Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2018, Volume 9, Issue 2, Page 385-393

https://doi.org/10.26872/jmes.2018.9.2.42

http://www.jmaterenvironsci.com

Utilization of Fly ash for sustainable environment management

Soma Gorai*

Department of Chemistry, Asansol Girls' College, Asansol 713304, West Bengal, India

Received 16 Jun 2017,
Revised 05 Sep 2017,
Accepted 11 Sep 2017

Keywords
- ✓ Fly ash,
- ✓ Waste management,
- ✓ Construction,
- ✓ Agriculture,
- ✓ Zeolite.

gorai_soma@rediffmail.com
Phone: **+917908341717**

Abstract
Fly ash is a fine powder generated during the burning of pulverized coal in thermal power plants. This industrial waste creates significant environmental problems when released into the atmosphere. In the past, vast majority of the material generated each year was held in ash dams or similar dumps but in recent years a number of technologies have been developed for the beneficial utilization of fly ash in different fields. The utilization of fly ash in construction, mine back fill, road sub-base, agricultural field, paints, wood substitute composites and also as a low-cost adsorbent for the removal of organic compounds is reviewed in this article with the aim of finding new areas that will increase the positive use of fly ash and reduce the environmental pollution impacts.

1. Introduction
The generation of fly ash is increasing every year in India as now-a-days a huge quantity of coal is combusted in thermal power plants to produce electricity for fulfilling our increasing energy demands. From a recent report published by the Ministry of Environment and Forests, Govt. of India, it was found that in the year 2015-2016 the status of fly ash generation from 151 thermal power stations in India is about 176.7441 million tonnes [1]. The Ministry of Power, Government of India estimates that 1800 million tonnes of coal used every year leading to generation of 600 million tonnes of fly ash by 2030-31. This large quantity occupies a vast area for its disposal. It also leads to many health and environmental hazards. Therefore, it is very important to develop some suitable scientific, technical and economic solutions for fly ash utilization. To reduce these fly ash related problems, Ministry of Environment & Forests (MoEF) has issued various notifications on its utilization. They prescribed to achieve 100% fly ash utilization in a phased manner for all Coal/Lignite based Thermal Power Stations in the country. History tells us that the utilization of ash is not a new idea; it was started about 2000 yrs ago when the Romans built the Colosseum by using volcanic ash in the year 100 A.D which is a very good example of durability. From the recent report published by the Central Electricity Authority, New Delhi in the year 2015-16 it can be observed that in the Year 2015-16, 60.97 % of the total fly ash were utilized. The State of Delhi has achieved maximum level of fly ash utilization level and the States of Gujarat, Haryana, Jharkhand, Punjab, Rajasthan, Tamil Nadu and West Bengal have also achieved the fly ash utilization level of more than 75% [2]. Now-a-days fly ash has been used for various purposes: for producing 'green building' materials, construction of roads and embankments, for improving the property of the soil and thereby increasing the agricultural yield, as mine back filling material, as a low-cost adsorbent (zeolites) for the removal of organic compounds or heavy metals etc. Fly ash is also been used to manufacture different items like doors, flooring tiles, false ceilings, etc. In the present paper, utilization of fly ash in India in the said fields is reviewed.

2. Fly ash characterization
The properties of ash mainly depend on types of coal and its pulverisation, burning rate, temperature, method of collection etc. From previous report [3] some typical properties of Indian fly ash can be observed which are shown in the table 1. The concentration of unburned carbon and iron present in the fly ash determines the colour of the material. It is generally observed that grey or black colour ash obtained when the amount of carbon

content is higher while presence of high iron content produces tin coloured ash. Most of the fly ash particles are solid spheres and some are hollow spheres. The particle size ranges from 0.5µm to 100µm. This micron sized particle consists mostly of silica, alumina, calcium and iron oxide. Previous investigations carried out on Indian fly ashes showed that the silica content present in it is between 38- 63%, alumina content ranges between 27 - 44%, calcium oxide and iron oxides are in the range of 0 - 8% and 3.3 - 6.4% respectively (Table 2) [4]. Besides, minor amounts of magnesium, sulphur, sodium, potassium, and carbon are also present in it. Depending on the concentration of calcium oxide, silica, alumina and iron oxide, fly ash is classified into two types: Class F and Class C (ASTM C618) [5] fly ash. Fly ash produced from the burning of anthracite and bituminous coal produces Class F fly ash whereas combustion of lignite or sub-bituminous coal produces Class C fly ash. Class C fly ash generally contains more than 20% lime (CaO) and has both pozzolanic and self-cementing characteristics whereas class F contains less than 10% lime (CaO) and only possess pozzolanic properties and requires a cementing agent, such as Portland cement, quicklime, or hydrated lime to produce cementitious compounds [6]. In Class C fly ash the amount of alkali and sulphate (SO_4) present is higher than Class F fly ash [7].

It is found that all the Indian coal ashes possess pozzolanic activity. ASTM defines a pozzolan as "a siliceous or siliceous and aluminous materials which in themselves possess little or no cementious value but will, in a finely divided form and in the presence of moisture, chemically react with calcium hydroxides at ordinary temperatures to form compounds possessing cementious properties" [5]. For this reason, it has been chosen for preparing building materials and materials for some other constructive works.

