wastes that can be used in the different land uses and include wide type of toxicity compounds. In this process the stability of hazardous wastes is fixed with cement and chemical compounds such as tar in order to decrease the toxicity, the dissolution of toxic compounds and their release in the environment (Ginneken et al. 2004). The cement as a connector matter is more acceptable selection because of its low cost, widespread accessibility, non-toxicity of its constituent materials and better physical and chemical performance toward other options (Walton et al. 1997). Second method is recovering and reuse of wastes or return them to the plant or transfer them to other plants. In this unit, convertor slag is recovered and reused in the production line. There is no burning waste process in the Isfahan iron melting plant, so the burning of industrial wastes is the third method. Hygienic landfill is the fourth waste disposal management method which is the most uncomplicated and reasonable price method, and it can be used in the iron melting plant for each waste, chemical sludge and even other produced wastes including slag deposits and slag wool. In order to best alternative selection, different management methods were evaluated based on economic, technical and environmental aspects (Table 6). Many approaches for evaluating mentioned criteria can be used to comprise different methods. Since various value judgment lead to different results, so these criteria were evaluated at three levels (law; medium; and high) due to uncertainty reduction.

Table 6: Comparison of Industrial Waste Management Methods in Isfahan Iron melting Plant

Comparison Criteria	**stabilization/ solidification**	**Recycling (method**	**Combustion (method No.**	**Landfilling (method**

		(method No. 1)	No. 2)	3)	No. 4)
Technical	**Technology complication**	medium	High	high	Low
	Expert operation	medium	High	high	Low
	Necessity to energy	medium	High	-	-
	Necessity to land for establishment	medium	medium	low	High
	Necessity to land residual disposal	low	Low	low	High
	Necessity to water	high	High	-	-
	Necessity to chemical materials	high	High	-	-
	Capability of hazardous pollutants removal	medium	Low	high	High
	Production of lateral hazardous materials	low	Low	high	High
Economical	**Investment costs**	high	High	low	Medium
	Current costs	medium	Low	low	Low
	Marketing for recovered product	low	Low	low	-
Environmental	**Existence of monitoring infrastructure**	high	High	low	Low
	Potential of hazardous pollutants emission	low	medium	medium	High
	Energy recovery	high	High	low	Low

Based on Table 6, the recycling and fixing and burial procedures are respectively more beneficial for the management of industrial wastes of the iron-melting plant. Using of advanced technology is essential if stabilization/ solidification and recovering methods are selected. Iran Environment Organization proposed hazardous waste landfill method for industrial waste disposal in which the similar solution can be used nearby the iron melting plant. As the result, the proposed hazardous wastes landfill method will be introduced as the best alternative for management of hazardous wastes.

Conclusion

The results of the research carried out about the industrial wastes of Isfahan iron melting plant illustrate that among the 11 identified waste products, 7 are hazardous and 4 are non-hazardous. Based on different categorizing and by weight, about 70% of the produced wastes by the plant are in the non-hazardous waste group and the remaining 30% are in the hazardous waste group. The most part of these wastes are made by slag and sludge. Around 60 till 70 percent of produced slags in the plant is stabilized and controlled. These slags can be stored in open storage after collection from coking units, converters, high-fired furnaces and steel making, and then can be returned to the iron melting to be used again as a primary material. Part of these slags can be used in the road construction through stabilization/ solidification method and the other part can be used at the cement plant. This is necessary to make a suitable space for keeping and storing wastes in this method. The produced sludge in this plant, which is a mixture of iron oxide dust (powder) and sponge iron dust, can be returned to the factory after drying in the desiccant ponds to recover and reuse the iron oxide present in it and a part of it is also deposed hygienically. Finally, the use of such a technique requires the consideration of a landfill design around the plant.

References

United State Environmental Protection Agency. The National Biennial RCRA Hazardous Waste Report (based on 2007 data). United State Environmental Protection Agency; 2009. Report NO: EPA 530-R-06-006.

UNEP, 2000, "Text of the Basel conventions and decisions of the conference of parties", http://www.unep.gov-visited on October 2005.

United States EPA, 2004, "Managing hazardous waste", RCRA subtitle C, chapter 1, section III, http://www.epa.govvisitedon April 2005.

ASTM D4687–95, "American standard guide for general planning of waste sampling", 2006.

Alqaydi S. Industrial solid waste disposal in Dubai, UAE: A study in economic geography. Cities. 2006; 23:140-8

Nema AK, Gupta SK. Optimization of regional hazardous waste management systems: an improved formulation.WasteManagement.1999;19:441-51.

Geng Y, Zhu Q, Haight M. Planning for integrated solid waste management at the industrial park level: A caseof Tianjin, china. Waste Management. 2007; 27(1):141-50.

Mrayyan B, Hamdi MR. Management approaches to integrated solid waste in industrialized zones in Jordan: A case of Zarqa City. Waste Management. 2006; 26:195-205.

Department for Environment, Food and Rural Affairs. Consultation on a stratege for hazardous waste management in England. London: Department for Environment, Food and Rural Affairs; 2009.

United State Environmental Protection Agency. The National Biennial RCRA Hazardous Waste Report (based on 2007 data). United State Environmental Protection Agency; 2009. Report NO: EPA 530-R-06-006.

Monavari M. Environmental Impact Assessment Guidelines For Industrial Estate. Tehran: Kosar-culturatourism publication; 2002. [Persian]

Ginneken, L.V., Dutré, V., Adriansens, W., & Weyten, H. (2004) Effect of liquid and supercritical carbon dioxide treatments on the leaching performance of a cement-stabilized waste form. Supercritical Fluids, 30, 175–188

Walton, J.C., Bin-Shafique, S., Smith, R.W., Guttierrez, N., & Tarquin, A. (1997) Role of carbonation in transienleaching of cementitious waste forms. Environ. Sci. Technol., 31, 2345.