American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-02, Issue-09, pp-147-153
www.ajer.org

Research Paper Open Access

Experimental Study of Turbidity Control by Coagulation for Salt Gradient Solar Pond

S P Shekhawat[1], Dr N V Halegowda[2], and Dr M Husain[3]
[1]*Research Scholar, North Maharashtra University, Jalgaon, India,*
[2]*Principal, Adsul College of Engineering, Ahmadnagar, India,*
[3]*Professor, SSBT's College of Engineering & Technology, Bambhori, Jalgaon, India.*

***Abstract*: -** Salt Gradient Solar Pond (SGSP) is futuristic energy option for Indian conditions. India's solar energy potential is immense. It has a long coastal line that can provide salt water for SGSP. The turbidity has a great influence on radiation transmission in SGSP water. In the present study, it is observed that the effectiveness of Aluminum Sulfate (Alum) in reducing the turbidity in the experimental SGSP is investigated. The optimum dose is worked out. It is hoped that the present work will assist the researchers in the solar energy and will provide them useful scientific data base.

***Keywords*: -** *Coagulation, Radiation, Salt Gradient Solar Pond, Turbidity*

I. INTRODUCTION

Mankind is not threatened with an energy crisis due to the exhaustion of oil, gas, and coal reserves if it masters the technologies for using renewable energy [1]. On May 26 2010, California, US President Barak Obama declared, "The nation that leads the clean energy economy will be the nation that leads the global economy" [2]. Now it is an urgent need for the scientists and technocrats to explore alternative sources of renewable energy. The dawn of twenty-first century has brought two major challenges for the human civilization i.e. energy crises and environmental degradations. Interestingly, both the issues are deeply interlinked. The alternative energy is the only reliable option to solve the problem of environmental degradation and energy crises. The conventional energy is rapidly depleting and civilization has come to a critical juncture.

A Salinity-Gradient Solar Pond (SGSP) is a combined solar energy collector and heat storage system reliant upon an aqueous solution of salt at varying densities to suppress natural convection and store thermal energy [3]. The SGSP consists of three different zones; the upper convective zone (UCZ) with uniform low salinity; a non-convective zone (NCZ) with a gradually increasing density; and a lower convective zone (LCZ), called the storage zone, having uniform density as shown in Figure 1.

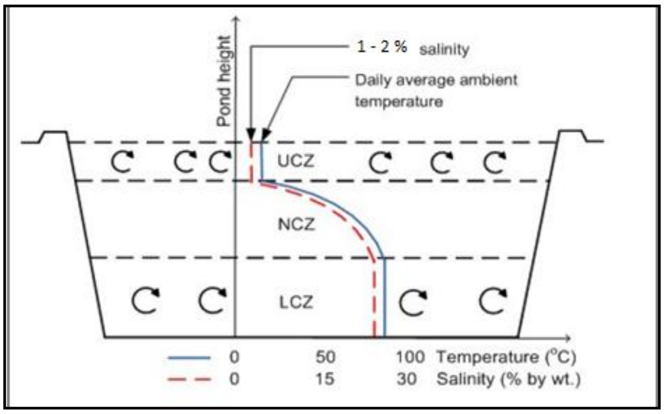


Figure 1. Schematics of a Salt Gradient Solar Pond.

Srinivasan has reported that the thermal efficiency of a solar pond is strongly dependent upon the clarity of the pond. Clarity is reduced by the presence of algae or dust [4]. Wind born turbidity and microbial growth in water are the principal sources of clarity loss in pond [4]. Clarity as such is a qualitative term. Wang and Yagoobi first used the term turbidity to quantify the same and used Nephelometric Turbidity Units (NTU) to express the it [5].

Turbidity is a complex phenomenon contributed by several natural and artificial sources. It is defined as a phenomenon of orthogonal scattering and absorption of visible light due to colloidal solids in fluid [6]. Researchers Many researchers have been extensively studied the effect of turbidity and its impact on thermal performance of SGSP. The water turbidity control of pond water is still a challenging problem during the operation period of solar ponds since its transparency is easy to get worsen in the open environment [7],[8],[9,[10].