Table 2: Chemical compositions of Indian coal ashes and soils [4].

Compounds	Fly Ash	Soils
SiO_2	38–63	43–61
Al_2O_3	27–44	12–39
TiO_2	0.4–1.8	0.2–2
Fe_2O_3	3.3–6.4	1–14
MnO	0–0.5	0–0.1
MgO	0.01–0.5	0.2–3.0
CaO	0.2–8	0–7
K_2O	0.04–0.9	0.3–2
Na_2O	0.07–0.43	0.2–3
LOI	0.2–3.4	5–16

LOI : Loss of ignition

3. Utilization of fly ash in different fields

The main purpose of reuse of this solid waste material (fly ash) is to minimize the environmental pollution which can occur from its disposal. Instead of this, there are also some other reasons for its utilization: (i) there may be some economic gain from the sale of the by-products, (ii) the by-products can replace some scarce or expensive natural resources, (iii) disposal costs can be minimized, etc. In recent years fly ash has been used for various purposes, some of them are discussed as follows:

3.1. *Use of Fly Ash for the manufacturing of Building materials and Construction activity*

3.1.1 Fly ash in Concrete

Use of fly ash in concrete is beneficial for its pozzolonic property which enhances the durability of concrete. It is used in Portland cement concrete to improve the concrete performance. When fly ash particles combines with water and free lime present in the cement matrix, produce additional cementitious materials (pozzolanic activity of fly ash) which results in denser and higher strength concrete. It also minimizes water demand and reduces bleed channels which increase concrete density. These factors produce concrete of low permeability with low internal voids and hence its durability is also increased. The reduction of permeability also helps to prevent sulphate penetration through the concrete and increases the resistance to corrosion. The pozzolanic reaction between fly ash and lime produces less heat and therefore reduces the possibility of thermal cracking when fly ash is used to replace Portland cement. Previous investigation reported that replacement of cement by 15% to 25% by fly ash results in lower porosity of concrete and plain cement mortars [8].

3.1.2 Fly ash Bricks

Fly ash bricks can be used as building material in place of clay bricks. It is environment friendly. Production of clay bricks requires large amount of clay which depletes top soil but fly ash bricks are prepared from fly ash, sand and cement. Furthermore, higher temperature is required to fire the kilns to produce clay bricks, whereas fly ash bricks are manufactured at room temperature. Another type of fly ash brick is FAL-G brick (mixture of fly ash-lime-gypsum or fly ash-cement-gypsum) which is also manufactured without using thermal energy, sets and hardens in the presence of moisture. With aging this brick becomes more durable. NTPC has manufactured more than 54 crores fly ash bricks in its various thermal power stations and utilized in construction activities. NTPC township at Faridabad (Haryana), Sipat (Chhattisgarh), Simhadri (Andhra Pradesh), and Talchar (Orissa) have been constructed with fly ash bricks. Fly ash bricks were used in NTPC's power plant construction works at Rihand, Dadri (Uttar Pradesh), Talchar- Kaniha (Orissa), and Ramagundam (Tamilnadu). NTPC has installed thirteen pilot plants for manufacturing of ash based bricks at its various power stations. More than 1500 lakhs ash bricks have been produced so far and utilized in various construction activities in power plants.

3.2. Use of Fly Ash for Road and Embankment Works

It is advantageous to use fly ash for road and embankment works for its significant properties such as gradation, compaction characteristics, shear strength, compressibility and permeability which are already shown in table 1. It is a lightweight material as compared to commonly fill conventional local soil, therefore, causes lesser settlements. Pozzolanic hardening property gives additional strength to the road pavements/ embankments and decreases the post construction horizontal pressure on retaining walls [9]. It can replace a part of cement and sand in concrete pavements thus making them more economical than roads constructed using conventional materials. By using fly ash road / flyover embankments have been successfully prepared at New Delhi, Dadri (U.P.) and Raichur (Karnataka). It has also been used in various locations throughout the world as a structural fill material for constructing highway embankments [10-11]. It alone or with granite or limestone can be used as a final top surface for roads, parking lots, other industrial and commercial applications.

3.3. Fly ash in flowable fill

Fly Ash can be used in the manufacture of Controlled Low Strength Material (CLSM). It is a fluid mixture made of 90-95% fly ash, 5-10% Portland cement and sufficient quantity of water. The most important physical characteristics of flowable fill mixtures are: strength development, flowability, hardening time and bleeding/subsidence. It can be used in place of conventional soil as structural fill and can also be an ideal material for use in restricted areas like narrow trenches, sanitary and storm sewer pipes, tunnels etc. where the placement and compaction is difficult. It can be placed in any weather, under freezing conditions also. The use of CLSM is beneficial in the areas of backfilling, structural filling, insulation fills, erosion control, pavement bases, underground construction etc. The use of CLSM on large scale will help in increasing the use of fly ash and to create more durable and safe road infrastructure.

