Strategic Plan for Ash Disposal in Abandoned Mines filled with Acid Mine Drainage

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Abstract - The present paper aims for the preparation of the fast lane assessment plan for exploring the possibility of ash disposal in abandoned mines filled with Acid Mine Drainage (AMD). The quantum of coal ash generation in India has been reviewed *vis-à-vis* India's total power generation installed capacity and coal based installed capacity as on today. This paper also mentions the various Notifications on Fly Ash Utilization issued byMinistry of Environment, Forest and Climate Change, Government of India (MoEF&CC) from time to time. An emphasis has been made on the fact that many times there is a problem created by Acid Mine Drainage (AMD), but there are no regulatory guidelines available to address such issues. This paper covers the steps on how to address the issue of AMD problem when coal ash is to be used to fill the abandoned coal mine.

Key words: Coal ash, Coal mine, Fly ash, Bottom Ash, Pond Ash, mine filling, ash haul back, mine back fill, mine reclamation, guidelines, ash placement, AMD, Fly ash Utilization, Fly Ash Notification

I. INTRODUCTION

Availability of needed Electricity is the mail support for the development of any country. Today, India's installed power generation capacity is touching 3,67,281 MW [1] and out of this coal based installed capacity is 1,98,495 MW [1], which is about 54.2% of total installed capacity [1]. This leads to the generation of coal ash comprising mainly of Fly ash and partly of Bottom ash. As per the annual data updated by the Central Electricity Authority (CEA) till 2017-18 [2], the utilization of coal ash has increased from 6.64 million tonne as was in 1996-97 to a level of 131.87 million-tonne in 2017-18. This is only the 67% utilization of ash generated i.e. 196.44 million tonne in 2017-18 [2]. The MoEF&CC (Ministry of Environment, Forest and Climate Change, Government of India) is aiming for the 100% utilization of coal ash produced from thermal power stations. This shortfall utilization level of 67% is behind the target mandated by MoEF&CC *vide* it's notification dated November 03, 2009 [3]. Further, as per CEA report [4] 93.26 million tonne of coal ash was generated in the first half of the year 2018-19 and it is estimated that 186.52 million tonne of coal ash was produced in the year 2018-19 [4]. Thus, it was felt that there should be proper guidelines for the safe disposal of coal ash produced from thermal power stations, when the coal ash is being used to fill the mine and where huge quantity of AMD (Acid Mine Drainage) is already present.

II. FLY ASH UTILIZATION NOTIFICATIONS ISSUED BY THE MOEF&CC

This huge amount of ash generated is nuisance to handle and it's disposal is threat to the environment. Thinking on these lines Government of India is consistently making efforts for its gainful utilization and with this objective the MoEF&CC issued the Fly ash Notifications from time to time. The best avenue for ash utilization appears to be mine reclamation. The Ministry of Environment & Forest & Climate Change, Government of India had issued Notification No. S.O. 763(E), Dated September 13, 1999 [3] & the same is amended on August 27. 2003 regarding the utilization of fly ash/ Bottom ash generated from Coal/Lignite based thermal power plant, to protect the environment, conserve top soil & prevent the dumping & disposal of fly ash discharged from coal or lignite based thermal power plants. Thus the said modified Notifications issued from time to time for coal ash utilization are mentioned below for the quick reference.

It is a matter of concern so MoEF&CC and other related government departments are addressing the bottlenecks/difficulties to achieve the target of 100% Fly Ash Utilization. In this regard recently, MoEF&CC has issued an amendment dated 25th January, 2016 to existing notification for the purpose of increasing fly ash utilization and for revising, the target date of 100% ash utilization to 31st December, 2017 [6,7].

III. FLY ASH UTILIZATION NORMS BEING MADE MORE STRINGENT

Thus Ministry of Environment, Forest and Climate Change (MoEF&CC) has revised and made the norms more stringent for fly ash usage and disposal by granting permission to use it for agriculture. The ministry has also made it mandatory for power plants to give fly ash free of cost to users located within 300-kilometre-radius [7]. Every construction agency engaged in making of roads within a radius of 300 kilometer [7] from a coal or lignite based thermal power plant would be bound to use fly ash in accordance with the guidelines or specifications issued by the Indian Road Congress [7].

A large number of technologies have been developed for gainful utilization and safe disposal and management of fly ash under the concerted efforts made by National Council for Cement & Building Materials (NCB), NTPC Ltd. (National Thermal Power Corporation Limited), DST (Department of Science and Technology, Ministry of Science and Technology, Government of India), CSIR (Council of Scientific & Industrial Research, Government of India) laboratories and many other entities including private entities since the year 1983 [8-11]. As a result, Fly ash earlier was considered to be "hazardous industrial waste" material, has now acquired the status of useful and sellable commodity.

