# Waste Paper Sludge Ash - State of art

**V. Logeswaran, G. Ramakrishna**

***Abstract*: The paper analyses the study of waste paper sludge ash from two different paper manufacturing industry mainly on the physical, chemical and Microstructural properties. Waste paper sludge is not a hazardous industrial waste mainly consisting of cellulose and calcite , waste paper sludge are calcined at 750oC,800 oC and 850 oC for a retention period of 2 hours, the calcined waste paper sludge ash exhibits excellent pozzolanic activity (as per Literature). On the grounds of the literature reviewed, waste paper sludge ash confirmed to be an environmentally sound source material that could be used as a supplementary cementitious material in the manufacture of future eco-efficient cements.***

***Index Terms*: Waste paper, Sludge, Microstructural Properties.**

## I. INTRODUCTION

Cement is one of commonly used construction material worldwide, the use of wastes from the industrial processes is the interest both from the environment point of view and also financial stand point. As we know to produce cement large amount of natural resources are being utilized (CaO, MgO and $Al_2O_3$,).Additionally the global warming also can occur because of the green house gases such as carbon-di-oxide emission to the environment (Pradeep Kumar Rana) Waste paper sludge ash is another important by product or wastes from the paper industry which can be partially used in cement as a supplementary cementitious material. Europe generate 11 million tons of Paper wastes yearly (Monte). Italy produces around $6x10^5$ tons of sludge yearly , Around 60 Kg of ash can be produced from 1000Kg of paper waste sludge (Valeria). For the past two decades, the use of recovered paper industry has gradually increased to an amount of 5 Million tons (J.Bai), Waste water released from the integrated pulp & paper industry is approximately 22 to $35m^3$ per ton of paper produced (K.Sudarshan). In India 300 million tons of industrial wastes are being produced per annum by chemical and agricultural process (Srinivasan). Waste paper sludge ash become a new innovative material that can be used as material masonry to support the green technology due to less presence of sulphate at only 0.57% of the total weight (Hiroji Ishimoto). The use of paper mill sludge in structural concrete could be economical and profitable for landfills, incinerators and other options for reducing paper mill sludge wastes , Paper mill sludge waste is suitable for use in small amounts of concrete mixes as a replacement for cement but it is not appropriate for large quantities (A.M.Md.Nazar). Waste paper sludge ash contains reactive components such as free lime (CaO), and less reactive inert mineral species (E.Mozaffari). When Waste paper sludge ash combined with Ground Granulated Blast furnace slag (GGBS) it enhance the cementitious properties of WPSA, also the strength obtained by these combination is increased with control mix (E.Mozaffari). Waste paper sludge ash contains hydraulic minerals such as (CaO), Mayenite ($Ca_{12}Al_{14}O_{33}$) and α'-$CaSiO_4$ in addition to gehlenite , as the main mineral (P.Segui). Calcined residual paper sludge contains highly reactive metakaolin exhibits good pozzolanic properties and permits its incorporation in cement systems (Raul Fernandez). Waste paper sludge ash consist of Calcite, Free lime , Gehlenite, Tricalcium, Aluminate, Belite, Talc, Quartz and glassy phase (Gregor J.G.Gluth). The main constituents element of paper mill sludge are Al, Mg, Si and Ca whose oxides are largely used in concrete industries, therefore burning paper sludge represents two sources of cost saving for paper mill : reduced disposal cost and reduced fuel consumption for Steam Generation/ Energy production (Gabriele Fava) The ash contents of the paper sludge were about 73.7, 46.2 and 38.1% with the particle size of below 0.15, 0.18-0.25 and 0.42-0.84 mm respectively which means lower the ash content and higher the cellulose fibre content, since the particle size of the paper sludge decreased the swelling thickness, water absorption and tensile , flexural strength of the composite improved (Jungilson). The Calcination Temperature for the waste paper sludge is $700^oC$ for 2 hours at this maintained temperature the sludge is transforming Kaolinite into Metakaolinite (R.Garcia)

