ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

# Acidification of River Discharge due to Abandoned Coal Mines and its Impact on Sustainable Development of Hydro Power Sector in North Eastern Region of India

Kachhal Prabhakar, Sharma Pankaj, Pathak R. P., Sameer Vyas, Murari Ratnam

*Abstract*— ***Coal is an essential source of energy. The primary impact arising from its unsystematic shallow mining includes water pollution due to abandoned mines and waste dumps. To minimize this it is essential to identify the areas vulnerable to environmental damage in the near future. Meghalaya, one of the seven north eastern states of India possesses rich deposits of coal at relatively shallow depth. Coal found in this area possesses high sulphurous content. The state being a Sixth Schedule State, its autonomy gives freedom to the people to mine at their own willh. Most of the mining activities are small scale units controlled by individuals who own the land. Mining operations has led to extensive environment degradation in the area. For assessing the impact of coal mines the catchment area of rivers Myntdu, Laichiki, Lamu, Makjai, Umshangphu, Khakar and Kopili which flow through the coal rich belt of the state has been surveyed. The rivers Myntdu, Laichiki, Lamu, Makjai, Umshangphu impound the reservoir of Myntdu-Leshka Hydro Electric project while rivers Khakar and Kopili impound the twin reservoirs of Kopili Hydro Electric project. The paper also presents various problems and economic liabilities encountered in sustainable development of hydro-electric sector arising due to acidified water.***

*Index Terms*—**Rat hole, Concrete, X–Ray Diffraction, supernatant liquid.**

## I. INTRODUCTION

The primary impact arising from its unsystematic shallow mining includes water pollution due to abandoned mines and waste dumps [1]. The State of Meghalaya possesses rich deposits of coal at relatively shallow depth. The estimated coal deposits in this State are about 600 million tons. These deposits are widely distributed in the entire state (Fig. 1). Presently large scale extraction is being carried in the Jaintia Hills.

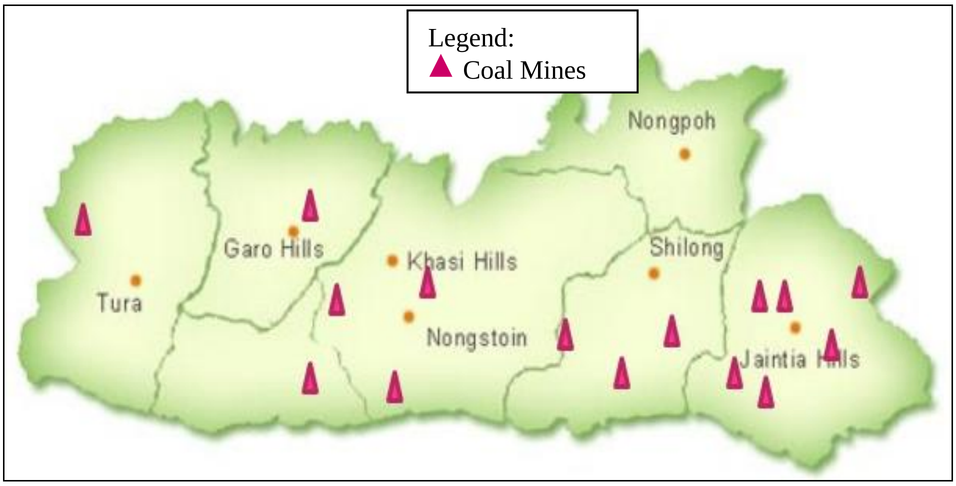


**Fig 1: Distribution of Coal Deposits in Meghalaya**

The state being a Sixth Schedule State, its autonomy gives freedom to the people to mine as they wish. Most of the mining activities are small scale ventures controlled by individuals who own the land. The topography of the study area is undulating. The soil is sandy in nature, reddish brown to yellow brown in colour, acidic in reaction, low

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

water holding capacity and has low organic matter and nutrient. The coal found in this area possesses high sulphurous content. After extraction of coal the mines are simply abandoned without any proper treatment. The area being one of the rainiest region, these abandoned pits get filled up with water. This leads to formation of sulfuric acid. Such unsystematic mining operations have led to extensive environment degradation [2], [3]. Meghalaya has a large scope for development in the hydro potential but due to acid mine discharge various problems and economic liabilities are encountered in its sustainable development [4] – [6]. To minimize such implications it is essential to scan the area around such projects to identify the source of contamination. For assessing the impact of coal mines the catchment area of rivers Myntdu, Laichiki, Lamu, Makjai, Umshangphu, Khakar and Kopili which flow through the coal rich belt of the state has been surveyed. The water of these rivers impound the reservoirs of Myntdu-Leshka (MLHEP) and Kopili Hydro Electric project (KHEP). Implications breeding due to acid mine discharge (AMD) to ensure smooth functioning of these projects have also been studied.