IV. CHALLENGE PROVIDED BY AMD (ACID MINE DRAINAGE) AND REMEDIATION THEREOF

In India, so far not many efforts have been made to use thermal power coal ash as backfill material in underground/ open cast mines which are filled with AMD (Acid Mine Drainage) and to predict its subsequent effect on ground water quality. One of the main problems in disposing of large quantities of coal ash is the possible leaching of different elements which are toxic, and generally speaking are Chromium (6+), Arsenic (As), Nickel (Ni), Cadmium (Cd), Lead (Pb), Antimony (Sb), Manganese (Mn), Boron (B) and many such other elements. In general these are normally found.

Although, Government of India-DGMS (Directorate General of Mine Safety) [12], CMPDI (Central Mine Planning and Development Institute Limited) etc. had issued the Guidelines for Mine Closer Plan 2013 and Coal Mine Regulations 2011-Mine Reclamation Plan, but without mentioning fly ash. MoEF&CC *vide* it's Office memorandum F. No. 22-13/2019-IA-III dated 28th August 2019 issued the Guidelines for disposal/utilization of Fly Ash for reclamation of low lying areas and for stowing of Abandoned mines/Quarries [13]. Although a lot of work has been done, but scientific aspects and requirements *vis-à-vis* AMD of such reclamation of mines with fly ash have not been worked out so far, for the mines which are filled with Acid Mine Drainage (AMD) or are likely to be created in future after completion of the de-coaling of working mines with Indian context. An extensive survey has been made where coal ash has been used in back filling the mines, development of demonstration projects to promote large volume coal ash utilization etc. [14-25].

V. METHODOLOGY ADOPTED BY EXPERTS

Example of the work National Mine Land Reclamation Centre, Morgantown, West Virginia, USA and other experts work are reviewed, which have been executed in USA under more severe conditions than Indian conditions. The problems of toxicity and occurrence of Arsenic (As) have drawn much attention in Indian scenario. The issue of release of Arsenic (As) from coal ash has risen from several thermal power plants and created air, soil and water pollution. The heavy metal Arsenic (As) exists in the −3, 0, +3 and +5 oxidation states (Smedley et al., 2001) [22]. As a result Arsenic (As) forms different types of compounds and impacts health differently in different cases. The burning of coal and smelting of metals are major sources of Arsenic (As) in the air. The most sensitive ecological indicator of environmental pollution of arsenic, via air, was a mass eradication of honeybee families, first described as "Tisin's disease" by Svoboda in 1936 [23], which occurred in the vicinity of agglomeration furnace facilities. Similar situations also have found in the vicinity of different smelters and power plants that burn coal with a high Arsenic (As) content (Bencko, 1987) [24]. The World Bank Group has also issued Pollution Prevention and Abatement Handbook on Arsenic Effective July 1998 [25]. This may emphasize environmental problem by Arsenic (As) leaching in to soils and groundwater and re-entry of Arsenic (As) in to atmosphere from fly ashes dumped near the plant area. This fact is referred here because there is lot of problem due to presence of Arsenic (As) in the eastern part of India say the areas of adjoining borders of states of Orissa, West Bengal and Chhattisgarh. A lot of information available on the environmental problems related to Coal ash in public domain.

VI. THE OBJECTIVE

The objective of this paper is to give confidence to the authorities and regulatory bodies that thermal power coal ash could be safely and environment friendly be placed in the de-coaled mines and 100% ash could be utilized. This way the requirements of the notification of government of India for 100% ash utilization could be met successfully.

This Paper also intends to chalk out the need for taking up the necessary experimental study for suitable locations in India, where there is possibility of AMD presence such as Gorbi Mine area in "Singrauli" region and North East part of India in particular etc. There is also a great problem of disposal of ash in the regions of "Singrauli", "Korba", "Angul" etc. In "Singrauli" region there is threat of damage of a huge water body the lake known as "Rihand Reservoir" and there are also major coal based power stations like (i) NTPC Singrauli, (ii) NTPC Rihand, (iii) NTPC Vindhyachal, (iv) Anpara, U.P. (v) Obra, U.P. (vi) Reliance-Sasan, (vi) Essar-Sasan, (vii) Hindalco-Bargawan, (viii) Chitrangi. For understanding purpose the Chitrangi thermal power station could be discussed here. This power station is having about 25,322 MW installed capacity [2] and would be producing about 1,85,695 tonne of coal ash every day as based on the data of NTPC Talcher power station which is having 3000 MW installed capacity and is producing at least 22,000 tonne [2] of coal ash every day when power stations run at normal PLF (Plant Load Factor) [2].

This huge amount of coal ash produced is big nuisance and threat to the environment as there is a limited scope of ash utilization because Singrauli region which is in a remote location.

