International Journal of Tropical Agriculture
Volume 40, Numbers (1-2) • 2022 : pp. 41-49
ISSN: 0254-8755

Impact and Reclamation of Red Mud of Refinary Unit of Nalco at Damanjodi, Odisha

Santoshini Dash, P. K. Pattajoshi* & A. K. Sahoo

Department of Natural Resource Management, College of Forestry
Odisha University of Agriculture & Technology, Bubaneswar-751003, India
**Refinery Unit, NALCO Ltd. Damanjodi, Koraput-763008, Odisha*
E-mail: carbonfinance.ouat@gmail.com

Abstract: Globally, there is approximately 90 million tonnes of red mud being produced every year. More than 4 million tonnes of red mud are generated annually in India only. The amount of red mud generated in refinery unit of NALCO, Damanjodi is 25 lakhs ton per annum. The amount of red mud generated per ton of alumina processed, varies greatly with the type of bauxite ore used in the refinery. During the process of extraction of alumina from bauxite ore, the insoluble residue generated after digestion with sodium hydroxide at elevated temperature and pressure is known as red mud or Bauxite residue. It is generated by the Bayer's process which is highly alkaline with pH usually ranging from 10-13. Due to its hazardous corrosive nature, it is posing a very serious and alarming environmental pollution problem in adjoining region, which needs its ecological rehabilitation.

It is observed that, the red mud of refinery unit of NALCO, Damanjodi is highly toxic and carrying pH 11.45. During reclamation of red mud, for developing vegetation, two leguminous species i.e. *Acacia auriculiformis, Acacia mangium* and two non leguminous species such as *Eucalyptus tereticornis* and *Terminalia chebula*are taken where,*Acacia auriculiformis* showed better results in its survival percent, plant height, collar diameter, chlorophyll a, chlorophyll b, chlorophyll a/b, fresh weight, dry weight followed by *Terminalia chebula*. Both the species are very hardy and adjusted to drier types overcome to alkaline conditions. Further, T_3 level (25% RM + 75% Soil mixture) with constant Nitrogen, Phosphorus, Potassium is significantly better performing than other treatments.

Keywords: Environmental pollution, red mud, reclamation, vegetation

INTRODUCTION

Environmental pollution now caused many ways globally particularly, in active mining. During the process of extraction of alumina from bauxite ore, the insoluble residue generated after digestion with sodium hydroxide at elevated temperature and pressure is known as red mud or Bauxite residue. The amount of red mud generated per ton of alumina processed, varies greatly with the type of bauxite ore used in the refinery. It is generated by the Bayer's process which is highly alkaline with pH usually ranging from 10-13. The ecological rehabilitation of red mud residue is complicated by many factors, including its hazardous nature, extremely high pH and salinity, poor water holding capacity, and extremely low microbial activity. In view of this, very few research studies were conducted in this field and among those successful studies were very limited. The residue has larger environmental impact, its reclamation and further utilization become a great problem for the industries as well as for the community. Globally, there is approximately 90 million tonnes of red mud being produced every year. More than 4 million tonnes of red mud is generated annually in India only. The amount of red mud generated in refinery unit of NALCO, Damanjodi is 25

Article History: Received: 02 February 2022; Revised: 22 February 2022; Accepted: 10 March 2022

lakhs ton per annum. Due to its hazardous corrosive nature, it is posing a very serious and alarming environmental pollution problem in adjoining region. So, for study and research findings would be very helpful in stabilizing the toxic red and in development of vegetation to reclaim the inhospitable red mud substrate into a substrate that will allow to grow appropriate plants and develop green cover is badly need for this region. Another important outcome of vegetation intervention is significant changes in the quality of red mud in the form of decline in the pH value and improvement in the proportion of sand, and increase in micronutrients.