3.4. Use of Fly Ash in Mine Back Filling

Large underground voids that are left out because of the mining operations have been creating various types of ground stability problems in many mining areas in India. Subsidence is a very common phenomenon in many coal mining areas. Backfilling or sand stowing technique has been followed for decades to counter the ground subsidence problem as well as to improve pillar recovery. Mill tailings and river sand have been used largely as mine back filling materials. However strict regulation and unavailability of river sand has created a huge problem for mining industry in India. Therefore easily available fly ash can be an attractive option for a filling material for reclamation of abandoned mines which results saving of top fertile soil and river sand. It may be seen that 0.65 million-ton of fly ash was used for backfilling/stowing of open cast and underground mines during 1998-99 which increased to 10.33 million-ton in 2015-16 constituting 5.85 % of total fly ash utilization in the aforesaid year and the trend is on increasing side [2]. Mine void filling using fly ash will not only help in reducing huge land requirement, but also help to increase the production of crops.

3.5. Use of Fly Ash in Agricultural Field

3.5.1. Benefits

Fly ash has the potential to improve the physical health of the soil. It serves as a soil modifier and also enhances the water retaining capacity and fertility of the soil [7, 12-13]. It contains macro and micro nutrients (table 3) [14] and thus promotes the growth of plants [15] and improves the crop yield 10-40%. The increase in yield of cereal crops have been reported 10-15%, in case of pulses and oil seeds 20-25% and in vegetable as well as in other crops up to 40% [16]. Previous report said that the soil texture could be changed from sandy and clayey soil to loamy by the addition of fly ash at 70 t ha^{-1} [17]. It can also be observed that some properties like porosity, workability, root penetration and moisture retention capacity of the soil can be improved by applying fly ash at 0, 5, 10 and 15% by weight in clay soil [18]. Fly ash can also be used to maintain the pH balance of the soils.

Table 3: Major and Trace Elemental Composition of Fly Ash* [14].

Major Elements	**(mg/kg)**
K	0.15-3.5
Ca	0.11-22.2
Mg	0.04-7.6
S	0.1-1.5
Al	0.1-17.3
Na	0.01-2.03
Fe	36-1333
Trace Elements	**(mg/kg)**
Mn	58 – 3000
Zn	10 –3500
Cu	14-2800
B	10-618
As	2.3-6300
Cd	0.7-130
Cr	10-1000
Hg	0.02-1.0
Mo	7-160
Ni	6.3-4300
Pb	3.1-5000
Se	0.2-134

*Unweathered electrostatic precipitator fly ash generated from F grade coal with 40% coal ash.

As the nature of most of the Indian fly ashes is alkaline its use in the agricultural soil minimizes the acidic nature of soil [19]. Matasi et al.[20], have shown that the use of fly ash as liming agent in acid soils may improve soil properties and increase crop yield. Fly ash can also be used to correct sulphur and boron deficiency in acid soils [21]. The pH of fly ash varies from 4.5 to 12.0 depending largely on the sulphur content of the parent coal [22] and the type of coal used for combustion affects the sulphur content of fly ash. Sikka and Kansal [23], showed that 2-4% fly ash significantly increased N, S, Ca, Na and Fe content of rice plants. Weinstein et al.[24], reported that fly ash increased crop yield of alfalfa, barley, Bermuda grass and white clover. Furr et al. [25], demonstrated that alfalfa, field corn, millet, carrots, onion, beans, cabbage, potatoes and tomatoes could be grown with a better yield by treating the soil with 125 mt ha^{-1} of fly ash. It was also found that higher yield of brinjal, tomato, cabbage can be obtained by using 25% fly ash in the soil. The application of fly ash in soil also beneficial for the growth of oil seed crops like sunflower, groundnuts [26]. Mishra et al. reported that the growth and metabolic rate of soybean and maize crops found to increase with the application of fly ash [27].

3.5.2. Economic evaluation of usage of fly ash in agriculture

It has been observed that the usage of fly ash along with fertilizer increases the fertility of the agricultural land. Fly ash used along with chemical fertilizer and organic materials can save chemical fertilizer as well as increases the fertilizer use efficiency. From a previous report [28] on application of fly ash to sunflower-groundnut cropping sequence in red soil under irrigated conditions at Raichur, Karnataka, India, it can be seen that how the benefit to cost ratio varies with the use of fly ash (Table 4). In another investigation Mittra et al

[29] found that N, P and K fertilizers could be saved to the range of 45.8%, 33.5% and 69.6% respectively by applying fly-ash with organic and inorganic fertilizers and it was also observed that mixing of fly ash increases the fertilizer efficiency more than the chemical fertilizers alone or used in combination of organic and chemical fertilizers in a rice–groundnut cropping system (Table 5).

Table 4: Economics of fly ash application to sunflower-groundnut cropping sequence in red soil under irrigated conditions, Raichur, Karnataka; Source [28].