## II. INVESTIGATED AREA

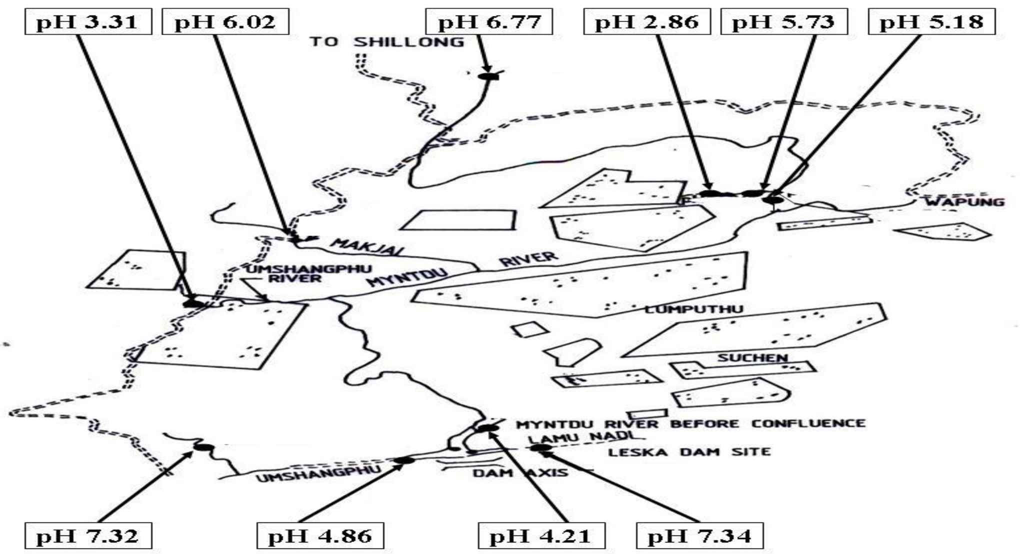


**Fig 2: Surveyed Catchment Area of rivers Myntdu, Laichiki, Lamu, Makjai, Umshangphu**

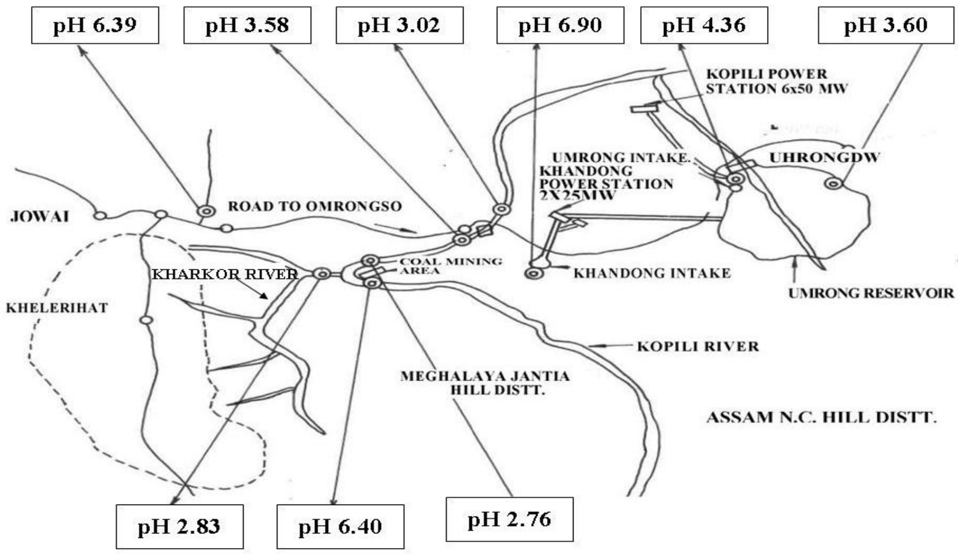


**Fig 3: Surveyed Catchment Area of rivers Kharkor and Kopili**

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

The catchment area of rivers Myntdu, Laichiki, Lamu, Makjai, Umshangphu, Khakar and Kopili which flow through the coal rich belt was selected for the present study. The rivers Myntdu, Laichiki, Lamu, Makjai, Umshangphu impound the reservoir of MLHEP (Fig. 2) while rivers Kharkor and Kopili impound the twin reservoirs of KHEP (Fig. 3).