Red mud created from bauxite ores is brick red in colour and has slimy appearance due to presence of high content of iron oxide and caustic soda. The average particle size is about <10micron meter but few particles having size greater than 20micron meter can also be found (Mohapatra *et al*., 2000). About 35% by weight of solids have size less than 5micron meter and 80% less than 8micron meter. The sand, silt, clay of red mud is 3-5, 79-80, 14-15% respectively. It is highly alkaline (pH > 11), saline-sodic and possess high surface area in the range of 13-16m^2/g with a true density of 3.30 g/cc (Paramguru *et al*., 2005). The free moisture content is highly variable (30-60%) depending upon the disposal method. The contamination of surrounding environment is a global environmental issue, which can be solved by utilization for environmental benefits. Although extensive uses for red mud have been investigated and many have already been pilot tested, there are limited examples of commercial scale reuse of it. There is an "inherent" safety in keeping red mud stored, as the risk of misuse or environmental damage is low (Tuazon and Corder, 2008). However, investigations into red mud reuse are continued if red mud could be reused then it would create a valuable synergy between the Gladstone alumina refineries and other reuse stakeholders (Cooling and Glenister, 1992). Several attempts have been employed for utilization of red mud throughout the world including in heap leaching of gold ores (Browner, 1995), in the removal of sulphur compounds from kerosene oil (Singh et al., 1993), in the hydrogenation of anthracites (Alvarez *et al*., 1995), coals and aromatic compounds (Eamsiri *et al*., 1992), in the extraction of iron and titanium oxides (Parek and Goldberger, 1976) and in the synthesis of inorganic polymeric material (Dimas *et al*., 2009). In India, it is reported that 2.5 million tons of red mud was utilized in the cement industry whereas in China, about 10% of RM used for metal extraction or utilized as a raw material for brick production (Agarwal and Sashikanth, 2008). Red mud has been successfully used as an amendment on sandy, acidic soils both in agriculture and mine spoils due to its neutralizing capacity (Fortin *et al*., 2000, Komnitsas *et al*., 2004; Hanumanth,*et al*., 2012; Paradis *et al*., 2007 and Summers *et al*., 2001). Two approaches are needed for rehabilitation of red mud. The first is amelioration of the surface layer of the residue by adding amendments and the second is the appropriate vegetation establishment. Based on the above facts the present study is designed to evaluate the impact and reclamation of red mud release from refinery unit of NALCO at Damanjodi, Odisha.

MATERIAL AND METHOD

The present investigation was conducted during the year 2018-19 at, Damanjodi, a refinery unit of NALCO, in the district of Koraput, Odisha and the trial & analysis made in Department of Natural Resource Management, College of Forestry, OUAT, Bhubaneswar. The investigations was comprised of two parts vis impact assessment and evaluation of relative performance of species in varied concentrations of red mud in Department of Natural Resource Management, College of Forestry, OUAT collecting the required amount of red mud from Damanjodi unit of NALCO, Koraput. Damanjodi unit of NALCO located at 18.7743°N latitude, 82.9125°E longitude at an elevation of 870m above mean sea level. It is situated about 450km to the south of Bhubaneswar city. The climate is characterized by warm and humid summer and a short mild winter. The average annual rainfall is about 1627mm (Anonymous, 2011). Whereas Department of Natural Resource Management, College of Forestry, OUAT, falls under Eastern and South-eastern coastal plain zone of Odisha and situated between 20°15′N latitude and

85°52'E longitude at an elevation of 25.9metres above mean sea level which is situated about 64km to the west of the Bay of Bengal. The climate is characterized by sub-humid, warm climate with a short mild winter. The annual rainfall is 1500mm.

The study was divided into two experiments. In the first experiment Environmental Impact Assessment of Red mud pond of Damanjodi unit of NALCO, Koraput was studied where as species screening, analysis in different concentration of red mud were analyzed in the nursery and laboratory of Department of Natural Resource Management, College of Forestry, OUAT, Bhubaneswar.

Design: RBD

Number of treatments: 4

T_1 - 100% RM + NPK

T_2- 50% RM + 50% PM + NPK

T_3- 25% RM + 75% PM + NPK

T_0- Control condition + NPK

Number of Replication: 2

Poly pot size: 9inch X 4inch

Species: S_1 - *Acacia auriculiformis*

S_2 - *Acacia mangium*

S_3 - *Eucalyptus tereticornis*

S_4 - *Terminalia chebula*

Observations are recorded such as on soil texture, water holding capacity, pH, organic carbon, available nitrogen, available phosphorous and available potassium by following standard methods (Jackson, 1973).

For plant observation, various qualitative and quantitative characteristics like number of individuals of various plant species, survival percentage for each species, plant height, collar diameter and vegetation study were studied.

The impact of red mud pond at Damanjodi unit of NALCO, Koraput was studied on its surrounding environment. Accordingly, the baseline data was collected there in.

The data obtained from the experiments in desired replicates on various growth parameters such as survival percent, plant height, collar diameter, chlorophyll a, chlorophyll b, chlorophyll a/b, dry weight, fresh weight, were arranged in appropriate tables and were analysed as per the procedure prescribed for randomized block design to obtain the analysis of variance (ANOVA) (Gomez & Gomez, 1984). The variances were tested at 5% level of significance. Critical differences (CD) were estimated for comparing the treatments.

RESULT AND DISCUSSION

The results obtained during the present investigation are mentioned here in details.The physical properties of red mud studied are red colour, clay-loam texture and its water holding capacityClay-loam with poor water holding capacity. Similarly, the chemical properties of red mud such as pH, electrical conductivity, total nitrogen, available phosphorous, available potassium and organic carbon are presented in Table 1.