## II. REVIEW OF LITERATURE

Waste paper sludge ash is a cementitious material in which some constituents hydrates faster than others the free lime in the waste paper sludge ash reacts with water immediately upon soaking & provides a highly alkaline pore solution, which then results in the release of more reactive phases such as $Al_2O_3$ and $SiO_2$ the system (E.Mozaffari). The physical, chemical and mineralogical characterization of waste paper sludge ash shows that as a fine powder, it is rich in calcium, silicon and aluminium, The amount of other elements are low (less than 2%), except for MgO (5%). The mineralogical characterization confirms the main mineral contained in waste paper sludge ash is Gehlenite that seems to be inert in the presence of water. Waste paper sludge ash can also be considered as hydraulic mineral admixture, the SEM observation shows that the waste paper sludge ash particles are porous. waste paper sludge ash is used for two main reasons(P.Segui) (i) The fast hydration of lime would give high alkalinity to the Solution which could be used as a active pozzolanic material (E.Mozaffari). (ii) Secondly lime is regularly used for soil stabilization of soil for road works because it has interesting properties (Rahmat & Kinuthia). Mortars containing paper sludge ash

Revised Manuscript Received on July 06, 2019.

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*Retrieval Number: I8572078919/19©BEIESP*
*DOI:10.35940/ijitee.I8572.078919*



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

(PSA) and Expanded polystyrene (EPS) had lower thermal conductivity than control mortars , bulk densities of mortars were also reduced by PSA and EPS. It is possible to manufacture sustainable mortars containing PSA & EPS that are in compliance with EU standards for rendering masonry and plastering works (V.Ferraadiz). Residual paper sludge generated by the paper industry can be reused by the construction industry after calcination (Raul. Fernandez). Hydration with water led to hydration of the free lime to give portlandite and rapid dissolution of the tricalcium aluminate, while portlandite and calcite dissolved continuously until 28-days of curing(Gregor J.G.Gulth). Paper sludge mainly consists of cellulose fibres, fillers such as calcium carbonate and china clay and residual chemicals bond up water, The moisture content is typically upto 40% after incinerating paper sludge at approximately 800$^{o}$C the resultant fly ash may contain reactive silica and alumina (in the form of Metakaolin) as well as (CaO) which contribute chemically to the portland cement ingredient (Dr.Andrew M.Dunster). Controlled calcination of wastes (500$^{o}$C-800$^{o}$C) supplies an alternative approach to obtain recycled metakaolin, a highly pozzolanic material for the manufacture of the commercial cements (Moies Frias). Paper sludge have different mineralogies that depend on the function of the industrial process, the ratio of the virgin/recycled paper used as raw material and the inorganic components present (M.Frias). The potential of using wastepaper sludge ah as a partial replacement in Ordinary portland cement material with the two-fold advantage of finding an additional outlet for this waste material as an alternative to landfilling, while producing less energy intensive types of concrete (Mavroulidou M) The replacement of 20% cement by Calcined paper sludge leads to better performance against freezing and thawing. Cement mortars containing 20% calcined paper sludge reach more than 100 freeze/thaw cycle before failure (I.Vegas, J.Urreta) Waste paper sludge ash has a significant effect on the water demand and setting times of the mixtures (M O Farrell). The replacing proportion of the cement and fine aggregate with waste paper sludge ash and Fine recycled concrete aggregate (FRCA) upto 20% & 15% respectively are found to contribute towards compressive strength by blending WPSA and FRCA exhibited favourable and equivalent compressive strength than those of control mixes (Siti Shahidah). The results indicate that the treatment at 700$^{o}$C at 2 hours is the best according to the pozzolanic activity for lime combination similar to those showed by metakaolinite type, for higher temperatures activity decreases as a consequence of three factors (1) Decarbonation process (2) Production of new mineral phases & (3) The decrease of the reactive surface, which is the consequence of the production of new crytalline phases (Raquel Vigil de la). The utilization of waste paper sludge ash reduce the polymerization of polymeric mortar due to more pores was produced as compared to polymeric mortar containing Fly ash. But alkaline activation of aluminosilicates wastes in the presence of calcium hydroxide using sodium hydroxide & sodium leads to the formation of an aluminosilicate geopolymer that possesses an enhancement microstructural properties (Ridzuan. A.R.M). Waste paper sludge is used for clay stabilization as an alternative to commonly used commercial Limes or Cements. This has been proved in terms of treated soil properties (Plasticity characteristics Unconfined Compressive Strength, water retention & volumetric stability). These were found to be in most cases superior for the waste paper sludge ash treated soils compared to lime-treated or cement-treated clays. waste paper sludge ah gives a positive approach for the potential of commercial exploitation in the Ground Engineering / Construction industry (M.Mavroulidou). The raw sludge (waste paper sludge) does not exhibit pozzolanic property, but once calcined at 650$^{o}$C during 2 hours exhibits a good pozzolanic activity, calcined paper sludge is used as a partial portland cement replacement of 10%. Further calcined paper sludge reduces the initial and final setting times of cement pastes (M. Frías). Waste paper sludge contains cellulose fibres and mineral fillers such as kaolinite, calcite & talc, in a controlled calcination process in temperature range of 650$^{o}$C - 800$^{o}$C it is possible to transform sludge into either pozzolanic or hydraulic material usable in cement industry (J.Pera). The amount of calcium oxide in waste paper sludge ash influence positively the mechanical strength of fly ash based geopolymer, also the inclusion of waste paper sludge ash in the geopolymer mortar presented a positive effect to the degree of reaction in the Geopolymerisation (Norbaizurah Rahman). The CaO content in the paper sludge ash is about 1/3 of the limestone with high CaO content but the sulphation conversion is about 1.5 times - 2 times higher than that of the calcined limestone (Seon Ah Roh).