It is very necessary to make an attempt to study the scope of ash filling in coal mines in this remotely located region. The Gorbi mine in located in this region and has Acid Mine Drainage (AMD) problem.

VII. STUDY REQUIRED ON INTERACTION OF COAL ASH WITH ACID MINE DRAINAGE

Coal ash and Mine water interaction study with the aim to provide a representative data regime to arrive at the common line of action is essential, which would serve as a basic document for the formulation of guidelines for use of ash in mine back filling or reclamation purpose especially for the mines having AMD problem. It is necessary to take up the study through the following activities for respective materials:

i. Fly Ash:
    a. Chemical Characterization : SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3,Na_2O, P_2O_5, K_2O, V_2O_5, and Organic carbon
    b. Physical Characterization: pH, Conductivity, Bulk Density, Specific Gravity, Porosity, Fineness, and Un-burned Carbon
    c. Mineralogical Characterization and Toxic, Trace and Heavy elements like Se, As, Co, Cu, V, Cr^{6+}, Pb, Mn, Hg, Ba, Ni, Zn, Cd, B, Fe

ii. Bottom ash:
    a. Chemical Characterization : SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3, Na_2O, P_2O_5, K_2O, V_2O_5, and Organic carbon,
    b. Physical Characterization: pH, Conductivity, Bulk Density, Specific Gravity, Porosity, Fineness, and Un-burned Carbon,
    c. Mineralogical Characterization and Toxic, Trace and Heavy elements like Se, As, Co, Cu, V, Cr^{6+}, Pb, Mn, Hg, Ba, Ni, Zn, Cd, B, Fe

iii. Pond ash:
    a. Chemical Characterization : SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3, Na_2O, P_2O_5, K_2O, V_2O_5, and Organic carbon,

b. Physical Characterization: pH, Conductivity, Bulk Density, Specific Gravity, Porosity, Fineness, Un-burned Carbon,
c. Mineralogical Characterization and Toxic, Trace and Heavy elements like Se, As, Co, Cu, V, Cr6+, Pb, Mn, Hg, Ba, Ni, Zn, Cd, B, Fe

iv. Acid Mine Drainage (AMD)/ Mine Water:
a. Se, As, Co, Cu, V, Cr6+, Pb, Mn, Hg, Ba, Ni, Zn, Cd, B, Fe, Th, U,
b. pH, Conductivity, SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3,Na_2O, P_2O_5, K_2O, V_2O_5 and Organic carbon,
c. Specific Gravity,
d. Acid Mine Drainage (AMD)/ Mine Water quality criteria for different uses (specified by CPCB, 1979 and the Bureau of Indian Standards, 1982) as per the Indian Standard for Industrial effluents

v. Soil in the mine area:
a. Chemical Characterization : SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3,Na_2O, P_2O_5, K_2O, V_2O_5,
b. Physical Characterization: pH, Conductivity, Bulk Density, Specific Gravity, Porosity, Fineness, Un-burned Carbon,
c. Mineralogical Characterization and Toxic, Trace and Heavy elements like Se, As, Co, Cu, V, Cr^{6+}, Pb, Mn, Hg, Ba, Ni, Zn, Cd, B, Fe

vi. Ground water as per Indian Standard: Surface water quality criteria for different uses (specified by CPCB, 1979 and the Bureau of Indian Standards, 1982)

vii. Surface water as per Indian Standard: Surface water quality criteria for different uses (specified by CPCB, 1979 and the Bureau of Indian Standards, 1982)

viii. Quick Lime:
a. Chemical Characterization : SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3,Na_2O, P_2O_5, K_2O, V_2O_5, Mostly for Lime Purity, and
b. Bulk Density

ix. Hydrated lime and Any other alkaline material available:
a. Chemical Characterization : SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, SO_3,Na_2O, P_2O_5, K_2O, V_2O_5, Mostly for Lime Purity
b. Bulk Density,
c. Kinetic studies of interaction of reaction of Hydrated Lime with Acid Mine Drainage (AMD)/ Mine Water

x. Leaching characteristics by TCLP/ SPLP procedure with AMD/ Mine water for

a. Fly ash
b. Bottom ash

c. Pond ash

xi. Broadly TCLP (Toxicity Characteristic Leachate Procedure) [17] is deployed to find out the organic and inorganic ions mobility present in liquid, solid, and multiphasic wastes present and in this case the is AMD.

xii. Synthetic Precipitation Leaching Procedure (SPLP) [18] is to be conducted as per EPA norm SW-846 Test Method 1312:

Quote

"Method 1312 is designed to determine the mobility of both organic and inorganic analytes present in liquids, soils, and wastes."

UnQuote

The technique of SPLP (Synthetic Precipitation Leaching Procedure), is useful when we have to test for certain materials on the exterior of surfaces, which are exposed to rainfall.