Table 1: Physico-chemical properties of red mud

Red mud properties	*Values*
Colour	Red
Texture Class	Clayey-Loam
Pore space (%)	48.1 ± 2.1
Water holding capacity (%)	58.2 ± 1.41
pH	11.45 ± 0.11
EC (mS/cm)	1.86 ± 0.01
Organic Carbon (%)	0.34 ± 0.01
Total N (mg/kg)	4.00 ± 0.01
Available P (mg/kg)	0.26 ± 0.03
Available K (mg/kg)	0.08 ± 0.95

The environmental impact of red mud pond is categorized as primary and secondary. Primary impacts are attributed directly by the red mud pond and the secondary impact is indirectly induced and typically include the associated with social and economic activities by the proposed action. The impact on land use change is presented in Table 2. It is observed that, there are no sensitive locations such as archaeological monuments, sanctuaries, national parks, etc within 10km radial distance around the red mud pond site. The chemical properties of red mud are presented in Table 3.

From the composition of the red mud, it can be observed that, the solubility of the constituents is minimal. It contains iron, silicon, calcium, titanium and sodium in form of oxides depending on the ore used. Apart from the high alkalinity from liquors the residue is chemically stable, non-toxic and non-hazardous in nature. The

Table 2: Land use pattern of study area

Sl. No.	Land use(in ha)	0-3km	3-7km	7-10km	%
1	Forest Area	55.28	206.01	402.48	2.25
2	Irrigated land	0.00	92.11	68.49	0.54
3	Un irrigated land	1749.21	4197.12	2542.58	28.81
4	Land under trees, crops area etc.	0.22	7.89	6.00	0.05
5	Area under Non-Agricultural Uses	258.05	479.39	361.53	3.73
6	Barren land	680.78	4325.74	3038.69	27.30
7	Permanent pasture and grazing area	26.77	247.77	160.07	1.47
8	Current fallow	225.29	411.57	112.67	2.54
9	Waste land	26.54	109.62	37.62	0.59
10	Urban areas	2506.00	3228.59	3518.11	31.40

Table 3: Chemical properties of red mud

Sl. No.	Parameter	Range (%)
1	SiO_2	5-7
2	Al_2O_3	10-15
3	Fe_2O_3	50-60
4	Na_2O	3-5
5	TiO_2	6-8

properties of untreated and treated wastewater from the project mingle with red mud pond is presented in Table 4. The impacts on terrestrial vegetation due to emission of gaseous pollutants like SO_2, PM and NO_2 andsoil properties are presented in Table5 and Table 6.

Table 4: Properties of water quality

Sl. No.	Parameters	Untreated Waste water	Treated Waste waster
1	pH	>9.0	6.5-8.5
2	Total Dissolved Solids (mg/l)	>5000	<2100
3	Total Suspended Solids (mg/l)	>300	<100
4	BOD (3d, 27 degree Celsius) (mg/l)	>100	<30
5	Oil & Grease (mg/l)	>50	<10

Table 5: Trees in and around red mud pond

Sl. No.	Scientific Name	Common Name	Family
1	*Grevillea robusta*	Silver Oak	Proteaceae
2	*Eucalyptus turliana*	Nilgiri	Myrataceae
3	*Syzygiumcumini*	Jamun	Myrataceae
4	*Psidium guajava*	Common guava	Myrataceae
5	*Syzygiumjambos*	Rose apple	Myrataceae
6	*Albizzia sripulata*	Tentra	Mimisaceae
7	*Dalbergialatifolia*	Sissoo	Fabaceae
8	*Alstoniascholoaris*	Chhatian	Apocynaceae
9	*Pongamiapinnata*	Karanj	Fabaceae
10	*Artocarpusheterophyllus*	Jack fruit	Anacardiaceae
11	*Haldinacordifolia*	Kadamba	Rubiaceae
12	*Azadirachtaindica*	Neem	Meliaceae
13	*Anogeissuslatifolia*	Dhaura	Combretaceae
14	*Cassia fistula*	Amaltas	Caesalpinaceae
15	*Diospyros melanoxylon*	Tendu	Ebenaceae
16	*Dendrocalamusstrictus*	Bans	Poaceae
17	*Ficus religiosa*	Peepal	Moraceae
18	*Ficus bengalensis*	Banyan	Moraceae
20	*Lanneacoromandelica*	Mohin	Anacardiaceae
21	*Morindatinctora*	Aal	Rubiaceae
22	*Pterocarpus marsupium*	Bija	Fabaceae
23	*Emblica officinalis*	Indian Gooseberry	Euphorbiaceae
24	*Tamaindusindica*	Imli	Fabaceae
25	*Terminalia belerica*	Bahera	Combretaceae

