EVALUATION OF ENVIRONMENTAL IMPACT ON GROUND WATER QUALITY IN AND AROUND ASH POND AND MITIGATION MEASURES

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ABSTRACT
This research paper discusses the impacts of the coal combustion in thermal power plant, emphasized the problems associated with fly ash, collection using Electro Static Precipitator, mitigation measures for fly ash has also been highlighted such as development of bricks, use of fly ash for manufacturing of cement, development of ceramics, fertilizer, development of distemper and use of fly ash in road construction and road embankment. This article gives the direction for the beneficial use of fly ash generated during coal combustion in power plants The dumping of fly ash leads to ground water pollution which releases heavy metals in the nearby water supplies and leads directly to a number of severe chronic illnesses. In North Chennai Thermal Power station , the fly ash generated is mixed with sea water in the ratio of 1:12.5 and discharged in the form of slurry into a fly ash pond and is having an area of 400 hectares with a storage capacity of 24 Mm3. The present study will be taken for investigating the impact of Fly ash slurry on ground water quality as well as the basic properties and engineering behavior of soil.
Keywords: Coal, fly ash, thermal power plant, combustion.

INTRODUCTION

1. POWER PLANTS AND ENVIRONMENTAL CONSIDERATIONS

There are a significant numbers of thermal power plants around the world and new plants are put into operation almost weekly. This rapid industrialization has resulted in an increased use of natural resources such as coal in case of fossil fuel burning power plants.

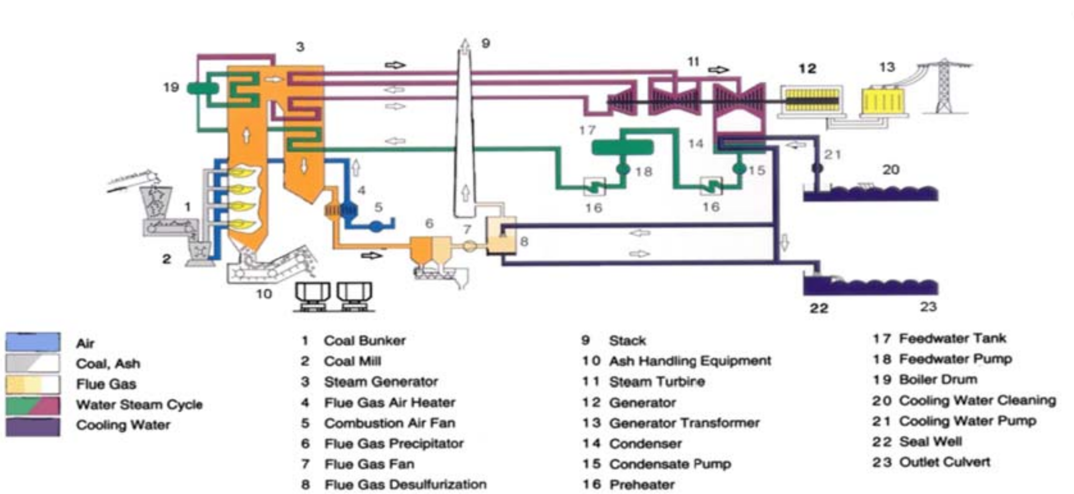

Fig.1. Thermal Station Flow Process Diagram

All these power plants brought along serious environmental imbalance due to the dumping of industrial wastes. The main impact factors over the environment of the thermal power plants that operate on fossil fuels are as follows: air emissions, greenhouse gas emissions and use of natural resources, water supply and wastewater, storage of solid waste, noise, location. The environmental impacts should be understood also from the local population point of view. Pollutants emissions in air, soil and water have serious consequences over human health. Depending on the location of the coal mine that is supplied as fuel for the power plant .Beside the coal source there are other important factors that influence its properties as follows: boiler unit, loading and firing conditions, storage and handling methods. Variations may occur from ash properties point of view not only between different power plants but within a single power plant too. The wastes generated by the power plants are the ones typical for a combustion process. Burning coal results in exhaust gases that contain primarily particles, sulphur and nitrogen oxides and volatile organic compounds. The ash residues resulted after coal burning may contain significant levels of heavy metals and may cause serious air, surface water and groundwater pollution.

