Characterization of bottom sludge waste in a thermal power plant evaporation pound (Case study: Damavand Combine-Cycle Power Plant, Tehran, Iran)

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Abstract

Thermal power plants are one of the most usual facilities to generate electricity in Iran. However Combined-Cycle Power Plant (CCPP) produces up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant and reduces air pollutants emission significantly, but generated industrial wastes during electricity generation must be considered. In spite of different investigations on solid waste generated in gas power plants in Iran, no evidence was observed about solid waste characterization in CCPPs. Primary reviews on electricity generation process in CCPPs shows that the main generated solid waste in a CCPP is residual sludge which is settled in wastewater evaporation pound. As different chemicals was added to water for corrosion prevention, so probably this kind of waste can be classified as a hazardous waste. Also existence of heavy metals in wastewater with significant concentrations can strengthen this hypothesis. Thus in this research, characterization and classification of bottom sludge in evaporation pound in a CCPP in Tehran (Largest CCPP in Middle East; namely Damavand) was done. For this purpose, composite sampling method was used for determination of heavy metals concentration and hydrocarbons pollutants in settled bottom sludge. Results shows amongst 11 heavy metals that were of concern in this analysis, Cr, V, Pb, Ni and Zn are more considerable with total concentration of 91, 38, 70, 61 and 499 mgkg-1 respectively. Also total petroleum hydrocarbon (TPH) concentration in the sludge was 350 mgkg-1. According to the Waste Management Act of Iran this waste is classified as specific waste and should be disposed of in accordance with hazardous waste disposal regulations. More specifications on this waste and proposed disposal methods have been expatiated in this paper.

Keywords: Solid waste, Bottom sludge, Power plant, Heavy metals

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1. Introduction

Industrial activities have led to the generation of the large amount of sludge which its disposal is a serious environmental issue because it contains harmful level of pollutants including heavy metals [1-2]. One of the important industries is power generation. Thermal power plants are the major source of generation of electricity for any developing [3]. Demand for electricity in Iran is growing exponentially and is increasingly based on power generated from coal. Waste management has become an acute problem in many countries. Management options require extensive waste characterization since many of them may contain compounds deleterious for the ecosystem, such as heavy metals. Heavy metals are part of many industrial sludge and they are considered as hazardous waste [4]. Although, waste generation is increasing in many countries, but considerable economic as well as environmental benefits can be achieved when appropriate industrial waste management is implemented [5].

One of the important generated wastes in most of power plants is ash so most of the studies determine fly ash and bottom ash and their management. The disposal of fly ash from coal-fired power station causes significant economic and environmental problems. In most countries at least 75% the fly ash generated annually is dumped with no subsequent reutilization. So after looking at the structure of power station fly ash can be utilization as novel materials, waste management, recovery of metals and agriculture [6].

The coal-fired-power plants all over the world generate a large amount of solid wastes from the burning process. The chemical properties of generated solid wastes changed from one plant to another depending on type of coal burned and techniques use for handling and storage. They usually contain a quantity of valuable metals. By applying mineral processing technologies and hydrometallurgical and biohydrometallurgical process, it is possible to recover metals such as Al, Ga, Ge, Ca, Cd, Fe, Hg, Mg, Na, Ni, Pb, etc, from solid wastes [7]. In 2006, a research was conducted in the thermal power plant in Turkey. In this study fly ash samples were investigated for leachability of metals under different acidic and temperature conditions. The experimental results showed that a decrease in pH of the leachate favors the extraction of metal ions from fly ash [8]. India has some of the largest reserves of coal in the world. Nearly 73% of the country's total installed power generation capacity is thermal of which coal-based generation is 90%. Some of the problems associated with fly ash are large area of land required for disposal and toxity associated with heavy metal leached to ground water. In this study reviews the potential applications for coal fly ash as a raw material: as a soil amelioration agent in agriculture, use, in highway embankments, in construction of bricks, as an aggregate material in Portland cement, filling of low lying areas etc in the manufacture of glass and ceramics, in the synthesis of geopolymers, for use as catalysts and catalysts support, as an adsorbent for gases and waste water process, and for the extraction of metals [9-11]. Another study in Serbia showed that power plants have a negative impact on the environment. According to the waste classification system in republic of Serbia and generated ash and sludge from thermal power plants are classified as hazardous waste, but with an option of usability [12].

In another study in Shahid Rajaei thermal power plant in Iran, sludge originating from air heater washing wastewater was classified as specific industrial waste that should be disposal considerations or should be stabilized before disposal. The most likely pollutants that were of concern in this study were heavy and other hazardous metals (Cd, Co, Cr, Mn, Ni, Pb, Zn and V) [13-15]. Also In a study in Yazd combined cycle power plant, samples from evaporation pond wastewater were analyzed. Results determined that concentration of some heavy metals such as Cd, Cl, B, Mn, Fe and Se is higher than discharge to the absorbent well [16].

There are, however, a lot of studies on ash management, but one of the important waste in power plants are evaporation pond bottom sludge. The main generated solid waste in a Combined-Cycle Power Plant (CCPP) is residual sludge which is settled in wastewater evaporation pound. As different chemicals was added to water for corrosion prevention, so probably this kind of waste can be classified as a hazardous waste. Most of power plants in Iran use evaporation pond system to treat power plants chemical wastewater. All of the construction and operation phase wastewater enter to evaporation pond so its composition can be toxic and classify as hazardous waste. As waste characterization is the first step for waste management, so this investigation tries to determine the physicochemical characteristics of evaporation pond's bottom sludge in Damavand combined cycle power plant.