Table 6: Shrubs in and around red mud pond

Sl. No.	Scientific Name	Common Name	Family
1	*Andrographis panic-ulate*	Kirayat	Acanthaceae
2	*Lantana camera*	Wild sage	Verbanaceae
3	*Gardenia gummifera*	Gummy gar-denia	Rubiaceae
4	*Holarrhenapubeseens*	Korvaindraju	Apocynaceae
5	*Woodfordiafruticose*	Dhatki	Lythracea
6	*Leucas aspera*	Chhotahalkusa	Lamiaceae
7	*Rugiarepens*	Kharmor	Acanthaceae
8	*Arundinellasetosa*	Jhadu grass	Poaceae
9	*Aristida setaceae*	Ghoralengi	Poaceae
10	*Cynodondactylon*	Doob grass	Poaceae
11	*Eragristisunioloides*	Chinese love grass	Poaceae
12	*Heteropogancon-tortus*	Black spear grass	Poaceae
13	*Dioscoreatomentosa*	Taranga	Dioscoreaceae
14	*Glioriosa superb*	Flame lily	Colchicaceae
15	*Mucunapruriens*	VevetBean	Fabaceae

However, the study and analysis made in Department of Natural Resource Management are presented here. The survival percent (%) as influenced by different species at different red mud mixture level have been presented in the Table 7& Fig. 1 and Fig. 2.

Table 7: Survival percent as influenced by different species at different red mud mixture level

Month / Species	*1st Month (February)*	*2nd Month (March)*	*3rd Month (April)*	*4th Month (May)*	*5th Month (June)*
A. auriculiformis	99.62	99.25	99.12	99.00	99.12
A. mangium	94.00	92.62	92.00	91.50	91.12
E. tereticornis	94.62	93.75	93.25	93.00	92.87
T. chebula	98.12	97.62	96.75	96.62	96.62
L.S.D (0.05)	**0.78**	**0.55**	**0.706**	**0.72**	**0.68**
T_0	99.50	99.00	99.00	94.87	94.62
T_1	95.92	95.00	92.50	92.25	91.00
T_2	97.87	96.25	96.00	95.75	95.75
T_3	98.37	97.62	97.50	97.25	97.25
L.S.D (0.05)	**0.78**	**0.55**	**0.706**	**0.720**	0.68