## III. EXPERIMENTAL INVESTIGATION

### *A. Paper sludge*

The Samples Waste paper sludge were collected from two different places (Paper manufacturing Industries), i.e. from Pondicherry region and Tamilnadu region. The sample are sun dried for 10 to 14 days to become dry the dried sludge was burnt in an electric furnace @ 750,800 and 850$^{o}$C each sample for 2 hours, the calcined products were cooled to room temperature in a desiccator . Table 1 & 2 shows the designation of the different products and burning conditions. The Physical properties of waste paper sludge ash were studied as per Indian standards and tabulated in Table 3 and 4.

**Table-1 (Pondicherry Sample)**

| Designation | Temperature | Retention Period |
|---|---|---|
| $S_1$ | 750$^{o}$C | 2 hours |
| $S_2$ | 800 $^{o}$C | 2 hours |
| $S_3$ | 850 $^{o}$C | 2 hours |

**Table-2 (Tamilnadu Sample)**

| Designation | Temperature | Retention Period |
|---|---|---|
| $S_4$ | 750$^{o}$C | 2 hours |
| $S_5$ | 800 $^{o}$C | 2 hours |
| $S_6$ | 850 $^{o}$C | 2 hours |

**Table:3 Physical Properties of Waste Paper sludge Ash Pondicherry region Sample:**

| Sl .No | Description | Values |
|---|---|---|
| 1 | Specific Gravity (Sample- $S_1$, $S_2$ & $S_3$) | 2.454 |
| 2 | Colour | Pearl White |
| 3 | Phase | Amorphous form |
| 4 | Particle Size | |

The Chemical composition test for waste paper sludge ash (WPSA) are conducted as per Indian standards, and were carried out by (NLC-CARD) Neyveli, Tamilnadu. The SEM analysis for the WPSA were performed using Hitachi S3400N and were carried out by CIF (Central Instrumentation Facility), Pondicherry University-Pondicherry. The Scanning Electron Microscopy (SEM) & EDAX images of WPSA (S1,S2,S3,S4,S5 & S6) samples is shown in Fig1- Fig-12. As can been, the particles shape of the WPSA were generally Spherical shape. Energy dispersive X-ray Spectroscopy EDAX was done to obtain the elemental analysis of the WPSA produced. All the basic elements in the WPSA , activator are found Si,Al,Na,Mg, Fe, Ca, K, Cl & S , all the elements are shown in the spectrum taken.