2. Material and Method

Damavand combined cycle power plant has been built on an area of 193 hectares of land in southeast Tehran, 35 km from Garmsar. Damavand CCPP is the biggest power plant in Middle East comprising 12 gas units, each with a capacity of 159.9 MW, and six steam units each with a capacity of 160 MW and totally produces about 2880 MW at ISO conditions. Gas and gas oil are the fuel needed by Damavand power plant. Gas is the primary fuel and gas oil is the backup fuel. The cooling systems used for steam units of this project are of Heller type [17-18].

A combined cycle power plant uses both a gas and a steam turbine together to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycle plant. The waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power. All of the wastewater from process comes into the evaporation pond with approximately area of 4 hectares.

2.1. Sampling method

In order to characterization of evaporation pond's bottom sludge, 16 waste samples were taken from evaporation pond. One composite sample was prepared by homogenized 16 samples. Sludge sample was transported to the laboratory in glass and polyethylene bottles, and kept refrigerated (4°C) until processing (< 1 week).

2.2. Analyses method

Standards Method was used to analyze most of the parameters such as pH, Total Dissolve Solid (TDS), Electrical Conductivity (EC). Also concentration of organic carbon, nitrate and extractable phosphore was measured by using ICARDA standard method. A heavy metals test was conducted through ICP method. Concentration of total petroleum hydrocarbon (TPH) determined by GC-FID according to EPA-3550 standard.

3. Results and Discussion

The analyses made of evaporation pond sludge samples are summarised in Table 1. Metals behaviour in soil and uptake by organisms can be strongly affected by pH [19]. The pH of study sludge was alkaline considering using NaOH for neutralizing wastewater in neutralization pond. The EC amount for the sludge was higher than some other sludge samples reported by different researchers [1, 20]. Higher EC means higher salinity, which makes the studied sludge unsuitable for land application. Table 1 also shows concentration of TDS, nitrate, soulfate, organic carbon and TPH. High concentration of TPH show that the oily wastewater intake to the evaporation pond.

Table 1. Physicochemical characteristics of the slurry sludge

Parameter	Unite	concentration
pH	-	9.2
TDS	Mg/l	48.4
EC	µs/cm	96.9
NO_3^-	Mg/kg DM	83.37
SO_4^{2-}	Mg/k DM	424949
OC%	%	2.69
P	Mg/kg	6.7
TPH	µg/g	350
PAH	µg/g	245.4

The concentration of metals is presented in Table 2. As results show, Fe and Al had high concentration among the studied metals, which can come from HRSG blow down. Among the heavy metals, Zn and then Cr were the ones with the highest concentration.

Table 2. Concentration of metals in slurry sludge

Parameter	Unite	concentration
Al	%	1.21
As	Mg/kg DM	< 20
V	Mg/kg DM	38
Co	Mg/kg DM	8
Cr	Mg/kg DM	91
Cu	Mg/kg DM	49
Fe	%	2.80
Mn	Mg/kg DM	272
Ni	Mg/kg DM	61
Pb	Mg/kg DM	70
Zn	Mg/kg DM	499

In our study, a comparison of the studied heavy metals with the standards determined by CSQG and NJDEPSCC showed that according to CSQG, Zn concentration in the studied sludge was higher than acceptable values for residential/ parkland, agricultural, commercial and industrial applications (see Table 3). Also Cr concentration is higher than standards for such applications, on the other hand, according to NJDEPSCC standard; the studied sludge can be used for residential and non- residential purpose.

Table 3. Statistical results of comparing the studied heavy metals with the standards determined by CSQG and NJDEPSCC

Heavy metal	CSQG								NJDEPSCC			
	Residential/ parkland		Agricultural		Commercial		Industrial		Residential		Non residential	
	standard (mg kg-1)	PV*	standard (mg kg-1)	PV*	standard (mg kg-1)	PV*	standard (mg kg-1)	PV*	standard (mg kg-1)	PV*	standard (mg kg-1)	PV*
As	12	<0.0001 ↓	12	<0.0001 ↓	12	<0.0001 ↓	12	<0.0001 ↓	20	<0.0001 ↓	20	<0.0001 ↓
Cd	10	0.009↓	1.4	<0.0001 ↓	22	0.188↓	22	0.188↓	39	<0.0001 ↓	39	<0.0001 ↓
Cr	64	<0.0001 ↑	64	<0.0001 ↑	87	0.188↓	87	0.004↑	-	-	-	-
Cu	63	<0.0001 ↓	63	<0.0001 ↓	91	<0.0001 ↓	91	<0.0001 ↓	600	<0.0001 ↓	600	<0.0001 ↓
Ni	50	<0.0001 ↓	50	<0.0001 ↓	50	<0.0001 ↓	50	<0.0001 ↓	250	<0.0001 ↓	2400	<0.0001 ↓
Pb	140	<0.0001 ↓	70	0.05↓	260	<0.0001 ↓	600	<0.0001 ↓	400	<0.0001 ↓	600	<0.0001 ↓
Zn	200	<0.0001 ↑	200	<0.0001 ↑	360	0.017↓	360	0.017↓	500	0.896↓ 20	1500	<0.0001 ↓

P *_value <0.05 is considered as significant.
↑and↓ indicate that the measured amounts are higher and lower than the standards, respectively.

4. Conclusion

In this study, some physicochemical characteristics of combined cycle evaporation pond was studied and result showed that among the metals Fe and then Al had the highest concentration and Zn was the heavy metal with highest concentration. So compared results with CSQG, investigate that Zn and Cr concentration is higher than for residential/parkland, agriculture, commercial and industrial applications. According to NJDEPSCC standard, the studied sludge can be used for residential and non- residential purpose. It should be noted that there are other parameters in CSQG and NJDEPSCC than those studied in this study, and it would be better for these parameters to be considered in future studies. As a general view, bottom sludge in CCPP evaporation ponds can be classified as a hazardous waste and should be considered for waste management practices.

5. References

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