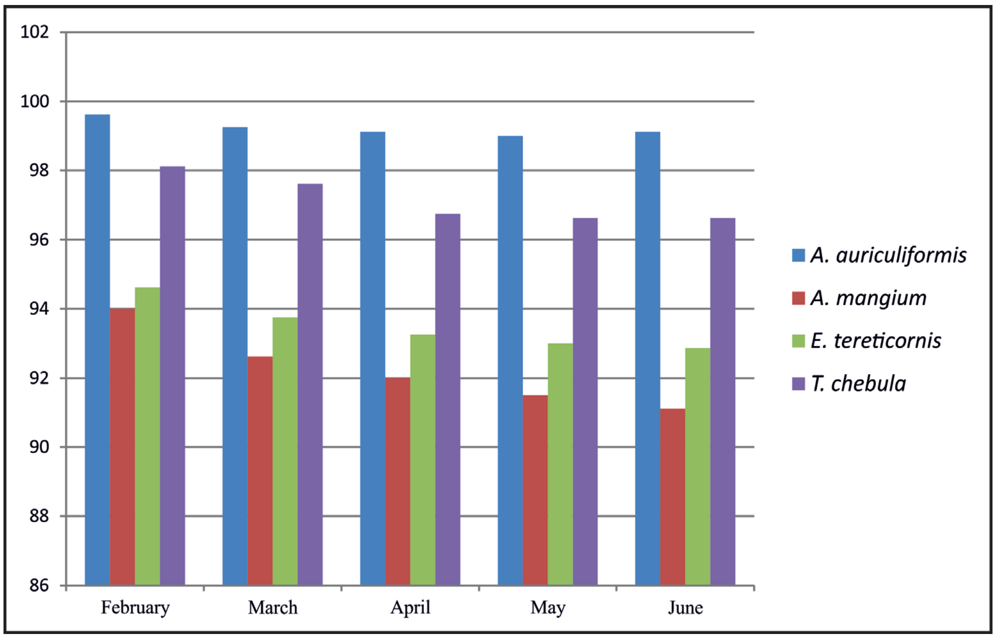

Fig. 1: Survival % of different species

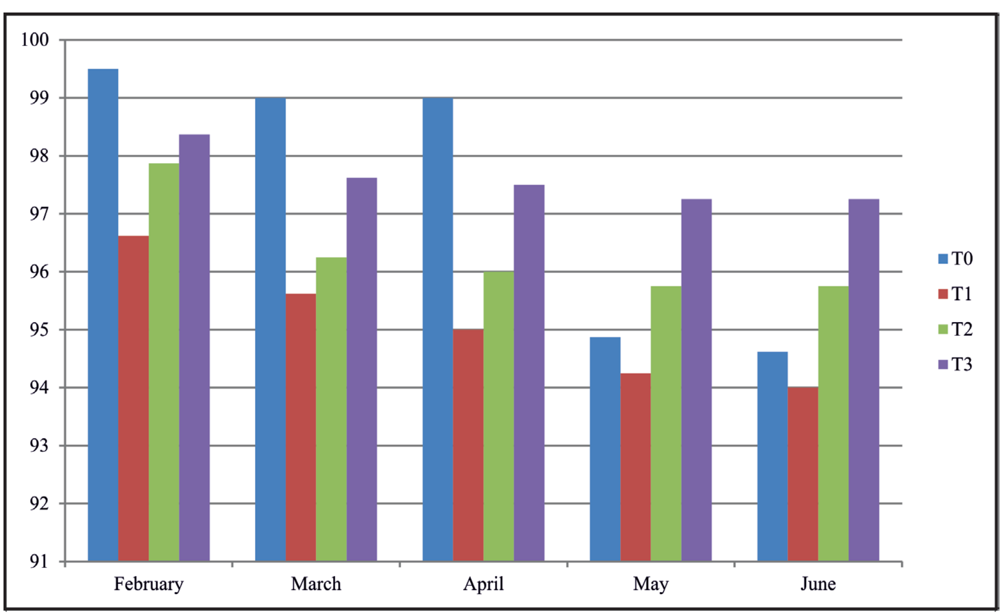

Fig. 2: Survival percent of plants in different treatments level

The survival percent is seen high in *Acacia auriculiformis* followed by *Terminalia chebula* and least in *Acacia mangium.* The survival percent in T_1 (100% RM) is least. However, it improves with treatment having lower concentration of red mud. Plant height as influenced by different red mud mixture is presented in Table 8.

It is evident from the data that the overall rate of increase of plant height was slow in T_1 (100% RM) as compared to the T_0 (Control). The highest height growth is observed in *Acacia auriculiformis*is higher where, lowest in *Terminalia chebula.* The plant height among different species at the age of 5 months stage is in the order $T_0 > T_3 > T_2 > T_1$.

The collar diameter (mm) recorded as influenced by different species at different red mud mixture level in represented in Table 9.

From the above data it is revealed that, collar diameter increased in T_3 as compared to $T_{1.}$ The maximum collar diameter was recorded in *Acacia auriculiformis* and least in *Acacia mangium*. It grows vigorously after the 3rd month. It is observed that the increase in collar diameter is least in T_1 (100% RM) and increasing continuously with lowering of the concentration of red mud.

Table 8: Plant height (cm) as influenced by different species at different red mud mixture level

Month / Species	*1st Month (February)*	*2nd Month (March)*	*3rd Month (April)*	*4th Month (May)*	*5th Month (June)*
A. auriculiformis	21.18	22.57	24.26	28.20	31.73
A. mangium	19.42	20.26	20.91	22.48	24.60
E. tereticornis	20.00	20.91	21.91	24.28	27.16
T. chebula	8.97	9.90	11.40	13.03	14.07
L.S.D (0.05)	**0.16**	**0.16**	**0.17**	**0.18**	**0.19**
T_0	24.07	25.73	26.45	30.05	33.42
T_1	23.26	23.92	25.07	27.47	31.22
T_2	24.85	26.07	27.46	30.80	34.33
T_3	8.97	9.90	11.40	13.03	14.07
L.S.D (0.05)	**0.16**	**0.16**	**0.17**	**0.18**	0.19

Table 9: Collar diameter (mm) as influenced by different species at different red mud mixture level

Month / Species	1st Month (February)	2nd Month (March)	3rd Month (April)	4th Month (May)	5th Month (June)
A. auriculiformis	1.86	2.26	2.37	2.88	3.30
A. mangium	1.68	1.84	1.92	2.18	2.46
E. tereticornis	1.68	1.91	2.09	2.38	2.84
T. chebula	1.80	2.09	2.23	2.64	3.10
L.S.D (0.05)	**0.042**	**0.046**	**0.065**	**0.061**	**0.084**
T_0	2.16	2.43	2.68	3.00	3.40
T_1	1.22	1.27	1.31	1.40	1.43
T_2	1.65	1.70	1.75	1.79	2.42
T_3	1.99	2.19	2.27	2.65	2.88
L.S.D (0.05)	**0.042**	**0.046**	0.065	0.061	0.084

Fresh weight of plant is an important index of tree growth. The data on mean plant fresh weight recorded at successive month have been presented in Table 10. The highest fresh weight was recorded in *Acacia auriculiformis* and least in *Acacia mangium. Terminalia chebula* shows a good growth rate. The fresh weight of plants in various treatment is $T_0 > T_3 > T_{2 >} T_{1.}$ While, the dry weight of plant recorded at successive month have been presented in Table 11 & Fig. 3&4. The highest dry weight was recorded in *Acacia auriculiformis* and least in *Acacia mangium. Terminalia chebula*shows a good growth rate. The fresh weight of plants in various treatment is $T_0 > T_3 > T_{2 >} T_{1.}$

