

STUDY OF SOLID WASTE AND ASHES CONTENT OF RADIOACTIVE AND HEAVY METALS IN ASSIUT THERMAL POWER PLANT

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The combustion of heavy fuel oil concentrates a high content of heavy elements in the ashes. These elements are vanadium, calcium, magnesium, sulfur, sodium, zinc, iron, silicon, nickel, aluminum and manganese, and radioactive metals as uranium and thorium. These elements have dangerous environmental impacts. Also water treatment unit's produces solid wastes. Such wastes later enter the environment by different pathways producing adverse effects on the quality of life, so reduction of the amount of solid wastes to be discharged to the environment goes in accordance with Egyptian Environmental Legal solid wastes discharge Regulations and man's welfare.

KEYWORDS: *Thermal power plant, Solid waste, Radioactive and Heavy Metals.*

INTRODUCTION

Oil is the largest source of energy in Egypt providing close to 90 % of all entire power needs. Where, most heavy oil is used as a fuel for electricity generating plants and its combustion produces fly and bottom ashes. Also, River Nile, constitute the main source of water used in electricity generating plants. Ashes from fuel oil combustion and suspended solids from the Nile constitute the major solid wastes from power plants in Egypt. Sludges and ashes that are produced during operation and combustion became a solid waste burden and contain toxic and hazardous wastes. Solid wastes from power plants can be classified into three categories; Fuel wastes (flyash, bottom ash) and chemical sludge (from water and wastewater treatment systems), of the two wastes, partial utilization of ash has been commonly practiced, as fill for roads, runways, construction sites, as cement and brick admixtures has become more commonly practiced. Some possible fly ash applications and utilizations are [1]:

- As a Portland cement admixture or partial replacement.
- As a light aggregate for producing lightweight concrete blocks and structural lightweight concrete.

- As road bed material, loose aggregate, soil stabilizer, clean fill, or soil nutrient.
- Recovery of the metallic components of fly ash, such as aluminum, vanadium, titanium, and iron.
- Production of mineral wool.

Both ashes from the flue-gas and boiler residue are fed to the agriculture growing area to enhance the soil, where the minerals in these ashes will increase crop growth and yield more food per acre [2]. Accordingly the main objective of the current study is to investigate the ash's constituents and assist in terminating the environmental impacts of the solid wastes from Assiut power plant.

ASHES:

Fossil fuel combustion results in gaseous products, called flue gases, and non-gaseous non-combustible residues called ash. A portion of the ash is carried along with the flue gas; this portion is called fly ash. The remainder of the ash settles to the bottom of the furnace and is called bottom ash [1, 3]. The amount and characteristics of each type of ash produced depends on the type of fuel and boiler. Coal produces a relatively large amount of both ashes, while oil produces little bottom ash but more fly ash, and gas produces little of either ash. Ash contains the non-combustible constituents of the fuel, many of which may be toxic. For example, fuel oil fly ash may contain vanadium and other noncombustible and potentially toxic chemicals that may have been in the oil. The recovery modes of vanadium from the vanadium-containing ashes of thermal power stations are shown that there is no single approach to directly recovering vanadium from various ashes, each ash needs its own leaching mode depending on its chemical and phase compositions [4]. Fossil fuel combustion results in concentration of most trace elements in ash by approximately 10 times the concentration in the original fuel [5]. Waste samples were taken from bottom ash of oily fuelled combustion power plant, physical properties and chemical composition were investigated and the following elements were detected V, Ni, Fe, Cr, Pb, and Cd [6]. A 1997 analysis by the U.S. Geological Survey (USGS) found that fly ash typically contained 10 to 30 ppm of uranium, comparable to the levels found in some granitic rocks, phosphate rocks, and black shale [5]. The combustion of oil concentrates in the ashes those radioelements, which later enters the environment by different pathways producing adverse effects on the quality of man life. The concentration of radioelements varies greatly between oil fields, and then still requiring local survey studies in this area. The concentration of radioactivity and heavy metals in crude oil, fuel oil N° 6 and the ashes from power plants were determined; the analysis includes the two major thermoelectric power plants in Venezuela, Ricardo Zuluaga on the northern seaside of Caracas and Planta Centro on the littoral of Carabobo State. The study covers different samples: fuel oil N° 6, heavy and medium petroleum as well as fuel Oil N°6 ashes. Gamma spectrometry was used for measuring ^{226}Ra , ^{214}Pb , ^{214}Bi , ^{228}Ac , ^{212}Pb , ^{212}Bi , ^{208}Tl and ^{40}K , and heavy metallic cations were determined by ICP-MS, which also allows the direct determination of ^{232}Th and ^{238}U [7]. The reuse of fly ash as an engineering material primarily stems from its pozzolanic nature, spherical shape, and relative uniformity. Fly ash recycling includes usage in; Portland cement and grout, embankments and structural fill, waste stabilization and solidification, raw feed for cement clinkers, mine reclamation, stabilization of soft soils, road subbase, aggregate,