Wang and Seyed-Yagoobi introduced turbidity in their radiation transmission model, and indicate that water turbidity plays a critical role in the thermal performance of solar ponds[11]. High turbidity levels can prevent ponds from storing energy. Therefore, the turbidity levels within the pond must be regularly monitored and kept as low as possible. Coagulation-flocculation is a well known phenomenon to remove turbidity. Coagulation in water is a four stage phenomenon as described by following schematics:

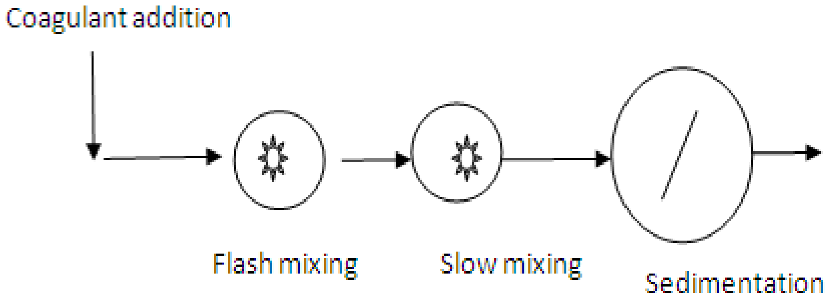


Figure 2: Coagulation Process

It was reported that alum, a low-cost chemical, has the ability to well depress the breeding of algae and bacteria, largely reduce the turbidity of seawater and keep it a long-lasting limpidity [12]. Therefore, it can be applied in the solar pond on a large scale as an efficient and economical turbidity reduction chemical. alum when added to water reacts with the natural alkalinity to form insoluble aluminum hydroxide. The rapid mixing is done with an objective of dissolving the alum in water and mixing it with the entire volume. The slow mixing is done to bring in contact the insoluble molecules together which get polymerized and form floc. The floc comes in contact with colloidal particles and forms larger floc. However in case of SGSP, there are density gradients prevailing. Hence mixing is not permitted. Thus coagulation in SGSP is a simplified two step process:

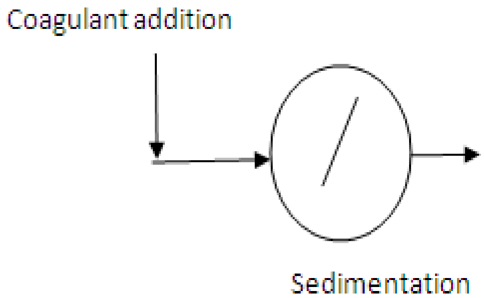


Figure 3: Simplified Coagulation Process

II. SCOPE OF SGSP IN INDIA

Salt gradient solar ponds have great scope in India. This is because the sea water which is an economical raw material to establish a SGSP is available in ample in India due to its long coastal line. Solar energy which is the driving force for solar pond, is available is India in abundance due to its geographical placement and clear sky. Over and above this, India has technical expertise in this area due to its great scientists and engineers who have worked in this field. In Kutch area of Gujarat one commercial SGSP has worked successfully for several years during early 90s. Experimental SGSPs have worked successfully at Indian Institute Technology, Delhi, Indian Institute of Science, Bangalore and Birla Institute of Technology, Ranchi. Thus India has a great scope of harnessing solar energy through s SGSP.

Estimation of SGSP potential in India:
Power requirement of India = 120000 MW
Solar radiation (Average) = 200 W
Thus land area of SGSP required to harness desired
level of energy = $120000*10^6/200$
$= 600 *10^6 m^2$.
However, SGSP has conversion efficiency around 20%.
Thus actual area required = $600 *10^6/20\% = 3000* 10^6 m^2$ = 3000 sq km only.

When a thermal or nuclear power plant is established, they occupy area not only for construction and waste disposal, but also for safety and pollution control purpose. Their effective area coverage is significantly large. However data regarding actual land area covered by thermal power plants and nuclear power plants is not found in literature.

India has ambitious plan gaining manufacturing expertise, especially in solar thermal technology, to be able to deliver 2000 MW off-grid applications during 2017-2022 [13]. Solar Pond is one of the important options for off-grid solar thermal applications as mention in directions, innovations and strategies for renewable energy in Vision – 2020 by The Energy and Resource Institute (TERI) [14].