## III. MINING METHODS

During field survey it was observed that traditional unsystematic coal mining methods are being practiced in the catchment area of these rivers. Rat hole technology (Fig. 4) and open surface mining (Fig. 5) were the common techniques used for excavation of coal from the mines. Excavated coal is stacked unsystematically (Fig. 6)

**Fig 4: Rat Hole Mines**

**Fig 5: Abandoned Surface Mine**

**Fig 6: Stacked Coal Deposits**

## IV. MINERALOGY OF COAL

### *A. X–Ray Diffraction Studies*

The result of XRD studies are presented in fig 7. The test was conducted to identify the mineralogical composition. Qualitative identification of minerals present was done with Match software using ICDD databas. The coal sample predominantly showed presence of minerals Pyrite, Nacrite, Muscovite and Kaolinite.

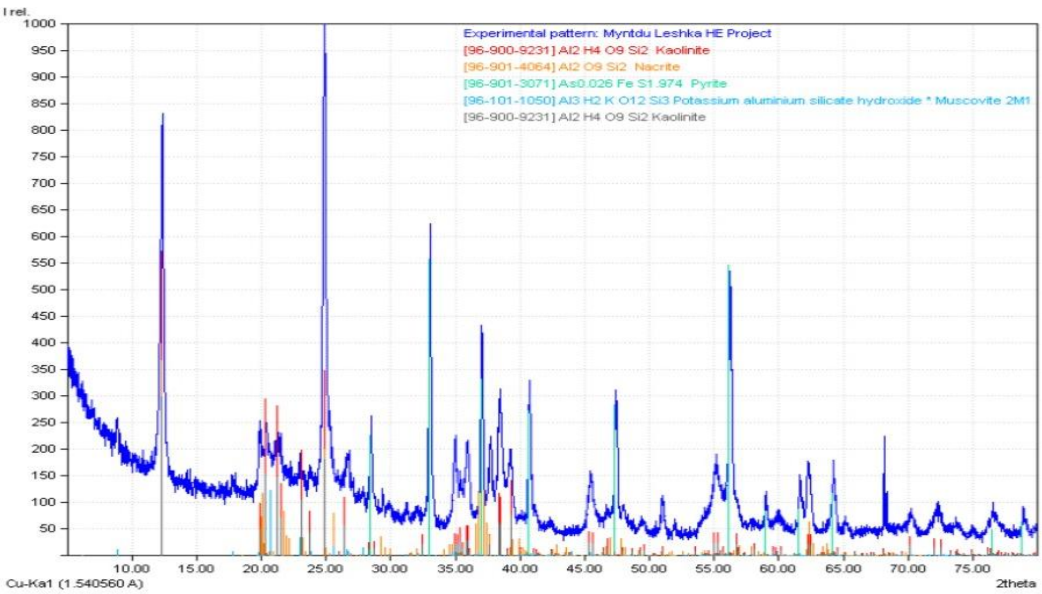


**Fig 7. X-ray Diffractogram of Coal Sample**

## V. ACIDIFICATION OF WATER

To ascertain the effect of interaction between coal and water with respect to change in pH, conductivity and sulphate concentration, a study was carried out. Coal samples were collected from the coal mines located in the catchment area of Myntdu River (Sample 1) and Kharkor River (Sample 2). These samples were kept in distilled

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

water. The pH, conductivity and sulphate concentration values of the supernatant liquid were recorded till 180 days. The result of these observations is reproduced in the Figs. 8 – 10.