flowable fill and mineral filler in asphaltic concrete, other applications include cellular concrete, roofing tiles, paints, metal castings, and filler in wood and plastic products [8,9].

SLUDGE:

Sludge is a water-formed deposit that will settle, and may include all suspended solids (SS) carried by water. Generally physical treatment includes processes like filtration, sedimentation used to separate and concentrate various components of all suspended solids without chemically altering their form [10]. By physical treatment as a primary treatment, floating and suspended solids are settled and removed by sedimentation in clarifiers from raw water, where inorganic and organic suspended solids are settled out then blowdown [11,12], if chemicals and coagulants are used, such as lime, alum and ferric sulfate, ferric chloride inorganic sludge will be generated; Sludge that settles to the bottom of the clarifier is blowdown and pumped into a filter press for dewatering, solidification and stabilization, which reduce the mobility of pollutants in the environment thus making land disposal safer. Generally, solidification and stabilization technology is effective for inorganic waste, solidification refers to disposal techniques that convert a liquid, semi-solid, or finely divided solid particles into a stable solid. Sludge which is usually generated at 3 to 7 percent solids (by weight) is usually thickened and dewatered to 35 to 45 percent solids to reduce its volume then disposed of in a landfill [13].

SPECIFICATIONS OF ASSIUT POWER PLANT

The present study has been developed in Assiut electric power plant with a maximum power of 2×312 MW/h Image (1); each unit is equipped with a high capacity steam boiler with 16 burners distributed in four floors, placed tangentially in the corners of the furnace to induce a vertical swirl motion of the combusting gases, and there are no flue gas desulphurization beds. Also there are a pre-treatment with capacity of 60 m³/hr, waste water with capacity of 40 m³/hr for unit (I) and 60 m³/hr for unit (II), and filter press unit for both.



Image 1; Assiut thermal power plant

The main parameters of the steam boiler are: steam power of 1024 ton/h (maximum), superheated steam pressure of 170 bars, and temperature of 540 °C for both as in Table (1).

Table 1; Specifications of the two units

Item	Unit (1)		Unit (2)	
	Designed	N. operation	Designed	N. operation
Load MWh	312	155	312	200
Steam ton/h	1024	484	1024	671
Fuel cons. m ³ /h	70	35.8	78	51
No. of burners	16	12	16	12
Steam temp. °C	541	540	541	540
Stack height	120 m (+50 m from sea level),		120 m (+50 m from sea level),	
Stack top width (φ)	φ = 5.13 m		φ = 4.9m	

In Assiut power plant, burning of heavy fuel oils (Mazout) that contains high sulfur content (approximately 3.89 %), sodium (40.13 ppm) and high vanadium (approximately 106.94 ppm), led to flue gases with obnoxious emissions, flyashes and bottom ashes. The physicochemical properties of the fuel to be used can be read in Table (2).

Table 2; Chemical analyses for fuel oil

Test	Ash wt %	Asph. wt %	C %	H %	N %	Na ppm	S %	V ppm	Waxes wt %	Gross C.V. Cal/gm	Net C.V. Cal/gm
Result	0.069	2.0	83.8	11.5	0.65	40.13	3.89	106.94	3.7	10323	9740
Method	ASTM. D-482	IP 143	ASTM. D-5373		SOLAAR S4	ASTM. D-1552	SOLAAR S4	IP 143	ASTM. D-4809		

Also, raw water used come from the River Nile, and contains the different suspended and dissolved solids as analyzed and shown in Table (3).