Treatment	Total cost (A) (Rs/ha)	Total cost (B) (Rs/ha)	Net returns (A) (Rs/ha)	Net returns (B) (Rs/ha)	Gross returns** (Rs/ha)	Benefit : Cost Ratio (A)	Benefit : Cost Ratio (B)
Recommended Fertilizer Dose (RDF)	14380	14380	13370	1370	28110	1.95	1.95
RDF + Fly ash @ 30t/ha/yr	20080	15580	17690	22190	37770	1.88	2.42
RDF + Fly ash @ 30t/ha/ once in 3 years	15060	13060	19500	21500	34560	2.29	2.64

** The market value of sunflower seeds: Rs. 1200/q and groundnut pods: Rs. 1500/q
A= Inclusive of transportation cost of fly ash from RTPS Shaktinagar to Raichur (20 Km distance)@ Rs. 150/tonne
B= Excluding the transportation cost of fly ash
Labour cost for spreading fly ash was taken as Rs 20/tonne.

Table 5 : Saving of chemical fertilizers and nutrient use efficiency under different modes of fertilization sources in rice-peanut cropping system; source [29].

Fertilization sources	Saving of chemical fertilizer (%)			Nutrient use efficiency (kg grain or kg pod kg^{-1} nutrient)		
	N	P	K	N	P	K
Chemical fertilizer (CF)	-	-	-	34.44	34.4	45.9
Organic[a] + CF	37.5	22.0	32.0	37.2	86.5	59.8
Organic + Fly ash + CF	45.8	33.5	69.6	45.4	105.5	72.9

[a] Mean of farmyard manure and paper factory sludge at 30 kg N ha^{-1} for rice and half of these dose for peanut.

3.5.3. Risk associated with fly ash amendment

Though the use of fly ash in agricultural field has several advantages, there are some risks too. Fly ash has been reported to contain a number of trace and heavy metals like As, Cu, Zn, Cd, Pb, Co, Mo, Mn, Hg, Ni, Cr, Se, B, etc. [14]. Therefore when it is applied at a high rate in agriculture as a soil amendment, there may be a possibility of accumulation of these elements at a higher concentration in the plant bodies and finally enter into the food chain. Researchers [25, 30] found that some plants growing on soils amended with fly ash contained higher amount of As, Ba, B, Mo, Se and V. Gupta et al [31] observed that the accumulation of metals in the plant of mung bean increased with increasing fly ash amendment. From another investigation [32] it was found that a very low concentration of Cu, Mn and Ni were accumulated in mung bean, urad beans and wheat but there were no Cd and Pb content. It was also observed that the concentration of Fe, Mg and Zn accumulation was slightly higher but remained within the permissible level of Indian Standards and WHO. Mahale et al [32] reported that the use of fly ash as an admixture in agriculture up to 60% for the wheat, 10-20% for mung bean, and 20% for urad beans is safe. An investigation [33] showed that application of fly ash did not change the Na content of rice-roots, but the contents of K, P, Mn, Ni, Co, Pb, Zn, Cu, Cr, and Cd showed a progressive increase. It was also found that seeds of plants grown in fly ash amended soils contained Cu, Pb, Cr and Cd below allowable limits. Another study on the heavy metal content in grain and straw of rice by Karmakar et al [34] revealed that there was a marginal increase in content of Se, Cd under different treatments and no increment in Ni content. They concluded that these marginal variations does not affect the plant and remains safe for human consumption. Long-term field studies on different types of soils waste/alkaline land and mine soil) using fly ash from different Thermal power plants [35, 36, 37, 38, 39] have revealed that most of trace/heavy metals concentration in the crop produce and plant species was within permissible limits. However, Adriano et al [40] found that at higher level of fly ash amendment some heavy metals might become more active and hinder the microbial activity. Alteration in soil texture has been reported by some workers due to amendment of fly ash in soil [21, 41]. Another risk of using higher concentration of fly ash may be due to the presence of soluble salts which increase the soil and groundwater salinity. The salinity may also affect physiology of the plants; alter the osmotic potential, soil structure, permeability, hydraulic conductivity etc [42]. Besides, when fly ash is applied in a high rate in the field, enhanced levels of toxic heavy metals may percolate into the soil and may lead soil, surface and ground water pollution. After performing some laboratory experiments on leaching potential Natusch et al [43] found that 5-30% of toxic elements, especially Cd, Cu and Pb are leachable. In another experiment Wang et al [44] found that the concentrations of Ni, Co, As, Cd, Mo and U in leachate exceeded the permissible limits but Li et al. [45] found no detectable As, Cr, Hg, Pb, and Se in the leachates, only Cd and Mo were detected in few leachate samples.

Risk may also come from the radionuclides present in the fly ash. Fly ash contains certain amounts of radionuclides of uranium and thorium series [46-47]. It was found that the level of radionuclides in the grain has been increased with the addition of higher dose of fly ash but no regular trend of the residual effect of fly ash in respect of radionuclides content in the paddy grain was observed [48]. Studies conducted by Goyal et al. [49] proved that in soil containing up to 24% fly ash, the activity levels of gamma emitting radionuclides ^{40}K, ^{226}Ra and ^{228}Ac remained in permissible limits and found that ground water was not contaminated with radionuclides. Mittra et al [50] reported that the marginal variations of radioactivity with the application of fly ash remained within the safe limit. Therefore, by analysing the previous reports of various researchers, it can be said that though fly ash has the potential to increase the yield of several crops, there is a possibility of harming the environment and human health also, hence it should be used carefully and marginally within permissible limits as an agricultural soil amendment and requires long term researches, mainly on concentration-response relationship before its large scale application in global agriculture.