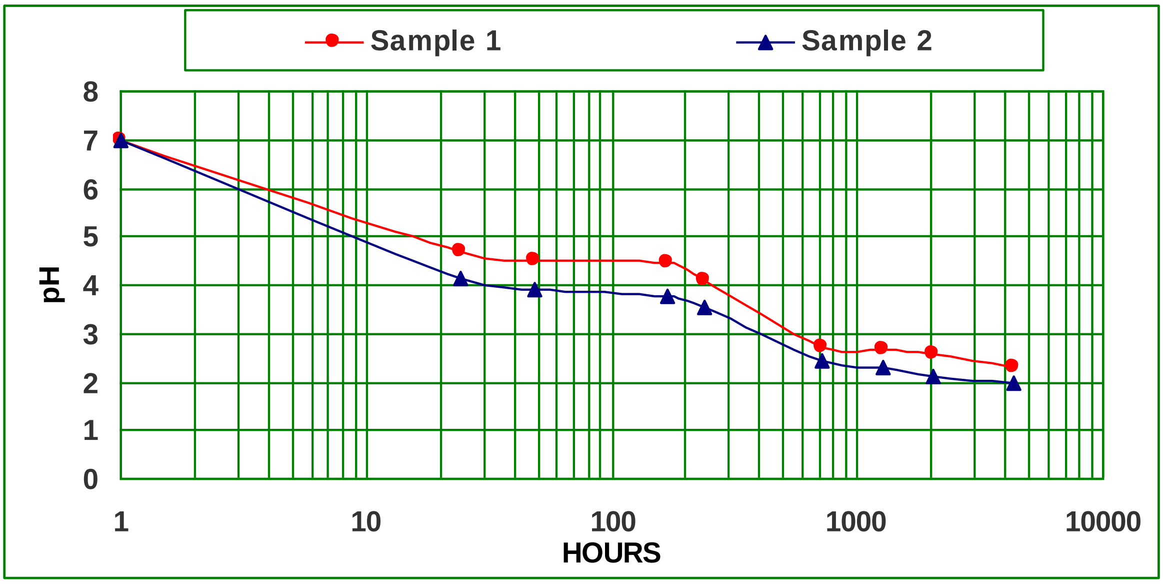


**Fig: 8 Change in pH with time**

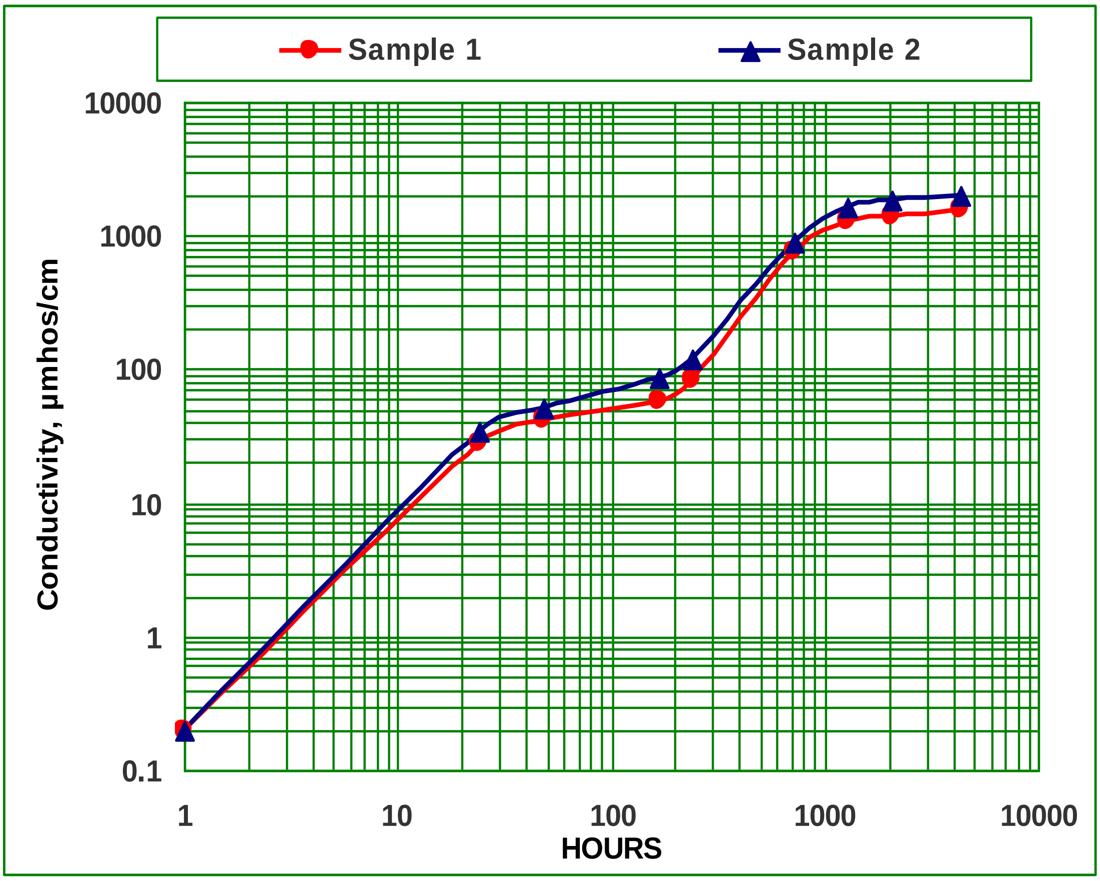


**Fig: 9 Change in Conductivity with time**

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

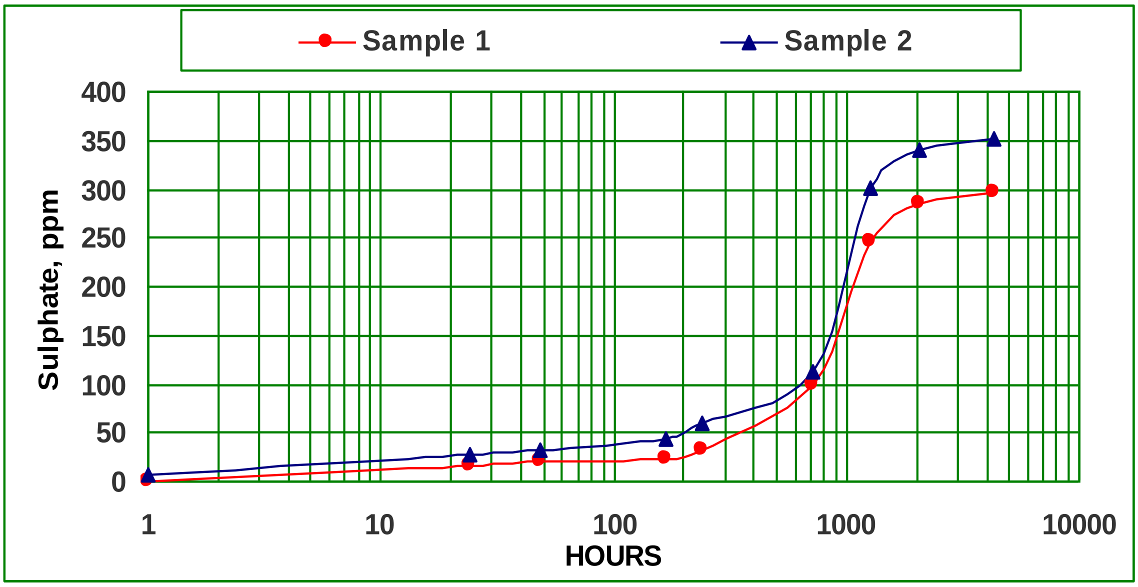


**Fig: 10 Change in Sulphate Concentration with time**

Presence of certain bacteria e.g. *Thiobacillus ferrooxidans* and *Thiobacillus thioxidans* promote sulphur and/or iron oxidation (Corrans et al., 1972). Pyrite gets oxidized to sulphate in contact with oxygen and moisture in air. These sulphates in contact with water forms sulphuric acid.

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ FeSO_4 + 2\ H_2SO_4$$

$$4\ FeSO_4 + O_2 + 2\ H_2SO_4 \rightarrow 2\ Fe_2\ (SO_4)_3 + 2\ H_2O$$

$$7\ Fe_2\ (SO_4)_3 + FeS_2 + 8\ H_2O \rightarrow 15\ FeSO_4 + 8\ H_2SO_4$$

Once the mining activity was over, these holes and pits are left unattended. During monsoon season these get filled with water. This acid joins the reservoir through various tributaries flowing through this region. Samples were collected from different locations in the catchment area. The in situ parameters viz. pH, Conductivity, Temperature, Calcium Carbonate Saturated pH were determined in these water samples.

## VI. DETRIMENTAL EFFECTS OF ACIDITY

Lowering of pH is major cause of deleterious effects on concrete and various hydro mechanical components. It may cause

- Leaching of lime may occur from concrete
- Loss of concrete strength over a period of time
- Frequent outages in power generation due to corrosion and erosion of hydro mechanical components.