**Table:4 Physical Properties of Waste Paper sludge Ash Tamilnadu region Sample:**

| Sl.No | Description | Values |
|---|---|---|
| 1 | Specific Gravity (Sample- $S_4$, $S_5$ & $S_6$) | 2.847 |
| 2 | Colour | Pure White |
| 3 | Phase | Amorphous form |
| 4 | Particle Size | |

| Chemical Composition for Waste Paper sludge ash in Paper Industry from Pondicherry region | | | |
|---|---|---|---|
| Oxides % | $S_1$ | $S_2$ | $S_3$ |
| $SiO_2$ | 17.29 | 17.28 | 16.58 |
| $Fe_2O_3$ | 6.28 | 3.72 | 1.85 |
| $Al_2O_3$ | 2.80 | 6.93 | 6.72 |
| CaO | 37.40 | 36.44 | 38.51 |
| MgO | 4.71 | 5.43 | 5.42 |
| $SO_3$ | 4.91 | 4.82 | 5.68 |
| $Na_2O$ | 11.59 | 10.36 | 9.55 |
| $K_2O$ | 0.56 | 0.57 | 0.54 |
| $TiO_2$ | 0.06 | 0.08 | 0.05 |
| LOI (Dry sludge) | 77.65 | | |

| Chemical Composition for Waste Paper sludge ash in Paper Industry from Tamilnadu region | | | |
|---|---|---|---|
| Oxides % | $S_4$ | $S_5$ | $S_6$ |
| $SiO_2$ | 16.90 | 16.98 | 17.93 |
| $Fe_2O_3$ | 1.50 | 1.27 | 1.22 |
| $Al_2O_3$ | 0.78 | 3.24 | 3.11 |
| CaO | 52.77 | 67.84 | 65.24 |
| MgO | 0.77 | 3.18 | 3.06 |
| $SO_3$ | 0.44 | 0.47 | 0.79 |
| $Na_2O$ | Nil | Nil | Nil |
| $K_2O$ | Nil | Nil | Nil |
| $TiO_2$ | Traces | Traces | Traces |
| LOI (Dry sludge) | 58.25 | | |