1.1 THE ENVIRONMENTAL IMPACTS DUE TO ASH PONDS

The storage of ash in ash pond may cause serious air, surface water and ground water pollution. The pollutants movement through all this modes is schematically represented below figure 2.

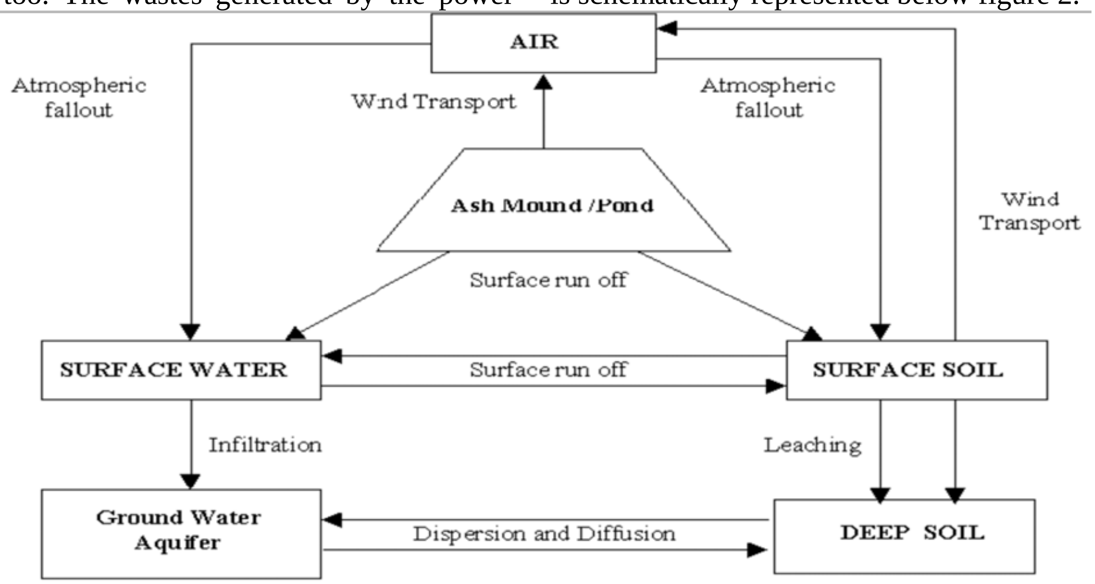

Fig. 2 Pathways Of Pollutant Movement Around Ash Disposal Facility

In case of the power plants that are using the wet scheme the ash is discharged directly into the nearby surface water system. The long storage of ash under wet conditions can cause leaching of heavy metals into the underlying soil and groundwater system. In order to avoid heavy environmental pollution in case of a wet ash disposal scheme engineering measures have to be taken when constructing the 'ash pond' and nevertheless a strong monitoring system has to be implemented also.

1.2 SOURCES OF GROUND WATER

Most of the ground water is derived from any one of the following sources.

1.2.1 Meteoric Water is the water derived from precipitation (rainfall and snowfall). Although a great part of rainwater reaches the sea through surface flow or runoff, considerable part of the rainwater reaching the surface in the form of precipitation, infiltrates and percolates downward below the surface and forms ground water. Most of the water obtained from underground belong to this category. The infiltration of the rainwater obtained from underground belong to this category. The infiltration of the rainwater and melt water starts immediately after the water reaches the ground and it ma y also take place from surface water reaches the ground and it may also take place from surface water bodies such as rivers, lakes, sea in the form of an almost continuous process.

1.2.2 Connate water is the water entrapped in the rocks during their formation due to sedimentation in an aqueous environment. Many important sedimentary rocks like limestone, sandstone and gravel are deposited and consolidated under water initially present in the pores between grains, yet some water might still be retained in the intergranular spaces of such rocks. It is however of not much importance in yielding supplies for human consumption

1.2.3 Juvenile Water

Juvenile water also called as magmatic water is of only theoretical importance. It is water formed in the cracks of crevices or pores of the rock due to condensation of steam emanating from hot molten masses or magma that are believed to exist at places below the surface of the earth. Some hot springs or geysers are such origin (Todd,1959).