Table 3; Analysis results for River Nile dissolved solids (2009)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PH	8.88	8.80	8.53	8.57	8.44	8.34	8.30	8.76	8.95	8.73	8.8	8.86
Cond.(μs/cm)	343	290	310	299	292	285	290	293	308	338	317	326
Tur.(NTU)	4.10	3.40	3.20	2.25	2.47	2.50	2.31	2.77	4.10	4.41	2.8	3.75
Cl (ppm)	15	14	10	10	10	8	10	10	11	12	13	13
SiO ₂ (ppm)	2.10	1.93	3.12	2.86	3.71	5.53	6.52	4.42	3.22	0.26	3.1	2.16
Na (ppm)	20	24	25	27	22	23	28	29	25	25	24	26
Fe (ppm)	0.17	0.12	0.10	0.17	0.16	0.15	0.14	0.11	0.28	0.14	0.1	0.2
T. Hard. (ppmCaCO ₃)	122	110	118	118	110	108	111	110	110	112	114	126
Ca. H.	76	72	72	74	68	70	71	70	70	62	72	74
Mg. H.Org.	46	38	46	44	42	38	40	40	40	50	42	52
M.(ppmKMnO ₄)	6.4	4.0	5.3	4.88	5.2	4.05	4.5	4.96	4.69	4.0	6.8	5.22
TSS (ppm)	25	24	26	22	20	29	21	25	18	20	16	19

SOLID WASTES DISCHARGES' LAW

A number of laws address solid waste management. The following laws apply to scrap and sludge from the WWTP [14]:

- Law 38/1967 which addresses public cleanliness regulates the collection and disposal of solid wastes from houses, public places, commercial and industrial establishments.
- Ministry of Housing, Utilities and Urban Communities (MHUUC) decree No. 134 of 1968, which provides guidelines from domestic and industrial sources, including specifications for collection, transportation, composting, incineration and land disposal.
- Law 31/1976, which amended law 38/1967
- Law 43/1979, the Law of Local administration, which provided that city councils are responsible for “physical and social infrastructure”, effectively delegating responsibility for infrastructure functions.
- Law 4/1994 regulates incineration of solid waste

ASH ANALYSIS

The ashes formed in different places in the steam generating unit at tubes surfaces, in the furnace bottom, flue gases and in the chimney, were gathered and chemically analyzed as in Table (4), analyzed by X-Ray diffraction as results show in Table (5) and analyzed for uranium and thorium by X-Ray diffraction and spectrophotometric determination respectively Table (6).

Table 4 Chemical analysis of the ash

Chem. Comp.	SiO ₂	Fe ₂ O ₃	NiO	CaO	MgO	Na ₂ O	V ₂ O ₅	MnO	ZnO	Al ₂ O ₃	SO ₄ ⁻⁻	Ash	
												pH	Ac
%	1.7	2.6	0.5	17.8	14.6	10.2	37.2	0.05	3.6	0.37	11.4	3.6	0.32

Table 5 X-Ray diffraction of the ash

Item	Dominant phase detected
Ash sample	Na ₂ SO ₄ +Na ₂ Ni(SO ₄) ₂ +Na ₆ Mg(SO ₄) ₄ +MgSO ₄ +Mg ₂ V ₆ O ₁₇ +CaSO ₄ +Na ₆ Mg ₃ (VO ₄) ₄ +NiSO ₄ +NaV ₆ O ₁₅ +Na ₂ Mg(SO ₄) ₂ +Ni ₃ V ₂ O ₈ +Fe ₄ S ₅ O ₂₁ .

Table 6 Radioactive metals in the ash

Item	Uranium		Thorium	
	Furnace Ash	Chimney Ash	Furnace Ash	Chimney Ash
Concentration ppm	450	50	400	20

SLUDGE DISCHARGE

The pre-water and wastewater treatment plant generate sludge that settles to the bottom of the clarifiers by about 5% of the total production and with 40-50% solid that are pumped out to the thickener tanks in the wastewater units and the slurry then pumped into the filter press units for dewatering Image (2), Fig. (1). Water exits through the filter to the wastewater area drain pit and concentrated solids are screwed out and periodically removed and disposed of in a landfill.