III. COAGULATION STUDIES

The experimental studies are carried out at Shrama Sadhana Bombay Trust's College of Engineering and Technology, Bambhori, Jalgaon, MS, located in Jalgaon city (21.05N, 75.57E, at 250 m from mean sea level) of India. The location is having tropical climate. The study is carried out in the months of April to August. April has clear sky and very high radiation with mild winds. May also has the same parameters associated with high winds. The high winds are responsible for large dust loads. In June the climate turns with the arrival of monsoon. The sky is cloudy with heavy winds. Sometimes sky is clear too with high radiation. In July and August the wind velocity again reduces. Sky is almost covered. Due to rains the landscape soil becomes moist and wind carries less dust load.

Figure 4: Experimental Pond

Turbidity Control and Alum

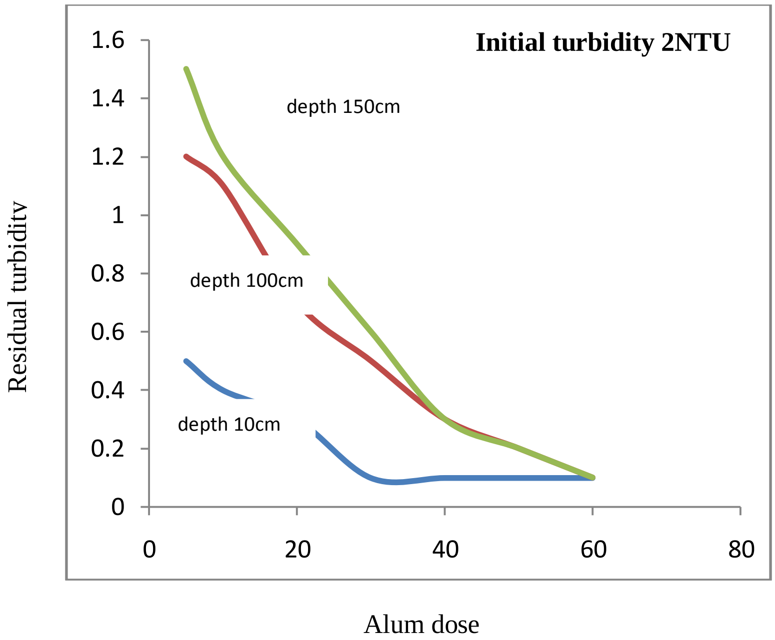
The present study has investigated the efficiency of alum in reducing the turbidity in the experimental pond. The experimental methodology is described in following steps:

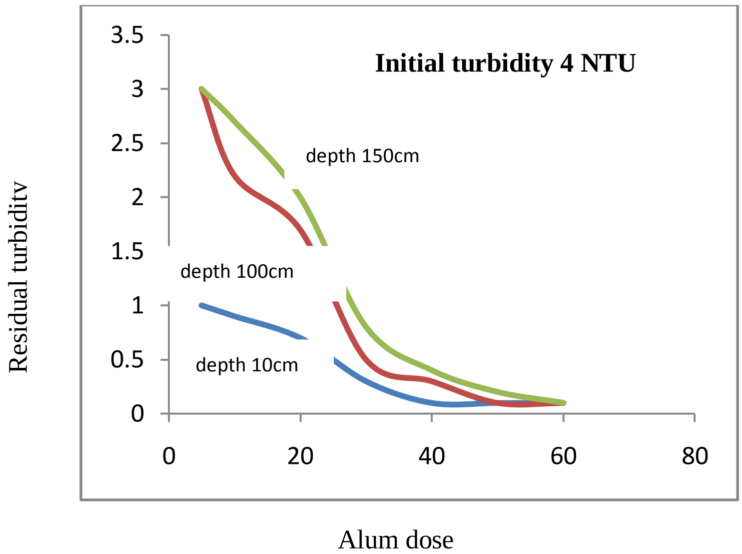
- Stock alum solution is prepared by dissolving laboratory grade alum in to water having strength of 1mg/mL.
- Artificial turbidity is created in the pond by using clay. Clay is first dissolved in water buckets. The large size particles are allowed to settle down for 6 hours. The supernatant is poured in the experimental pond. Then it is mixed with the tank content using large size rods.
- The turbidity of the tank water is measured. It is adjusted to the desired level (~2 NTU) by adjusting the quantity of supernatant being poured.
- Now the tank is added with alum solution. Taking into account the volume of tank, 5 mg/L alum is added (1 mL of alum solution contains 1 mg of alum).
- The turbidity is allowed to settle for 24 hours.
- Now, samples of water are collected from top 10cm, 1 m depth and 1.5 m depth. The samples are examined for turbidity level under Nephelo-turbidity meter.