## VII. CASE STUDIES

### *A. Myntdu Leshka H.E. Project, Meghalaya (Pre Construction Problem)*

MLHEP is located in the Jaintia Hills District of Meghalaya at an altitude of 563.00 above MSL. It is a 59 m high concrete gravity dam located just below the confluence of three rivers (Leshka) viz. Myntdu, Laichiki (Umshariang) and Lamu. The project envisages 3667 m long tunnel, penstocks and a power house for generating 2 X 42 MW power.

- Problem: Very low pH of water.

  For assessing the long-term effect of water quality of Myntdu River and its tributaries on durability of concrete and hydro-mechanical equipments [7] intensive investigations were carried out.
- Aggressivity of AMD Water Samples with Reference to Codes and Practices

  As per IS 456: 2000 Code for plain and reinforced concrete, values of Lengalier Index, French National standard p18-011, May 1985 and USBR classification for relative degree of sulphate attack most of the water samples are classified as highly aggressive

- Suggested Remedial Measures Include
    1. W/c ratio less than 0.40, Good dense concrete.
    2. Appropriate grade of concrete; Minimum cement content shall be 280 Kg/M$^3$ for plain concrete and 360 Kg/M$^3$ for reinforced concrete structures for exposed surface.
    3. Preference to be given to blended cements.
    4. Adequate protection of reinforcement with good concrete cover. Non-corrosive steels or coatings or chemical inhibitors or cathodic protection for protecting the reinforcement.
    5. Use of good quality turbine blades, which can withstand acidic environments under pressure.
    6. Treatment of catchment area surface runoffs i.e. Acid mine discharge.

### *B. Kopili H.E. Project, Assam/Meghalaya (Post Construction Problem)*

Kopili HEP is situated in the N.C.Hills district of Assam and Jantia Hills district of Meghalaya on the river Kopili. It is a twin project comprising of 2 dams, 2 reservoirs, 2 water conductor system and 3 Power houses commissioned in 1984, 1988 and 1997. Up to year 2006, the project has been continuously serving the region smoothly by providing electric energy. Frequency of outages was rare till year 2006 which suddenly increased abruptly. During post outage maintenance, it was detected that the reason of outages was corrosion/erosion of hydro- equipment. The deterioration was caused by acidified water in the reservoir charged by river Kopili and its tributaries flowing through coal fields of Meghalaya.

- Problem**:** Very low pH of water.

  For assessing the long-term effect of water quality of Kopili River and its tributaries on durability of concrete and hydro-mechanical equipments intensive investigations were carried out.

- Aggressivity of AMD Water Samples with Reference to Codes and Practices

  As per IS 456: 2000 Code for plain and reinforced concrete, values of Lengalier Index, French National standard p18-011, May 1985 and USBR classification for relative degree of sulphate attack most of the water samples are classified as highly aggressive.

- Detrimental Effects Of AMD

  As the problem of AMD in present project is not very old, the concrete in the structure has already started showing the signs of distress in the form of seepage (Fig. 11 a), leaching of binding material through drain holes (Fig. 11 b) and slushing of materials (Fig. 11 c). In long term low pH will continue to bleed the binding material out from concrete and high sulphate content will lead to expansion of concrete consequently causing its spalling and loss of strength.

(a) (b) (c)

**Fig 11: Signs of Distress observed in the concrete structure**

The acidic discharge frequently erodes/corrodes the installed hydro-mechanical equipments [7] which lead to frequent outages. Fig. 12 shows some of these affected components. These parts need to be repaired or replaced.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

**Fig 12: Corroded/Eroded Hydro-mechanical Components**

Multifold investigations which include tackling the menace of AMD and protection of various elements of the structure to find a sustainable solution to the issue have been proposed. These include

1. Eco-friendly treatment of surface runoffs in catchment area to improve the pH conditions [8], [9].
2. Provision of impermeable membrane as a barrier between the concrete and acidic water.
3. Provision of suitable polymeric coatings viz. epoxies etc. for applying in galleries to protect these structures from direct contact with acidic water.