3.6. Use of Fly Ash in Synthesis of Zeolite

Generally, zeolites are three-dimensional, microporous, crystalline solids that contain aluminium, silicon and oxygen in their regular framework; water and cations are located in the pores [51]. The major components of fly ash are silicon dioxide (SiO_2) and aluminium trioxide (Al_2O_3), which are the essential reagents in the synthesis of zeolites. Due to the high specific surface area of fly ash, it is suitable starting material for the synthesis of zeolites. All the methodologies developed for the synthesis of zeolites from fly ash are based on the dissolution Al-Si-bearing fly ash phases with alkaline solutions (predominantly NaOH or KOH solutions) and the subsequent precipitation of zeolitic material [52-53]. Ojha et al. [54], reported that the best quality Na–X zeolite, in terms of surface area and crystallinity, was obtained at the following conditions: NaOH/fly ash ratio, 1:3; fusion temperature, 823 K; aging time, 24 h and 6 h of hydrothermal treatment. Fly ash zeolites could be cost-effective sorbents for controlling SO_2 emissions from industrial sources. Zhang et al. [55], reported that the synthesized zeolite is a promising material for removing ammonium ion from wastewater. Janos et al. [56], was investigated that both basic as well as acidic dyes can be sorbed onto the fly ash and the dye sorption decreased in the presence of organic solvents (methanol, acetone). They can also be used for removal of radioactive wastes [57].

The easy availability of fly ash makes it a good choice in the investigation of an economic way of COD removal. Previous investigations [58-61] showed that an activated carbon component played an important role in adsorption capacity and has been tested as an adsorbent for the treatment of wastewater. Carbon fraction of fly ash was also found to be a significant parameter for removal of NOx from flue gases [62-63] and for some heavy metals [64] also. Zeolites derived from Indian fly ash were used for the removal of Cu^{2+}, Co^{2+}, Ni^{2+} and Cd^{2+} from aqueous solutions [65-66]. It was observed that the metal uptake increased with the increasing concentration, pH and temperature. Coal combustion ash was used for Cadmium removal in aqueous solutions and observed a monolayer adsorption with an uptake of 67 mg/g [67]. Study showed good percentage removal of five metallic ions (Cu^{2+}, Ni^{2+}, Zn^{2+}, Cd^{2+}, Pb^{2+}) by fly ash/ lime mixing [68]. Experiment revealed that fly ash can be used as an adsorbent in both gaseous and aqueous applications [69]. Eleven different adsorbents were compared for the removal of heavy metals out of which one was fly ash. The data revealed that fly ash has significantly higher affinity towards heavy metals mainly present as cationic or non charged species compared to those present as anionic species [70]. The material can be utilized for Cr (VI) removal from wastewater even in the presence of other metal ions and surfactants [71, 72]. Peloso et al. [73], investigated the adsorption of toluene vapours on fly ash. They found satisfactory result when the product of fly ash, obtained after particle aggregation and thermal activation, adsorbed toluene vapours [74]. The adsorption of o-xylene on fly ash was investigated by Banerjee et al. [75]. Adsorption rate of o-xylene increases significantly with increased initial concentration, and gradually approaches a plateau. Between the rate of adsorption and inverse of the square of particle diameter, a significant correlation was found. It is reported by Jain et al. [76] that adsorption of oxalic acid from aqueous solution by fly ash has two linear components each follows Langmuir isotherm. Fly ash was also used as adsorbent for the removal of alcohols, aldehydes, ketones and aromatics [77]. Some organic pollutants, such as phenolic compounds, pesticides, and dyes, etc., can be removed very effectively using fly ash as adsorbent [78-81]. Another experiment revealed that [82] removal of malachite green from aqueous solutions could be possible by using fly ash. It was observed that maximum removal was obtained at pH 8.0. The adsorption of Congo red from solution was carried out using calcium-rich fly ash with different contact times, concentrations, temperatures, and pH [83]. Kara et al. [84], examined the adsorption of reactive dyes (Remazol Red, Remazol Blue and Rifa-cion Yellow) from aqueous solutions using fly ash as an adsorbent. They described the dye adsorption on fly ash by using pseudo-first order and pseudo-second order kinetics.

3.7. Fly Ash in Paints and Enamels

White cement is commonly used as a base material for the preparation of distemper. Fly ash is utilised to replace white cement for the preparation of distemper. The distemper manufactured from fly ash has been utilised in many buildings and the performance is satisfactory. Paints based on fly ash have better resistance to abrasion and corrosion. It has no adverse effect on film properties, such as drying time, thickness, brushability and gloss [85]. It exhibits better extending properties (less oil absorption). In paints fly ash percentage is about 30-40 % (in paints) and in enamel the percentage is 18- 22%.