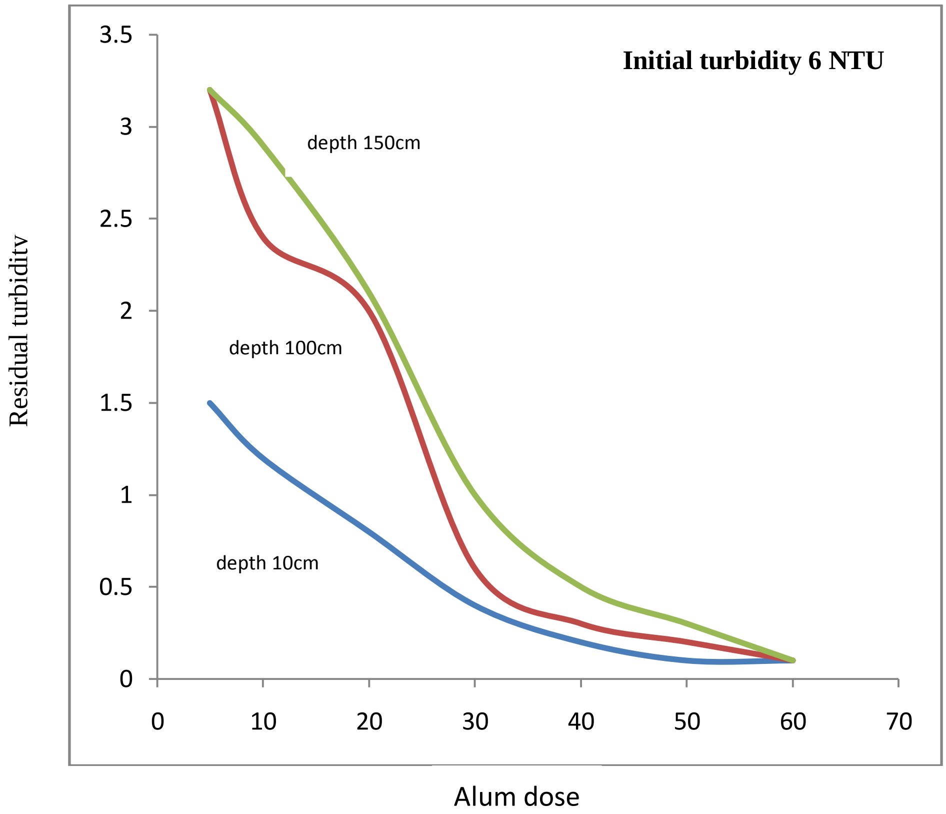
- The tank is emptied and refilled with tap water. Artificial turbidity to the *same* desired level is again created in the tank as described above.
- The tank is dosed with 10 mg/L alum. The entire process is repeated.
- Similar process is done with alum dose varying from 10 mg/L to 60 mg/L with steps of 10 mg/L.
- Again, artificial turbidity is created by the process described above. This time the desired level is kept as 4NTU.
- The entire process of removal is followed.