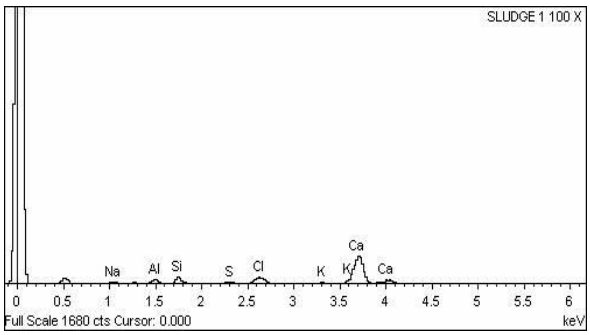


**Fig-1 EDAX Image of Waste Paper Sludge ash $S_1$**

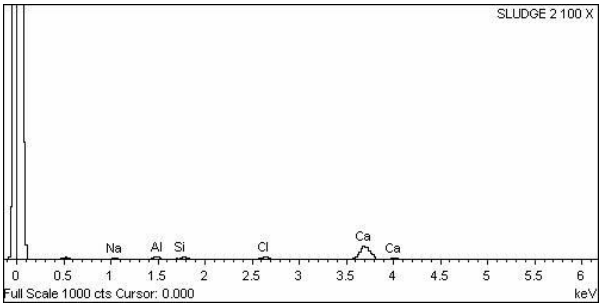


**Fig-2 EDAX Image of Waste Paper Sludge ash $S_2$**

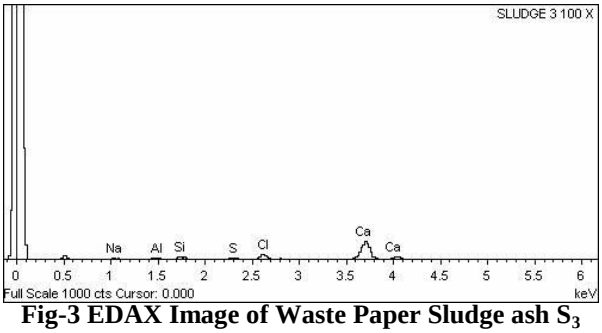


**Fig-3 EDAX Image of Waste Paper Sludge ash $S_3$**

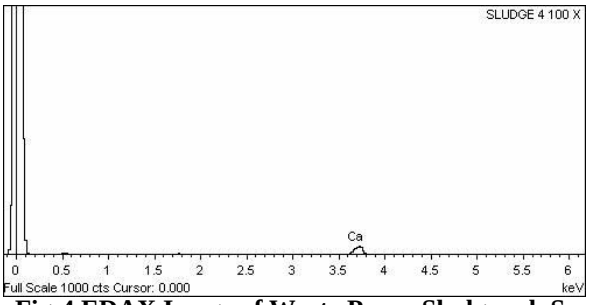


**Fig-4 EDAX Image of Waste Paper Sludge ash $S_4$**

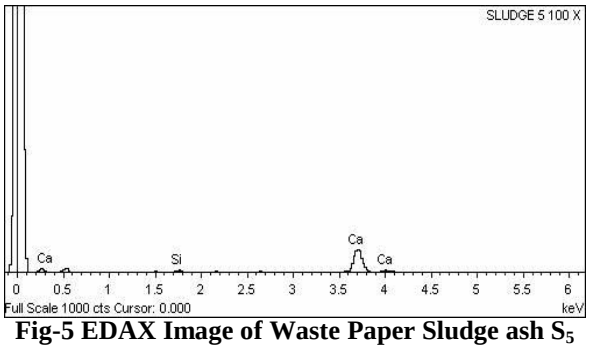


**Fig-5 EDAX Image of Waste Paper Sludge ash $S_5$**

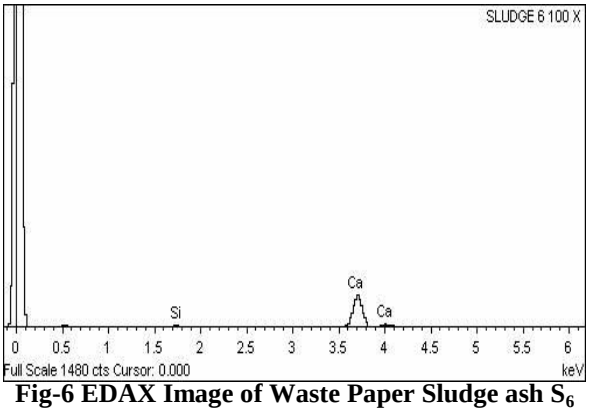