3.8. Fly Ash as Wood Substitute Composites

The main objective for using fly ash as wood substitute composites (i.e. fly ash polymer composites) is that by using alternative to timber products deforestation can be reduced which is very much required to save our environment. Development of fly ash based composites needs fly ash as filler and jute cloth as reinforcement. This technology can be applied in many applications like door shutters, partition panels, wall panelling, ceiling, etc. Such types of doors have some useful properties, such as these are resistant to weather, termite, fungus and fire. Regional Research Laboratory, Bhopal in collaboration with Building Materials & Technology Promotion Council (BMTPC) and TIFAC has been working on this technology. Near Chennai, one commercial plant has also been set up based on this technology [86].

3.9. *Floor Tiles and Wall Tiles*

Fly ash is also used to manufacture floor tiles and wall tiles with fly ash content not exceeding 50%. Fly ash based blocks/tiles are as good as clay based conventional building products. These types of tiles can also be used in the exterior part of the building to give a longer life, even in coastal areas. This technology has been developed by Central Power Research Institute, Bangalore.

Conclusion

The disposal of fly ash from coal-fired power stations causes significant economic and environmental problems. Although, fly ash causes environmental pollution, it is an important raw material for various applications. Poor understanding of the chemistry of fly ash and its derivatives for proper end applications, poor public awareness about the products, lack of proper coordination between thermal plants and ash users etc. are the cause of low level utilization of fly ash. But now-a-days the utilization of fly ash has been increasing. Central Electricity Authority, New Delhi in the year 2015-16 published a report which stated that the highest level of fly ash utilization of about 60.97% was achieved in the year 2015-16. The utilization of fly ash in different field such as: in construction, agricultural field, mine back filling, organic dye and heavy metals removal is reviewed here which clearly shows that a waste material can be used as a potential resource material in various fields.

References

1. Updated on : 19/07/2016, ENVIS Centre on Flyash, http://cbrienvis.nic.in/Database/flyashgeneration.html.
2. Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2015-16, Central Electricity Authority, New Delhi, October, 2016, http://www.cea.nic.in/reports/others/thermal/tcd/flyash_final_1516.pdf
3. Department of Forests, Ecology and Environment, Government of Karnataka. *Parisara Envis News Letter* 2 (2007) 6.
4. N.S. Pandian, S. Balasubramonian, *J. Testing Eval.* 28 (2000) 44.
5. ASTM C618 – 08a. *Annual Book of ASTM Standards, Concrete and Aggre.* American Society for Testing Materials, (*2005)* 04.02.
6. A. Dwivedi, M.K. Jain, *Recent Res. Sci. Tech.* 6 (2014) 30.
7. A.L. Page, A.A. Elseewi, I.R. Straughan, *Residue Rev.* 71 (1979) 83.
8. C.S. Poon, L. Lam, Y.L. Wong, *J. Mater. Civil Eng.* 11 (1999) 197.