Table 10: Plant Fresh weight (g) as influenced by different species at different red mud mixture level

Month / Species	*1st Month (February)*	*2nd Month (March)*	*3rd Month (April)*	*4th Month (May)*	*5th Month (June)*
A. auriculiformis	87.15	90.50	93.77	105.16	116.62
A. mangium	79.33	83.38	85.63	91.73	97.12
E. tereticornis	82.15	85.90	89.40	95.70	101.30
T. chebula	84.80	87.95	91.15	100.25	108.08
L.S.D (0.05)	**0.302**	**0.541**	**0.224**	**0.366**	**0.49**
T_1	89.85	95.20	98.07	106.85	114.21
T_1	77.90	82.15	85.86	93.30	99.92
T_2	81.73	84.36	87.06	95.48	103.50
T_3	85.37	90.54	95.41	101.3	109.8
L.S.D (0.05)	**0.302**	**0.541**	**0.224**	**0.366**	0.49

Table 11: Plant Dry weight (g) as influenced by different species at different red mud mixture level

Month / Species	1st Month (February)	2nd Month (March)	3rd Month (April)	4th Month (May)	5th Month (June)
A. auriculiformis	30.83	33.76	36.88	41.37	45.16
A. mangium	24.68	29.76	31.55	34.11	36.30
E. tereticornis	26.93	31.63	33.41	36.08	38.92
T. chebula	29.12	32.55	34.82	38.53	42.42
L.S.D (0.05)	**0.200**	**0.235**	**0.382**	**0.324**	**0.163**
T_0	30.63	37.45	40.35	42.70	46.03
T_1	23.98	26.31	28.78	33.61	36.23
T_2	26.41	29.77	31.75	35.61	38.55
T_3	30.55	34.17	35.75	38.18	41.98
L.S.D (0.05)	**0.200**	0.235	0.382	0.324	0.163