1.3 STANDARDS OF POTABLE WATER

Planning, design in and execution of public water supply schemes have been and continues to be one of the most important activities of environmental engineers. Since the demand for water us always increasing in developing counties like ours, engineers are required to be busy in meeting the quantitative requirement of water supply. Water has to be however clean, potable and should not contain any disease carrying germs or harmful toxic substances that it has to be of a certain quality requirement or standards for potable water. A guideline value represents the level (a concentration or a number) of a constituent that ensures an aesthetically pleasing water that is suitable for human consumption and for all usual domestic purposes including personal hygiene. When a guide line value is exceeded the cause should investigated with view to taking corrective measures. The amount by which and duration for which, any guideline value can be exceeded, without affecting public health will depend on the specific substance or characteristics involved. The present world is quality conscious. We expect certain standards of quality for all substances produced and good manufactured. The prescribed standards for those major parameters are given in Table .1

Table 1 drinking water quality (CPHEEO): IS (10500-1991)

Parameter	Acceptable	Cause for rejection	Effects
pH	7.0 to 8.5	< 6.5 > 9.2	Beyond this range , water will affect the mucous membrane and water supply system
Total dissolved solids	500	1500	Taste affected
Total hardness as CaCo3	200	600	Low hardness causes corrosion, high hardness consumes excess soap and detergents causes scaling
Chloride as Cl	200	1000	More than 100 imparts salty taste
Sulpahte as So4	200	400	Bitter taste
Iron as Fe	0.1	1.0	Turbidity, stains on plumbing fixtures laundry and cooking tensile growths in mains
Maganese as Mn	0.05	0.5	As for iron
Nitrate	45	> 45	Causes infant disease
Cupper as Cu Zinc as Zn Lead as Pb Nichel as Ni	0.05 5.0 0.1 0.5	1.5 15.0 >0.1 >0.5	Chronic disease

All units except pH are in mg/l. Note: The figures indicated under the column “Acceptable” are the limits up to which water is generally acceptable to the consumers. Figures in excess of those mentioned under “Acceptable” render the water not acceptable, but still may be tolerated in the absence of alternative and better sources but up to the limits indicated under column “cause for rejection” above which the supply will to be rejected

2. OBJECTIVES OF THE PRESENT STUDY.

A Study on the impact of fly ash slurry on ground water quality is taken up with the following objectives: i. Characterization of the fly ash pond effluent for pH, alkalinity, total hardness, chlorides, sulphates, total iron, total dissolve solids (TDS) as well heavy metal ions such as nickel (Hi), copper (Cu), lead (Pb) and zinc (Zn).

ii. Monitoring of ground water quality around the ash pond by collection and analysis of water samples from eleven locations which are at different directions and different distances from the pond.

iii. To study the effect of fly ash slurry on the properties and engineering behavior of Soil to the ash pond site.

iv. To determine appropriate preventive or control methods to reduce the Fly ash leaching v. To determine the best waste management plan based on economic viability and sustainability.

vi. To suggest suitable Mitigation measures for reducing pollution

2.1 Study Area

The site for the proposed North Chennai Thermal Power Station (NCTPS) is located at about 20km North of Madras. The plot is flanked on the East by the Bay of Bengal. West by Buckingham Canal, South by Ennore Greek and North by Kattupalli village. The present study is taken up for ash pond of the North Chennai Thermal Power Station (NCTPS), which is having an area of 400 hectares with a storage capacity of 24 Mm3. The ash pond is in continuous use for the past 12 years. Initially entire ash generated from the plant was sent to dyke for storage. Only few quantities of fly ash were collected from ESP hoppers manually. After installation of PDFACS (Pressurized Dense Fly ash Collection system) , the collection of fly ash from ESP hoppers was made easy and transported to Ash silo and from there ash was disposed to Cement companies. At the present rate of ash dumping the ash pond will serve for a period of 10 years.

2.2 GROUND WATER AVAILABILITY IN THE AREA

The ground water is the only source which serve the need of public for water usage. The study area identified is having a radius of 7.5km from the ash pond. It is found that ground water is at a depth of 1 to 2m from ground level in rainy season and 10 to 12m from ground level in summer season. The adjoining areas of ash pond site is purely dependent on ground water only. So there is a need to assess the ground water in the area, since the local enquiries which were made from the public also revealed that the water has become hard only after the commissioning of ash pond.