9. M. Ahmaruzzaman, *Prog. Ener. Combustion Sci.* 36 (2010) 327.
10. D.V. Singh, *Ash Ponds and Ash Disposal Systems*, Narosa Publishing House, New Delhi, (1996) 374.
11. B.V.S. Viswanadham, *Proceeding of International Ash Symposium, Kentucky, USA, 18-20, October (1999).*
12. M. Ghodrati, J.T. Sims, B.L. Vasilas, *J. Water Soil Air Pollut.* 81 (1995) 349.
13. R.K. Khan, M.W. Khan, *Environ. Pollut*. 92 (1996) 105.
14. D. Goyal, K. Kaur, R. Garg, V. Vijayan, S.K. Nanda, A. Nioding, S. Khanna, V. Ramamurthy, *Industrial fly ash as a soil amendment agent for raising forestry plantations*. In: Taylor, P.R.(Ed.), 2002 EPD *Congress and Fundamental of Advanced Materials for Energy Conversio*n. TMS Publication, Warrendale, PA, pp. 251–260 (2002a).
15. P. Kishor, A.K. Ghosh, D. Kumar, *Asian J. Agric. Res*. 4 (2010) 1.
16. V. Kumar, G.K. Jha, *International Workshop on Agricultural Coal Ash Uses,* WACAU, Israel, 27-29 May, (2014).
17. J.P. Capp, *Reclamation of Drastically Disturbed Lands, Schaller*, F. W. and P. Sutton (Eds.). Madison, W. I., ASA. (1978) 339.
18. D.R. Kene, S.A. Lanjewar, B.M. Ingole, *J. Soils Crops* 1 (1991) 11.
19. H.T. Phung, H.V. Lam, H.V. Lund, A.L. Page, *Water, Air Soil Pollut.* 12 (1979) 247.
20. T. Matasi, V.Z. Keramidas, *Environ. Pollut*. 104 (1999) 107.
21. A.C. Chang, L.J. Lund, A.L. Page, J.E. Warneke, *J. Environ. Qual*. 6 (1977) 267.
22. C.O. Plank, D.C. Martens, *Soil Sci. Soc. Am. Proc*. 38 (1974) 974.
23. R. Sikka, B.D. Kansal, *Bioresour. Technol*. 50 (1994) 269.
24. L.H. Weinstein, J.F. Osmeloski, M. Rutzke, A.O. Beers, J.B. McCahan, C.A. Bache, D.J. Lisk, *J. Food Safety* 9 (1989) 291.
25. A.K. Furr, T.F. Parkinson, R.A. Hinrichs, D.R. Van Campen, C.A. Bache, *Environ. Sci. Technol*. 11 (1977) 1194.
26. L.C. Mishra, K.N. Shukla, *Environ. Pollut.* 42 (1986) 1.
27. M.P. Sharma, U. Tanu, A. Adholeya, *Proceedings of the 7th International Symposium on Soil and Plant* Analysis, Edmonton, AB, Canada, July 21-27, 43 (2001).
28. V. Kumar, G. Singh, R. Rai, *Fly ash utilization programme (FAUP), TIFAC, New Delhi-110016, XII 2.1* (2005).
29. B.N. Mittra, S. Karmakar, D.K. Swaine, B.C. Ghosh, *Proceeding of International ash utilization symposium Center for Applied Energy Research. University of Kentucky, Paper* # 28 (2003).
30. D.C. Adriano, A.L. Page, A.A. Elseewi, A.C. Chang, I. Straughan, *J. Environ. Qual.* 9 (1980) 333.
31. A.K. Gupta, S. Sinha, *Environ. Geochem. Health* 31 (2009) 463.
32. N.K. Mahale, D.P. Sachin, B.S. Dhananjay, B.A. Sanjay, *Pol. J. Environ. Stud.* 21(2012)1713.
33. M. Mishra, R.K. Sahu, R.N. Padhy, *Ecotoxicology* 16 (2007) 271.
34. S. Karmakar, B.N. Mittra, B.C. Ghosh, *Coal combustion and gasification product* 2 (2010) 45.
35. "Utilisation of Fly Ash in Agriculture at Neyveli Lignite Corporation, Neyveli," CFRI, Dhanbad, Jharkhand. CFRI Report No. TR/CFRI/3.01/2000–2001, 2001b.
36. "Demonstration trials in Farmer's Field for the Popularization of Bulk Use of Fly-ash from Anpara, Obra and Hardugang TPPs of UPRVUNL in Agriculture and for Reclamation of Degraded/Wasteland," CFRI, Dhanbad, Jharkhand. CFRI TR/CFRI/1.08/2002–2003, 2003a.
37. "Bio-restoration of O.B. Dumps Through the Plantation of Selected Efficient Photosynthetic/Soil Conserver Species in Eastern Jharia Coalfields (Sponsored by SSRC, Dept. of Coal)," CFRI, Dhanbad, Jharkhand. CFRI Report No.TR/CFRI/1.01/2002–2003, 2003b.
38. L.C. Ram, N.K. Srivastava, S.K. Jha, A.K. Sinha, *Proceedings of the 23rd Annual International Pittsburgh Coal Conf.,* 52 (2006b) 1.
39. L.C. Ram, N.K. Srivastava, R.C. Tripathi, S.K. Jha, A.K. Sinha, G. Singh, V. Manoharan, *J. Environ. Management* 79 (2006a) 173.
40. D.C. Adriano, T.A. Woodford, T.G. Ciravolo, *J. Environ. Qual.* 7 (1978) 416.
41. C.L. Carlson, D.C. Adriano, *J. Environ. Qual.* 22 (1993) 227.
42. K. Dominika, T. Kazimierz, *TEKA Kom. Mot. Energ. Roln. – OL PAN* 11 (2011)373.
43. D.F.S. Natusch, J.R. Wallace, *Science* 186 (1974) 695.
44. W. Wang, Y. Qin, D. Song, K. Wang, *Int. J. Coal Geol.* 75 (2008) 81.
45. Q. Li, J. Chen, Y. Li, *J. Environ. Sci. Health* Part B 43 (2008) 179.
46. M. Eisenbud, H.C. Petrow, *Science* 144 (1964) 288.
47. J. Tadmore., *J. Environ. Radioact.* 4 (1986) 177.
48. R.C. Tripathi, S.K. Jha, L.C. Ram, V. Vijayan, *Radiation Protection Dosimetry* 156 (2013) 198.