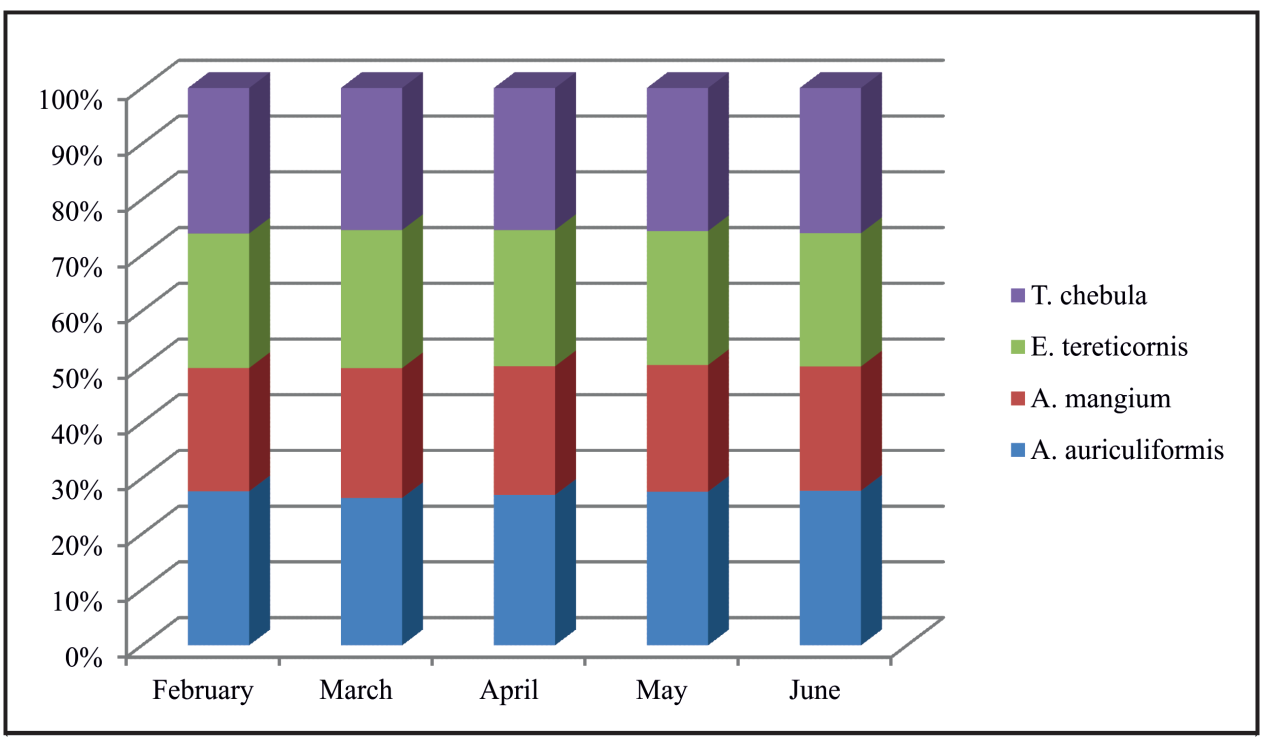

Fig. 3. Dry weight of different species

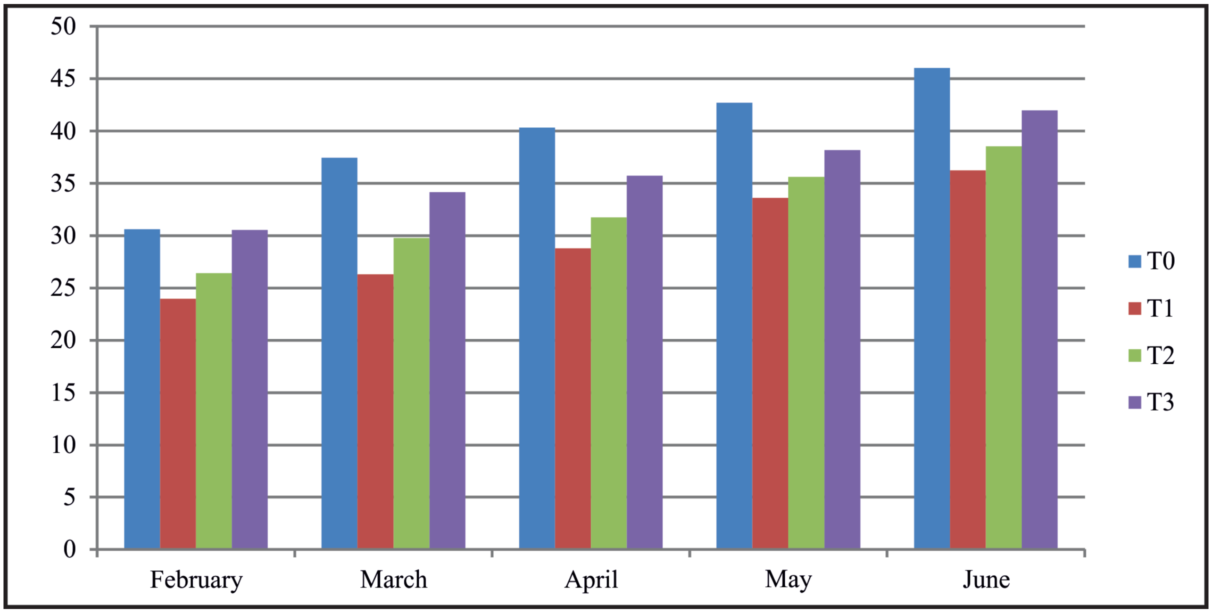

Fig. 4: Dry weight of plants in different treatments

In dry weight content of the plants it is observed that, in T_3 (109.8 g/ plant) possesses significantly higher dry weight than T_2 (103.5 g/ plant) & T_1 (99.12 g/ plant). It is also observed that *Acacia auriculiformis* has maximum dry weight (45.16 g/plant) followed by *Terminalia chebula* (42.42g/plant), *Eucalyptus tereticornis* (38.92g/ plant) and least in *Acacia mangium* (36.30g/ plant). So, the above experiment indicated that *Acacia auriculiformis* possesses higher dry weight at 5months stage in treatment level T_3 followed by T_2 and $T_{1.}$ *Acacia auriculiformis* has higher survival percentage in red mud composition and has higher efficiency than other species followed by *Terminalia chebula*. Similar findings were reported by Banning, *et al*., 2011;Chauhan and Silori. 2010; Wong and Ho, 1993 and 1994; and Krishna *et al*., 2005.

CONCLUSION

During the study of Environmental Impact Assessment of red mud of refinery unit of NALCO at Damanjodi of Odisha that, the red mud pond has least effect to the adjoining eco-regions. However, its utilization through vegetation and a strong green belt development need to be generated for wider impact and sustainability of the project. Sufficient measures required to conserve the local species particularly the dominant herb, shrubs and trees in the eco region. From the study on reclamation of red mud, steps have been taken to utilize red mud through two leguminous species i.e. *Acacia auriculiformis, Acacia mangium* and two non-leguminous species such as *Eucalyptus tereticornis* and *Terminalia chebula*. It is observed that *Acacia auriculiformis* showed better results in its survival percent, plant height, collar diameter, fresh weight and dry weight followed by *Terminalia chebula*. Both the species are very hardy and adjusted to drier types overcome to alkaline conditions. Further T_3 level (25% RM + 75% Soil mixture) is significantly better performing than other treatments. So it is recommended that the red mud can be utilized in afforestation activities to 25% in developing its greenbelt and other nurseries of the state.