VIII. DISCUSSIONS

It would be prudent if some basic are discussed here as described by Charles A. Cravotta III and Carl S. Kirby [18]. Acid Mine Drainage (AMD) is well characterized by high concentrations of dissolved sulfate (SO_4^{2-}), ferrous iron (Fe^{2+}), and ferric iron (Fe^{3+}) and colloidal or particulates Fe III compounds that are produced by the microbial oxidation of reduced forms of sulfur and iron in pyrite (FeS_2):

$$FeS_2 + 3.5\ O_2 + H_2O \longrightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+ \ldots\ldots\ldots\ldots\ldots..(1)$$

$$Fe^{2+} + 0.25\ O_2 + 2.5\ H_2O \longrightarrow Fe(OH)_3\ (s) + 2\ H^+ \ldots\ldots\ldots\ldots\ldots..(2)$$

The total stoichiometric oxidation of pyrite by oxygen (O_2) is shown by combining Equations 1 and 2. Half the protons (H^+), or acid, produced by the complete oxidation of pyrite results from the oxidation of pyritic sulfur to SO_4^{2-} (Eqn. 1) and the other half results from the oxidation of Fe(II) to Fe (III) and its consequent precipitation as $Fe(OH)_3$ (Eqn. 2). It could be discussed here more, but at the moment it is not required here. Acid Mine Drainage (AMD) is a dangerous pollutant of surface water. The main cause of AMD is the Pyrites (FeS and Fe_2S_3) encapsulated in coal seams and when it comes in contact with atmospheric oxygen, water and bacteria then it forms solutions of net acidity. This situation happens in abandoned and active coal mines in the mining process. AMD degrades surrounding landscapes and many a times is responsible for loss of life of animals and aquatic life.AMD also restricts water stream use for public consumption of water and industrial water supplies. Even it cannot be used for recreation purpose. After carrying out the investigations on the fly ash, bottom ash, pond ash, soil, lime/quick lime, the assessment has to be made for the pH, and acidity of the AMD accumulated in the mine pits. It would be prudent to understand at this moment the concept of Acidity of the AMD in coal mining parlance and is explained below [26].

Charles A. Cravotta III and Carl S. Kirby [26] demonstrated that the hot acidity is related to the pH, alkalinity, and dissolved concentrations of Fe, Mn, and Al in fresh mine drainage. They have shown that the hot acidity accurately indicates the potential for pH to decrease to acidic values after complete oxidation of Fe and Mn, and it indicates the excess alkalinity or that required for neutralization of the sample.

Computation of Acidity and Net alkalinity is very well explained by Charles A. Cravotta III and Carl S. Kirby [26]. The acidity due to metals was computed from pH and dissolved metals concentrations in milligrams per litre based on certain calculations the quantity of neutralising material such as lime/ quick lime is estimated and mixed with engineering tools in the mine filled with AMD. This is one of the water-quality measure which is useful as a very good estimate of the severity of acid mine drainage. After treatment of mine water with lime and making sure that whole of the AMD has been neutralized, then water is pumped out and discharged to the natural streams to merge with the surroundings. Many a times if the mine is near by an Acetylene production plant, where Calcium Carbide is used as a raw material, the lime sludge discharged by the acetylene plant could be used as a neutralizing material for the AMD. This water can be reused for mining purpose also and this way it would help coal mine industry to conserve its water consumption. This water could also be sent to ponds for creating Fisheries for the local people to start small business there. Alternatively this work could also be a part of CSR activity of the Coal Companies.

IX. CONCLUSION

This paper has discussed the use of thermal power station coal ash for filling in abandoned coal mines. Further, it emphasises the need of knowing that what parameters are to be tested for the materials and what studies are to be conducted to be used for filing ash in the abandoned coal mines that are duly filled with Acid Mine Drainage (AMD) to avoid the environmental threat imposed by coal ash filling in mines filled with AMD. This paper also covered the understanding of the interaction of thermal power plant coal ash with Acid Mine Drainage (AMD). An emphasis has been made for the requirement for strong planning of the methodology for neutralizing the AMD before discharging into the natural water streams, wet or dry. In the absence of experience available in India with such mine filled with AMD the ash could not be filled in such mines. It has also been stressed in this paper that the guidelines prepared by the regulatory authority need to include the planning and actions for protecting the environment “in and out” of the mines which are filled with Acid Mine Drainage (AMD), which were not covered in the guidelines for filling in mines recently issued by MoEF&CC and CPCB. In this paper a reference has been made for the mine filled with AMD, as such there exists a mine in central India, namely the Gorbi mine which is located in the remotely located Singrauli region. Certainly, other mines could be encountered elsewhere having high sulphur and/or pyrites in coal located in the North Eastern part of India, and these are to be dealt with such strategy.

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