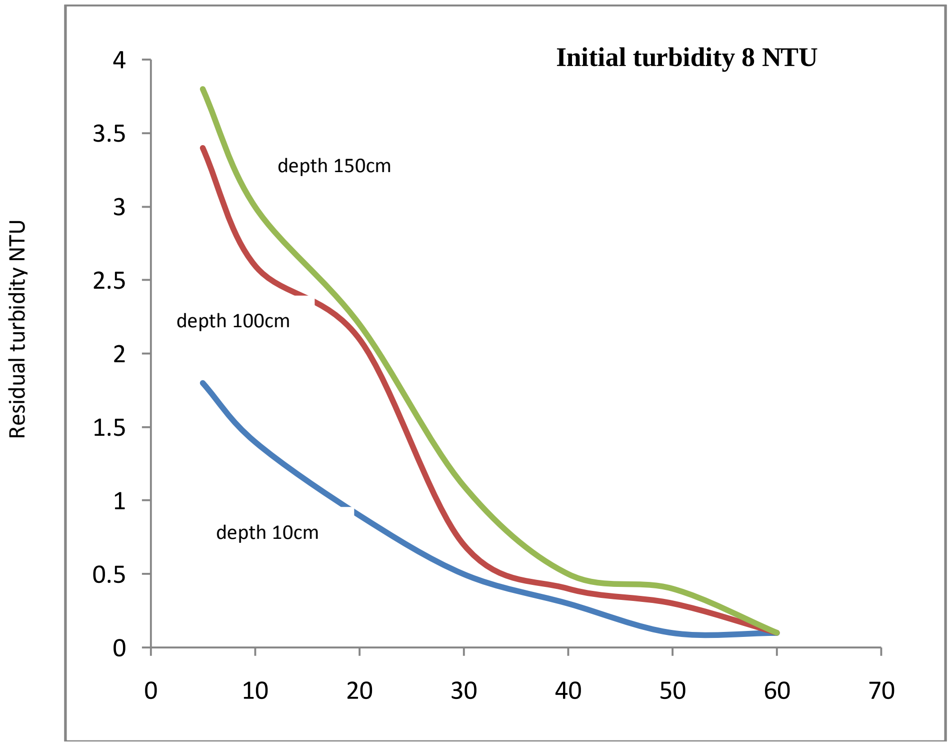
IV. RESULTS AND DISCUSSIONS

Turbidity removal is a complex process. Turbidity itself is a complex parameter. It includes a combination of concentration of suspended particles in a particular size range, their shape, their hydro-philicity, their color and many other parameters. These parameters cannot be measured with desired accuracy. Hence turbidity removal cannot be mathematically modeled. It can be only described by the experimental data. The experimental results are presented in following graphs.

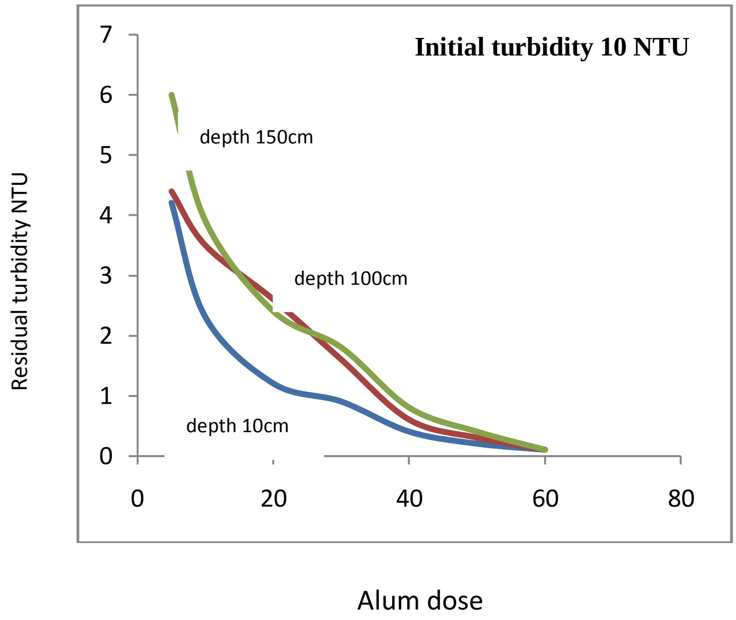


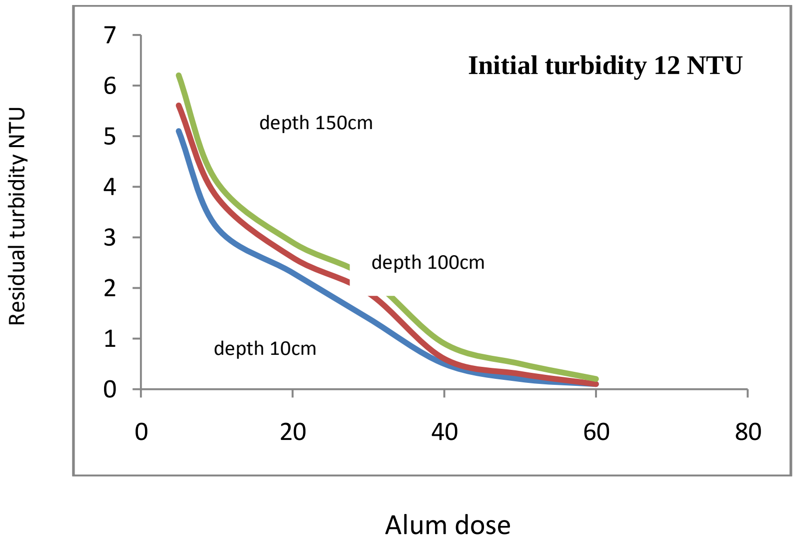



Initial turbidity 6 NTU
Residual turbidity
Alum dose
depth 150cm
depth 100cm
depth 10cm
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70