2.2.1 DETAILS OF SAMPING POINTS

The selection of sampling points around the ash pond site was done to accommodate all directions, all type of wells and all modes of drawal it was also ensured that the selected wells are in regular use. Three bore wells were selected to get an idea of water quality in bore wells. Eight open wells were selected to have an idea of water quality in open wells. The location of these eleven sampling wells are indicated and listed in Table.2. Of the eleven sampling points, three were taken as control points (indicated as G3,G9 and G11 in Fig.5) for which the water quality analysis were made already during 1996 (before the commissioning of ash pond) for the preparation of environmental impact assessment report for the North Chennai Thermal Power Station. Hence the impact of ash pond (which is commissioned during 1996) on the water quality is studied by comparing the present values with the previous values which were taken before the commissioning of ash pond

Table 2 Location of sampling wells

	Location	Distance (in km) and direction from ash pond site	Remarks
Bore wells			
G1	Koranjur	1.3 West	Private borewell motor suction
G2	IT11 Reddipalayam	2.7 North West	Private borewell motor suction
G3	Sahayanagar	7.3 South	Public Hand pump
Open wells			
G4	Sepakkam	0.20West	Private – open well hand drawn

G5	Movuttambedlu	0.90 West	Private – open well hand drawn
G6	Attipattu	2.0 South West	Private – open well hand drawn
G7	Movuttambedu Cololny	1.3 West	Private – open well hand drawn
G8	Attipattu	2.7 South West	Private – open well hand drawn
G9	Puludivakkam	2.5 North	Private – open well hand drawn
G10	Reddipalayam	3.0 North West	Private – open well hand drawn
G11	Vallur	3.20 South West	Private – open well hand drawn

3. ANALYSIS OF SOIL AND SOIL + FLYASH MIXTURES

In this study, the properties of soil which is taken at about 2.0km from the ash pond site (Control) and fly ash collected from North Chennai Thermal Power station are described. The details of various test procedures adopted to assess the index and engineering properties of soil and fly ash mixtures are also discussed.

3.1 Soil Sampling and analysis

The soil sample is collected at a depth of 0.6 to 0.9m by open trench excavation method in the site 2.0 km away from the ash pond site. To study the effect of fly ash on the engineering behavior of locally available soil, the soil thus collected was mixed with fly ash at different proportion which varied from 10%, 20%,30%, 40%, and 50%. The grain size analysis of locally available soil (Black cotton soil) shows 12% sand, 37% silt and 51% clay. The soil collected at about 2.0km from the ash pond site and the fly ash collected from NCTPS are analyzed for the following Parameter indicated in Table 3 as per I.S Methods.

Table 3 Soil analysis

Sl. No	Laboratory Tests	Methods and Equipment
1.	Grain size analysis	IS 2720 (Part 4) 1985
2.	Liquid Limit	Mechanical Method (Casasgrande tool)
3.	Plastic Limit	IS 2720 (Part 5)
4.	Shrinkage Limit	IS 2720 (Part 6)
5.	Compaction Test	Standard Proctor test

4. WATER QUALITY IN THE STUDY AREA

The key parameters of the ash pond effluent having high probabilities of exhibiting impacts on the ground water quality are pH, alkalinity, total hardness, chlorides, sulphates, total iron, and total dissolved solids. The ash pond effluent was suspected to have some impact on the concentration of heavy metal ions such as Nickel, Copper, Lead and Zinc in the ground water samples collected around the ash pond site. The results of ash pond effluent analysis (average of three values) are furnished in Table 4.