49. D. Goyal, K. Kaur, R. Garg, V. Vijayan, S.K. Nanda, A. Nioding, S. Khanna, V. Ramamurthy, *Industrial fly ash as a soil amendment agent for raising forestry plantations*. In: Taylor P.R. (Ed.), 2002. EPD *Congress and Fundamental of Advanced Materials for Energy Conversion*, TMS Publication, Warrendale, PA, (2002) 251.
50. B.N. Mittra, S. Karmakar, D.K. Swain, B.C. Ghosh, *Fuel* 84 (2005) 1447.
51. H. Hòller, U. Wirsching, *Fortschr. Mineral* 63 (1985) 21.
52. X. Querol, N. Moreno, J.C. Umana, A. Alastuey, E. Hernadez, A. Lopez-Soler, A. Plana, *Inter. J. Coal Geology* 50 (2002) 413.
53. N. Moreno, X. Querol, C. Ayora, C.F. Pereira, M.J. Jurkovicová, *J. Environ. Sc. and Technology*, 35 (2001) 3526.
54. K. Ojha, N.C. Pradhan, A.N. Samanta, *Bullet. Mater. Sci.* 27 (2004) 555.
55. M. Zhang, H. Zhang, D. Xu, L. Han, D. Niu, B. Tian, J. Zhang, L. Zhang, W. Wu, *Desalination* 271 (2011) 111.
56. P. Janos, H. Buchtov, M.R. Rýznarová, *Water Res.* 37 (2003) 4938.
57. L. Remenárová, M. Pipíška, E. Florková, J. Augustín, M. Rozložník, S. Hostin, M. Horník, *Nova Biotechnologica et Chimica* 13 (2014) 57.
58. Y.C. Sharma, Uma, A.S.K. Sinha, S.N. Upadhyay, *J. Chem. Eng. Data* 55 (2010) 2662.
59. Uma, S. Banerjee, Y.C. Sharma, *J. Indust. Eng. Chem*. 19 (2013) 1099.
60. P. Singh, *Int. J. Civil Eng. Technol*. 7 (2016) 67.
61.K.M. Doke, A. Chavan, R. Nalawade, E.M. Khan, *J. Mater. Environ. Sci.* 4 (2013) 374.
62. B. Rubio, M.T. Izquierdo, *Environmental Research, Engineering and Management* 63 (2013) 5.
63. B. Rubio, M.T. Izquierdo, M.C. Mayoral, M.T. Bona, J.M. Andres, *J. Hazard. Mater*. 143 (2007) 561.
64. M.M. Maroto-valer, Y. Zhang, E.J. Granite, Z. Tang, H.W. Pennline *Fuel* 84 (2005) 911.
65. T. Mishra, S.K. Tiwari, *J. Hazardous Mater.* B137 (2006) 299.
66. G. Das, N. C. Pradhan, G. M. Madhu, H. S. Preetham, *J. Mater. Environ. Sci.* 4 (2013) 410.
67. F. Montagnaro, L. Santoro, *J. Chemical Eng.* 150 (2009) 174.
68. P. Ricou-Hoeffer, I. Lecuyer, P.L. Cloire, *Water Res*. 35 (2001) 965.
69. R.S. Blissett, N.A. Rowson, *Fuel* 97 (2012) 1.
70. H.G. Fuhrman, P.S. Mikkkelsen, A. Ledin, *J. Water Res.* 41 (2007) 591.
71. Y.C. Sharma, Uma, S.N. Upadhyay, C.H. Weng, *Colloids and Surfaces A: Physicochemical and Engineering Aspects* , 317 (2008) 222.
72. V.K. Gupta, M. Sharma, K.T. Park, *The Environmentalist* 19 (1999) 129.
73. A. Peloso, M. Rovatti, G. Ferraiolo, *Resour. Conserv. Recycl*. 10 (1983) 211.
74. M. Rovatti, A. Peloso, G. Ferraiolo, *Resour. Conserv. Recycl*. 1 (1988) 137.
75. K. Banerjee, P.N. Cheremisinoff, S.L. Cheng, *Water Res.* 31 (1997) 249.
76. K.K. Jain, G. Prasad, V.N. Sinah, *Indian J. Chem.* 19A (1980) 154.
77. K. Baneriee, P.Y. Horng, P.N. Cheremisinoff, M.S. Sheih, S.L. Cheng, *Proceedings of 43rd industrial waste conference.* West Lafayette: Purdue University (1988) 397.
78. S.T. Towle, J.R. Barger, G.E. Brown, G.A. Parks, *J. Colloid Inter. Sci.* 187 (1997) 62.
79. S.K. Khanna, P. Malhotra, *Indian J. Environmental Health* 19 (1977) 224.
80. V.K. Gupta, I. Ali, *Water Res.* 35 (2001) 33. 81.
81. Y. Benjelloun, A. Lahrichi, S. Boumchita, M. Idrissi, Y. Miyah, Kh. Anis, V. Nenov, F. Zerrouq, *J. Mater. Environ. Sci.* 8 (2017) 2259.
82. S. Dubey, Uma, L. Sujarittanonta, Y.C. Sharma, *Desalination and Water Treatment* 53 (2015) 91.
83. B. Acemioglu, *J. Colloid Inter. Sci.* 274 (2004) 371.
84. S. Kara, C. Aydiner, E. Demirbas, M. Kobya, N. Dizge, *Desalination* 212 (2007) 282.
85. Fly ash based technologies developed by CSIR-AMPRI Bhopal, Asokan Pappu, Senior Principal Scientist, CSIR-AMPRI, Advanced Materials and Processes Research Institute, Bhopal.
86. M. Saxena, J. Prabhakar, *2nd International conference on Fly Ash Disposal & Utilization*, New Delhi, India, February (2000).

(2018) ; http://www.jmaterenvironsci.com