Initial turbidity 8 NTU
Residual turbidity NTU
depth 150cm
depth 100cm
depth 10cm
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70

Alum dose





The above results lead to the following interpretations:

- Alum is an effective coagulant for removal of turbidity.
- Alum dose cannot remove turbidity below 0.1 NTU. This is an important observation. In fact this means that pond designers must consider minimum 0.1NTU turbidity in water while estimating the thermal performance and efficiency for realistic estimations.
- The turbidity of top layer is reduced first and then it travels downward.
- Alum dose up to 50 mg/L can effectively reduce turbidity as high as 12 NTU.
- Alum dose does not increase in proportion to the turbidity. This is due to the complexities involved in the removal mechanism. In fact the alum removal process cannot be accurately modelled. Therefore data base is useful information for pond operators to control turbidity.
- The information generated by this experimental study will be a useful guideline for future pond researchers, pond designers and pond operators.
- It is observed that as turbidity level and depth of the pond increases, transmission of solar radiation reduces. It is also clear that turbidity due to dust or wind born debris adversely affects the solar radiation transmission of the pond or performance of the pond.

V. CONCLUSIONS

SGSP's are open to atmosphere. They essentially accumulate wind born turbidity. The present work has estimated the rate of turbidity accumulation and observed that the turbidity can be effectively removed by using alum for coagulation process. Alum dose in the range 50 mg/L can effectively reduce the turbidity of water. The turbidity cannot be reduced to zero level, yet it can be brought down to minimum permissible level.

VI. ACKNOWLEDGEMENTS

This work is supported by the Shram Sadhana Bombay Trust's, College of engineering and Technology, Jalgaon, India under Shram Sadhana Research Promotion Scheme. The authors wish to thanks the Management, Principal and Director of Research and Development of the institute for support and encouragement.

REFERENCES

[1] D. S. Strebkov, "Solar Power Engineering in the Future World: A View from Russia", Applied Solar Energy, Vol. 48, No. 2, 2012,pp. 71–75, ISSN 0003701X.

[2] Sun and Wind Energy, 2010, no.7, p. 8.

[3] Hull J R, K V Liu, W T Sha, J Kamal, and C E Nielsen, " Dependence of ground heat loss upon solar pond size and perimeter insulation: calculations and experimental results", Solar Energy, 33, 661-666., 1984

[4] Srinivasan J., "Solar pond technology", Sadhana, Vol. 18, Part 1, March 1993, pp. 39-55.

[5] Wang J and S Yagoobi , "Effect of Water Turbidity on Thermal Performance of a Salt Gradient Solar Pond", Solar Energy, 54(5), 301-308.,1994

[6] APHA, AWWA and WPCF, "Standard Methods for the Examination of Water and Wastewater", 16th edition, 1985.

[7] Atkinson, J.F., Harleman, D.R.F., A wind-mixed layer model for solar ponds. Solar Energy 31, 243–259, 1983.

[8] Nan Li , Fang Yin , Wence Sun , Caihong Zhang , Yufeng Shi, "Turbidity study of solar ponds utilizing seawater as salt source", Solar Energy 84 , 289–295, 2010

[9] Hassab, M.A., Tag, I.A., Kamaland, W.A., Al-Noaimi, F.M., "Problems encountered in operating salt gradient solar pond in the Arabian Gulf region", Solar Energy 43, 169–181., 1989

[10] Hull J R , " Computer simulation of solar pond thermal behavior", Solar Energy, 25,33-40.,1980

[11] M. A. Punyasena, C. D. Amarasekara, J. R. P. Jayakody, P. A. A. Perera, Construction and Commissioning of a Large-area Salt-gradient Solar Pond at Palatupana Salterns in Southern Sri Lanka. Proceedings of the 19th Technical Session of the Institute of Physics - Sri Lanka, 65, 2003

[12] Wang J and S Yagoobi , " Effect of Water Turbidity and Salt Concentration Levels on Penetration of Solar Radiation Under Water", Solar Energy, 52(5), 429-438, 1995

[13] Report of World Energy Council, 2010.

[14] R. K. Pachauri and Pooja Mehrotra, " Vision 2020: Sustainability of India's Material resources", TERI, New Delhi