Table 4 Ash pond effluent analysis

Parameters	Concentration
pH	7.7
Hardness as Ca	7.445
Total iron	0.1
Chlorides	23,255
Sulphates	2,614
Total dissolved solids	35,455

Alkalinity	93
Nickel	0.264
Zinc	0.143
Copper	-
Lead	0.097

Table 5 water quality analysis-III (Average values I &II)

SI.NO	Parameters	Bore wells			Open wells							
		G_1 1.3Km W	G_2 2.7Km N.W	G_3 7.3km S	G_4 0.2km W	G_5 0.9km W	G_6 2.0km S.W	G_7 1.3km W	G_8 2.7km S.W	G_9 2.5km N.W	G_{10} 3.0 km S.W	G_{11} 3.20km S.W
1	pH	6.72	6.93	7.08	7.32	7.5	7.42	6.48	7.23	7.06	6.88	7.50
2	Alkalinity	347.5	108.5	135	159	273	227.5	103	153	102	266	124
3	Total Hardness	2250	1325	618	1063	933	1233	273	2315	238	303	615
4	Chlorides	5074	2272	381	3103	3419	1948	788	2564	447	1162	666
5	Sulphates	2055	418	133	2050	1233	1228	768	1795	133	32	145
6	T0tal Iron	0.175	0.035	0.07	0.095	0.075	0.15	0.02	0.03	0.015	0.04	0.025
7	Total Dissolved solids	4920	1813	4213	5355	5025	4598	863	5316	808	3395	1915
8	Nickel(Ni)	0.145	0.038	0.025	0.082	0.072	0.064	0.044	0.106	0.101	0.050	0.087
9	Copper (Cu)	0.031	0.011	0.019	0.024	0.035	0.016	0.017	0.038	0.022	0.014	0.02
10	Lead (Pb)	0.091	0.103	0.060	0.10	0.07	0.085	0.016	0.04	0.115	0.052	0.105
11	Zinc (Zn)	0.044	0.087	0.029	0.031	0.028	0.019	0.039	0.031	0.015	0.062	0.012

All the units except pH are in mg/l

5 MITIGATION MEASURES

The problem of ground water pollution resulting out of dumping ash into ash pond can be mitigated by following methods a) Providing concrete lining over the bottom surface of the ash pond b) converting wet ash collection system into dry ash system

5.1 PROVIDING CONCRETE LINING OVER THE BOTTOM SURFACE OF THE ASH POND

In order to prevent the ground water pollution, the entire bottom surface of ash pond area can be impervious by providing 300mm thick reinforced concrete lining .The Capital Cost required for RCC Lining. This shall be done on the level of bed of the Ash pond, a layer of 300mm thickness of Reinforced concrete to be properly laid

Area of Ash pond to be made impervious = 400 hectare

40,00,000 m2

Thickness of RCC Lining = 300 mm or = 0.30 m

Volume of RCC Work = 4000000 X 0.3 m3 = 12X105 m3

Cost of R.C.C work = Rs.1000 per m3

Total cost of RCC Lining = Rs. 12 X 105 X 1000 Say = Rs.120 Crore

Considering the huge investment and continuous pumping of water which involves regular maintenance, huge water consumption, High maintenance costs due to corrosion and clogging. Hence, this option is not viable.

5.2 CONVERTING WET ASH COLLECTION SYSTEM INTO DRY ASH SYSTEM

The problem of ground water pollution resulting out of the Ash pond in the NCTPS has been mitigated by converting wet ash collection system into dry ash system.

5.2.1 Present system:-

In NCTPS , presently fly ash from ESP hopper were collected as dry fly ash and sold to Cement Companies. The ash collected in the bottom ash hopper are grinded and mixed with sea water and pumped to the ash dyke. The ash settled in the ash dyke could not be reused due to mixing of saline water.. CEA have instructed that 100% ash utilization should be achieved.. Hence implementation of dry bottom ash system for 100% ash utilization is proposed. In the existing Boilers of Thermal stations in Board, only the wet system of Bottom ash handling is installed. In this system, the hot clinkers and the bottom ash falling from the Boiler is mixed with water and powdered in clinker grinder and then formed into a slurry. This slurry is pumped into the Ash dyke and stored. After drying, the ash is reclaimed and used for land filling purposes.

5.2.2 Dry system:- The dry bottom ash collection is new to India. M/s.Magaldi have installed this system in Durgapur Power plant at west Bengal.