Image 2; Filter press unit

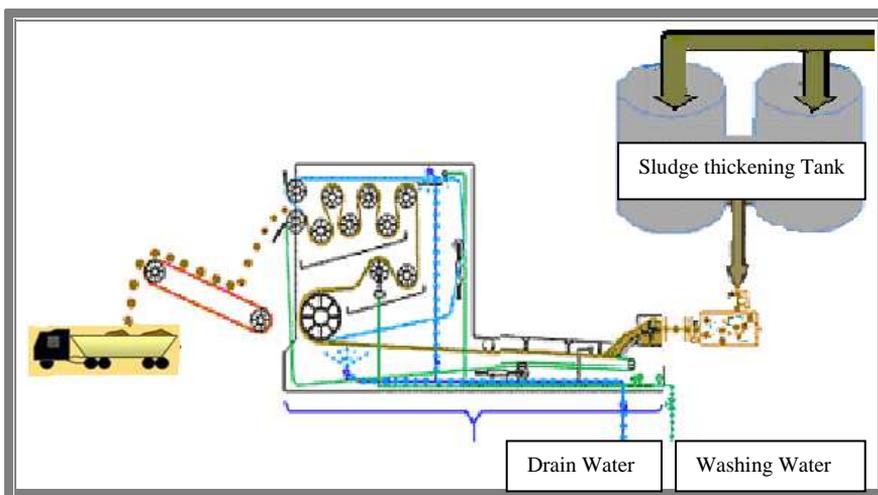


Figure1; Filter press unit

DISCUSSION AND ANALYSIS

ASH

As shown from the chemical analysis in Tables (3) and (4), there is high content of heavy elements as vanadium, calcium, magnesium, sulfur, sodium, zinc, iron, silicon, nickel, aluminum and manganese, and radioactive metals determination in Table (5), shows the presence of uranium and thorium and these elements has a dangerous environmental impact, so in the Assiut thermal power plant we informed the responsible of Egyptian Nuclear Authority, and they periodically brought their trucks

when the units went in shutdown to take the ashes to be land filled at the healthy landfill at Alexandria province.

SLUDGE

The sludge from the filter press units, after solidification is collected and sends to the municipal solid waste landfill to be land filled.

ENVIRONMENTAL IMPACTS

With the arrangements that be taken by the responsible of Assiut Power Plant, no ash wastes will reach the outside environment, the on-site land impacts and off-site land impacts of ashes and sludge were almost reduced, also the bad toxicity impact of the heavy metals and the harmful radiation impact of radioactive uranium and thorium, which has adverse effects on the quality of man life were eliminated. Finally, reduction of the amount of solid wastes to be discharged to the environment goes in accordance with Egyptian Environmental Legal solid wastes discharge Regulations.

CONCLUSION

The combustion of heavy fuel oil concentrated a high content of heavy elements in the ashes. These elements are vanadium, calcium, magnesium, sulfur, sodium, zinc, iron, silicon, nickel, aluminum and manganese, and radioactive metals as uranium and thorium. Such elements have dangerous environmental impacts. Also water treatment unit's produced solid wastes. These wastes when entered the environment had adverse effects on the quality of life. So reduction of the amount of solid wastes that discharged to the environment went in accordance with Egyptian environmental legal solid wastes discharge regulations and man's welfare.

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دراسة المخلفات الصلبة ومحتوي الرماد من العناصر الثقيلة والمشعة في محطة كهرباء اسيوط الحرارية

إن الرماد الناتج عن احتراق المازوت لإنتاج الكهرباء بمحطة كهرباء أسيوط الجديدة تتركز به المعادن والفلزات الثقيلة مثل الفناديوم، الكالسيوم، الماغنسيوم، الصوديوم، الزنك، الحديد، السليكون، النيكل، الألومنيوم، الكبريت والمنجنيز. هذا بالإضافة إلى أن اليورانيوم والثوريوم ذوي نشاط إشعاعي، وجميع هذه العناصر لها تأثير ضار بالبيئة، كما ينتج عن وحدات معالجة المياه راسب طينية صلبة. و يتم التخلص من هذه النواتج عن طريق استخلاص العناصر المفيدة الموجودة بالرماد بينما يتم التخلص من النواتج الصلبة الناتجة من معالجة المياه عن طريق دفنها بالمدفن الصحي المخصص لذلك بما يتماشى مع اللوائح والقوانين البيئية، حيث انه في حالة تسرب هذه المواد إلى البيئة سوف تضر بالبيئة والصحة العامة.