References

Agarwal, R and M. Shashikanth,2008. Sintering Characteristics of Red Mud Compact. B. Tech. Thesis, National Institute of Technology, Orissa, India.

Alvarez, J., R. Rosal, H. Sastre and F. V. Diez. 1995. Characterization and deactivation of sulfided red mud used as hydrogenation catalyst, Applied Catalysis, 128: 259.

Anonymous. 2011. Environmental Impact Assessment, Review of NALCO, Damanjodi, Odisha.

Banning, N.C., I.R. Phillips, D.L. Jones and D. V. Murphy. 2011. Development of microbial diversity and functional potential in bauxite residue sand under rehabilitation, *Restoration Ecology,* 19: 78–87.

Browner, R.E. 1995. The use of bauxite waste mud in the treatment of gold ores, *Hydrometallurgy,* 37: 339-348.

Cooling, D.J and D. J. Glenister. 1992. Practical aspects of dry residue disposal, Proceedings of the 121st TMS Annual Meeting 25-31.

Chauhan, S and C. S. Silori. 2010. Rehabilitation of red mud bauxite wasteland in India (Belagaum, Karnataka). Ecological Restoration 28: 81-86.

Dimas, D.D., I. P. Giannopoulou and D. Panias. 2011. Utilization of alumina red mud for synthesis of inorganic polymeric materials, Mineral Processing and Extractive Metallurgy Review, 30: 211-239.

Eamsiri, A., W. R. W. R. Jackson., K.C. Pratt., V. Christov and M. Marshall. 1992. Activated red mud as a catalyst for the hydrogenation of coals and of aromatic- compounds, Fuel 71: 449-453.

Fortin, S., A. Lamontagne., R. Poulin and N. Tasse. 2000. The use of basic additives to tailings in layered co-mingling to improve acid mine drainage control, In SWEMP 2000, Proceedings of the 6th International symposium on environmental issues and management of waste in energy and mineral production, Calgary, Alta, 549-556.

Gomez, K.A and Gomez, A.A. 1984. Statistical procedures for agricultural research, Secong Ed. An International Rice Research Institute Book, Welley, New York, pp 684.

Hanumanth, Rao., N. Ganapati.,P.P.V.Satyanarayan and S. Vand Adiseshu. 2012. Application of GGBS stabilized Red mud in Road Construction" ISSN: 2250- 3021 Volume 2, Issue 8: PP 14 – 20.

Jackson, M.L. 1973. Soil Chemical Analysis.Prentice Hall of India.New Delhi, 498 pp.

Komnitsas, K., G. Bartzas and I. Paspaliaris. 2004. Efficiency of limestone and red mud barriers: laboratory column studies, *Minerals Engineering,* 17: 183-94

.Krishna, P., M.S. Reddy and S. K. Patnaik. 2005. *Aspergillus tubingensis*reduces the pH of the bauxite residue (red mud) amended soils, *Water, Air and Soil Pollution,* 167: 201-209.

Mohapatra, B. K., M.B.S. Rao., .B.R, Rao and A. K. Paul. 2000. Characteristics of red mud generated at NALCO refinery, Damanjodi, India.

Paramguru, R. K., P. C. Rath and V. N. Misra. 2005. Trends in red mud utilization- a review. Miner. Process. Extr. Metall. Rev. 26, 1-29.

Paradis, M., J. Duchesne., A. Lamontagne and D. Isabel. 2007. Long-term neutralization potential of red mud bauxite with brine amendment for the neutralization of acidic mine tailings Applied Geochemistry, 22: 2326-2333.

Parek, B.K and Goldberger, W. 1976. An Assessment of Technology for Possible Utilization of Bayer Process Muds. Battelle Columbus Labs Report No. EPA- 600/2-76-301, Columbus, OH.

Singh, A.P., P. C. Singh and V.N. Singh. 1993. Cyclohexanethiol separation from kerosene oil by red mud, *Journal of Chemical Technology and Biotechnology,* 56: 167.

Summers, R.N., M D A. Bolland and M. F. Clarke. 2001. Effect of application of bauxite residue (red mud) to very sandy soils on subterranean clover yield and P response, *Australian Journal of Soil Research,* 39: 979-990.

Tuazon, D and G. D. Corder. 2008. Life cycle assessment of seawater neutralized red mud for treatment of acid mine drainage. Resources, *Conservation and Recycling,* 52: 1307-1314.

Wong, J.W.C and G. E. Ho. 1993. Use of waste gypsum in the revegetation on red mud deposits: a greenhouse study, *Waste Management Research,* 11: 249-256.

Wong, J.W.C and G. E Ho. 1994. Effectiveness of acidic industrial wastes for reclaiming fine bauxite refining residue (red mud), *Soil Science,* 158: 115-123.