This system can be implemented in TNEB due to the following advantages.

i) The heat available in the bottom ash is used back in the boiler and the boiler efficiency is improved.

ii) The un-burnt carbon in the existing system will be minimized and improvement in the boiler efficiency etc..,

iii) Further there is considerable reduction in Ground and Air pollution due to this modification. iv) The wet system involves huge water consumption. v) High maintenance costs due to corrosion and clogging.

iv) Environmental issues due to leakages of contaminated water and loss of boiler efficiency, and negative effects on boiler operation due to low reliability and poor maintainability of wet system. This wet system is objected by the MOEF, New Delhi since this system requires huge quantity of water which has become scarce. The wet ash stored in the dyke contaminates the ground water table and also large area is occupied by the ash dyke. If sea water is used for collecting the Bottom ash, then the ash can be used for land filling purposes only . If the wet system is replaced is by dry system the ash dyke area can be beneficially used for plant purposes. The dry bottom ash can be used for downstream industries like cement and brick making. Board will also be monetarily benefited by way of sale of dry fly ash to the user industries .Cost benefit analysis By introduction of the proposed dry bottom ash handling system, the need for pumps such as slurry pumps to pump the wet ash to ash dyke, pumps to supply water for the bottom ash handling system is eliminated. The energy saved by elimination of the above pumps will be around 9720 KWhr/day resulting in a saving of Rs.87,48,000/- per year @ Rs.3/- per unit. The revenue that may be accrued by sale of bottom ash will be approximately Rs.36,00,000/- per year @Rs.60/- per M.T.

The total savings per year will be Rs.1,23,48,000/- and the pay back period will be 12.15 years. The detailed cost benefit analysis is enclosed in the Annexure.

Further i) The expenditure towards maintenance of the existing system will be reduced

ii) The boiler efficiency may increase due to capture of heat energy of the ash which returns to boiler. iii) Land Acquisition for Ash pond is eliminated.

6. COST BENFIT ANALYSIS

Cost of the proposed system for units = Rs.45 Crores

6.1 Cost savings because of the introduction of the new system

I. Energy required for slurry pumps to pump the wet ash to ash dyke Presently 4 pumps of 150KW is run 8 hours a day and 1 pump of 150KW capacity is run 24 hours a day.

Energy required = 4 X 150 X 8+ 1 X 150 X 24 = 8400 KW hr

II. Energy required for pumps to supply water for the bottom ash handling system Water for bottom ash is supplied by running one pump of capacity 315KW continuously for 3 units.

Energy required for supply of water for bottom ash system for one unit will be 1/3rd of the energy spent for pumping water for all the 3 units.

Energy required = 315 X 1/3 = 105 KW per day = 105 X 24 hrs = 2520 KW hr

III. Energy required for Bottom ash water pump for allied systems One pump of 150KW is run 8 hours a day for pumping water. Energy required = 1 X 150 X 8 = 1200 KWhr Total energy required for the existing system = 8400 + 2520 + 1200 = 12120 KWhr /day

6.2 Energy required for the proposed system

It is noted from the technical pamphlet furnished for the dry bottom ash system that motors with a total capacity of 100 KW is being used for the system.

Hence the energy required = 100 X 24 = 2400 KWhr/day

The energy saving by way of introducing the new system = Energy required for the existing system – energy required for the new system = 12120 – 2400 = 9720 KWhr/day

Savings in terms of money @ Rs.3/- per unit per day = 9720 X 3 = Rs.29,160/-

Savings per year = Rs.29,160/- per day X 300 days = Rs.87,48,000/-.

Savings per year for 3 units = 3 X Rs.87,48,000/- = Rs. 2,62,44,000/-

The ash collected can be sold. The cement manufacturers have not given their consent to buy the same. However it can be sold to brick manufacturers.

The present rate of selling ash to brick manufacturers is Rs.60 per Ton

The quantity of ash to be collected = 600 T per day

Revenue towards selling ash = 600 X 60/- = Rs.36,000/- per day

Approximate revenue per year = Rs.1, 08, 00,000/-

Total expected revenue per year = .262, 44,000 + 1,08,00,000 = Rs. 3,70,44,000/-

Pay back period=45,00,00,000/- 3,70,44,000/- 12.14 years **Or say 12 years**

6.3 COMPARISONS OF BOTH SYSTEMS.

1. The capital cost of providing concrete lining over the dry fly ash collection system is about 120crore. The capital cost of dry collection system is about rs.45 crore less than that of concrete lining.
2. The dry collection system has least impact on water resources
3. The dry systems result in substantial savings of energy than that wet system.
4. Providing concrete lining is **most expensive, least efficient and** requires large amount of water. Hence this system has not been considered as an option in this study. Based on the above analysis, it is concluded that the 100% dry ash collection system would be a better choice considering environment impacts and economical viability and sustainability. This suggestion can be further validated with the MoEF's guidelines, which insists that 100% dry collection system is a minimum requirement for existing plants.