## VIII. CONCLUSIONS

The source of the acidification of water was identified to be surface runoffs from the surroundings coal mines on either side of the main rivers in Jantia Hill district of Meghalaya. Acidic hydro-environment causes severe corrosion/erosion complications to the hydro power equipments. In long term low pH will lead to weakening of concrete structure due to bleeding of binding alkaline material. The problem of acidic environment needs urgent attention before it poses far reaching economic implications in the power-producing sector. Evolving strategy, selection of appropriate tools and formulation of policy for implementation are the needs for tackling this problem at this moment. A sustainable solution to the issue is urgently desired.

## ACKNOWLEDGMENT

The authors extend their sincere thanks to MLHEP and KHEP Authorities, India for their cooperation in the field investigations. Sincere gratitude is extended to all the authors whose publications provided us directional information from time to time.

## REFERENCES

[1] Campbell R.S. and O.T. Lind, "Water quality and aging of strip-mine lakes", J. Water Pollut. Control Fed. 41:1943-1955, 1969.

[2] Swer, Sumarlin and Singh OP, "Status of Water Quality in Coal Mining areas of Meghalaya, India", Proceedings of the National Seminar on Environmental Engineering with special emphasis on Mining Environment, NSEEME-2004.

[3] Rathore, CS and Wright R., "Monitoring environmental impacts of surface coal mining". International Journal of Remote Sensing. 14: 1021-1042. 1993.

[4] Gupta SL, Mahure NV, Sharma Pankaj, Murari Ratnam, "Raising Mass awareness in respect of intrinsic and extrinsic interactions of water with concrete – A mandatory approach for enhancing durability of concrete" I. J. Multidisciplinary Educational research. Vol. 3 (2): 73-82, 2014.

[5] Sharma Pankaj et.al "Acid mine discharge – Challenges met in a hydro power project" International Journal of Environmental Sciences volume 1, no 6: 1274-82, 2011.

[6] Rajeev Kumar Sustainable Development of Hydroelectric Projects in Coal bearing area of Meghalaya International Journal of Earth Sciences and Engineering Volume 04, No 06 SPL: 319-322, 2011.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 2, March 2014

[7] Prabhakar Kachhal, Sharma Pankaj, Pathak RP and Murari Ratnam. "Assessment of durability of coated steel to be used in manufacture of hydro mechanical equipments operational in acidic hydro environment" published in International Journal of Research in Chemistry and Environment, Vol 3, Issue 3: 100-105, 2013.

[8] Das, B.K., A. Roy, M. Koschorreck, S.M. Mandal, K. Wendt-Potthoff and J. Bhattacharya,. Occurrence and role of algae and fungi in acid mine drainage environment with special reference to metals and sulfate immobilization. Water Res., 43: 883-894, 2009.

[9] Corrans, I.J., Harris, B. and Ralph, B. J., "Bacterial leaching and introduction to its application and theory and a study of its mechanism of operation", J. South African Inst. Min. Met.: 221-230, 1972.

## AUTHOR BIOGRAPHY

**Kachhal Prabhakar: Age 51 years.** 27 years research experience in the field of concrete chemistry. Presently working as Scientist at Central Soil and Materials Research Station, New Delhi. Have 25 technical papers to his credit in various national and international journal and conferences.

**Pankaj Sharma: Age 58 years.** 35 years research experience in the field of geotechnical engineering, rock fill technology, concrete chemistry and environmental engineering. Presently working as Senior Scientist at Central Soil and Materials Research Station, New Delhi. Have 68 technical papers to his credit in various national and international journal and conferences.

**Dr. RP Pathak: Age 50 years.** Presently working as Scientist at Central Soil and Materials Research Station, New Delhi. 26 years research experience in the field of soil chemistry, concrete chemistry. Have 42 technical papers to his credit in various national and international journal and conferences.

**Dr. Sameer Vyas: Age 42 years.** 17 years research experience in the field of concrete chemistry and environmental engineering. Presently working as Scientist at Central Soil and Materials Research Station, New Delhi. Have 40 technical papers to his credit in various national and international journal and conferences.

**Murari Ratnam:** Director Central Soil and Materials Research Station, New Delhi. **Age 58 years.** 35 years research experience in the field of geotechnical engineering, rockfill technology, rock mechanics, soil chemistry, concrete chemistry and environmental engineering. Have more than 150 technical publications to his credit in various national and international journal and conferences. Addressed various conferences and seminars at national and international level. Life member of various leading national and international societies.