7. SUMMARY

The fly ash from the North Chennai Thermal Power Station is mixed with the seawater in the ratio of 1:12.5 and dumped into the fly ash pond (commissioned during 1996) which is having an area of 400 hectares and 6m high. As the fly ash is mixed with seawater, it is very much susceptible for ground water pollution in the nearby areas due to the leachate from the ash pond. Therefore this study has been taken up for investigating the impact of flyash slurry on ground water quality as well as on the basic properties and engineering behavior of soil. Eleven sampling locations (G1 to G11) were identified and ground water samples were collected from these locations twice. The physio –chemical parameters (pH,Hardness, Alkalinity, TDS, Chlorides, Sulphates and Heavy Metals) of the ashpond effluent samples and eleven water samples were carried out as per Standard Methods. The locally available soil was mixed fly ash in different properties (i.e., 10%,20%, 30%, 40% and 50%) and analysed for basic and engineering properties of soil.

8. CONSULUSIONS

Based on the above study, the following conclusions were arrived.

1. In almost all the well, the concentrations of Total hardness (maximum value of 2315 mg/l at G8), Chlorides (maximum value of 5074 mg/l at G1) Sulphates (maximum value of 2055mg/l at G1) and TDS (maximum value of 5355 mg/l at G4), have exceeded the permissible limits and making the water unfit for drinking purpose.
2. The increase in the concentrations of Total hardness (from 110-371mg/l to 238-2315 mg/l), Chlorides (from 110-290 mg/l to 381-5074 mg/l), Sulphates (from 20-49mg/l to 133-2055 mg/l), TDS (from 402-670 mg/lto 808 -5355 mg/l, during the past twelve years (i.e,1998-2010) has proved the deterioration of groundwater quality in the study area and the cause for this deterioration could be the leachate from the ash pond.
3. As far as heavy metals are concerned, the concentrations of Nickel (maximum value of 0.145 mg/l at G1) Copper (maximum value of 0.038mg/l at G8), Lead (maximum value of 0.115 mg/l at G9) and Zinc (maximum value of 0.087 mg/l at G2) are well within the permissible limits and also there is no significant change in their concentration during the past twelve years (Table 4.5). Hence it is understood that the

impact of ash pond has to significance on the heavy metals.

4. From the view point of basic properties (Table 12,) fly ash can be effectively utilized in reducing the compressibility and s welling potential of expansive soils.

5. The maximum dry density decreases from 1.75 g/cc to 1.00 g/cc as the fly ash percentage increases from 0 to 100%. Hence the present of fly ash may not be beneficial to the improvement of shear strength and bearing capacity of soil.

6. At the present rate of ash dumping, the ash pond will serve for a period of 10 years. Hence it is necessary to go in for periodical monitoring of ground water quality around the ash pond area.

7. As the production of fly ash in power plants is massive, more attention towards rapid utilization practices in construction activity, high way pavements, chemical fixation and solidification of hazardous wastes, brick and hollow block manufacturing and agricultural purposes should be given so that the purpose of disposing fly ash as a waste product is served advantageously. Hence the Indian Government's policy goal of increasing ash utilization to 100 percent of the total generated by 2011 could be achieved.

8. In order to control the ground water pollution due to the leachate from the ash pond, the entire ash pond bed shall be made impervious by providing 300mm thick RCC cover Alternatively, the entire ash can be collected in dry form by providing dry bottom ash collection system. By this method, total ash generated is available for utilization.

9. FINAL RECEOMMENDATION

It is recommended that the dry ash collection system would be a better choice considering the tangential benefits elaborated. This suggestion can be further validated with the MOEF's guidelines, which mandate that 100% dry collection system is a minimum requirement for existing plants.

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