**Fig-6 EDAX Image of Waste Paper Sludge ash $S_6$**

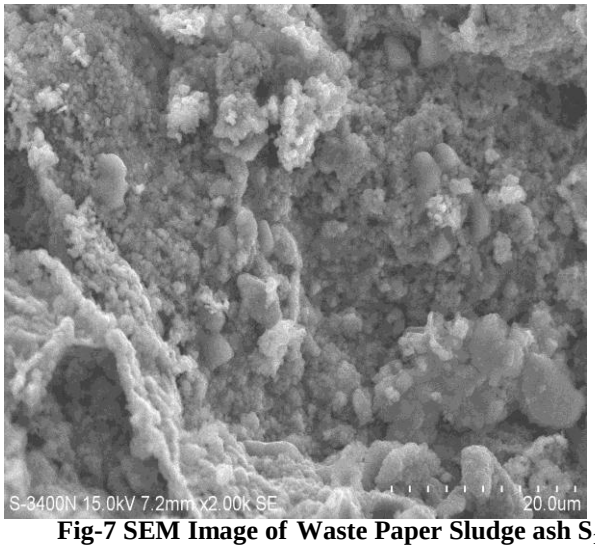


**Fig-7 SEM Image of Waste Paper Sludge ash $S_1$**

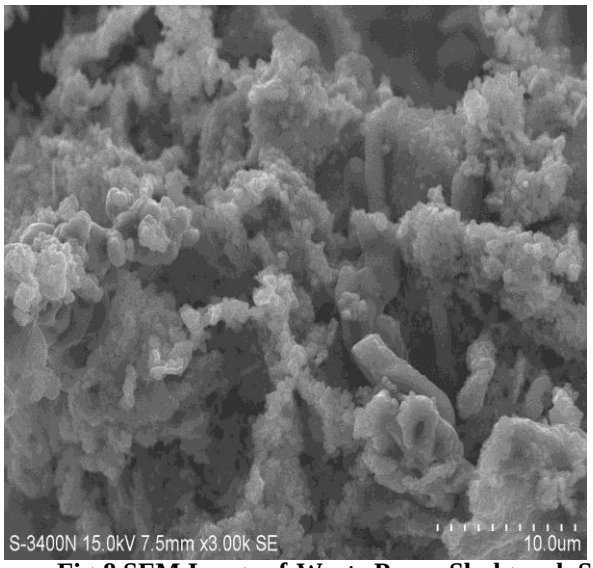


**Fig-8 SEM Image of Waste Paper Sludge ash $S_2$**

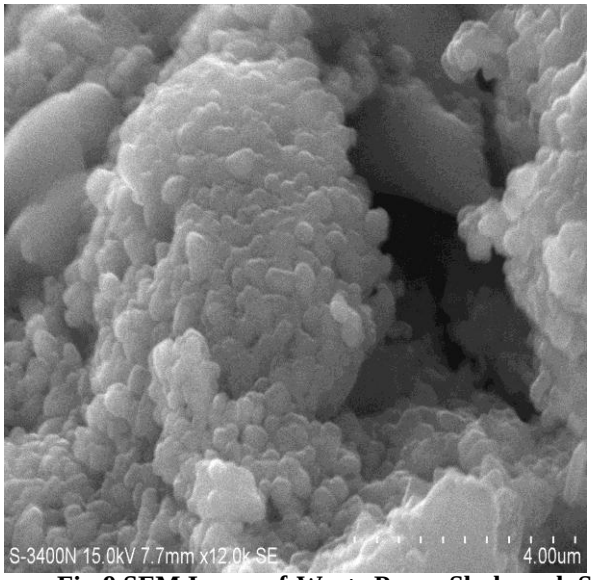


**Fig-9 SEM Image of Waste Paper Sludge ash $S_3$**

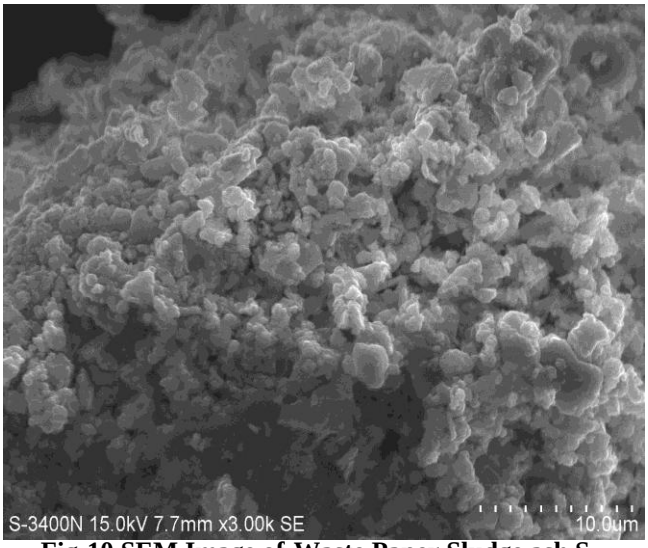


**Fig-10 SEM Image of Waste Paper Sludge ash $S_4$**

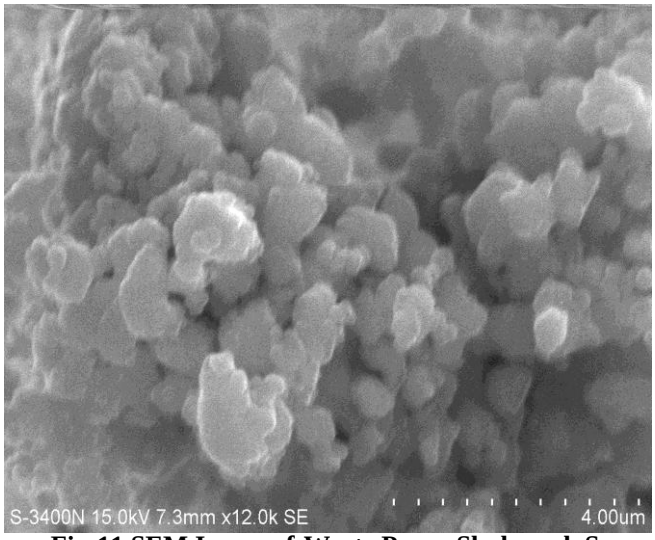


**Fig-11 SEM Image of Waste Paper Sludge ash $S_5$**

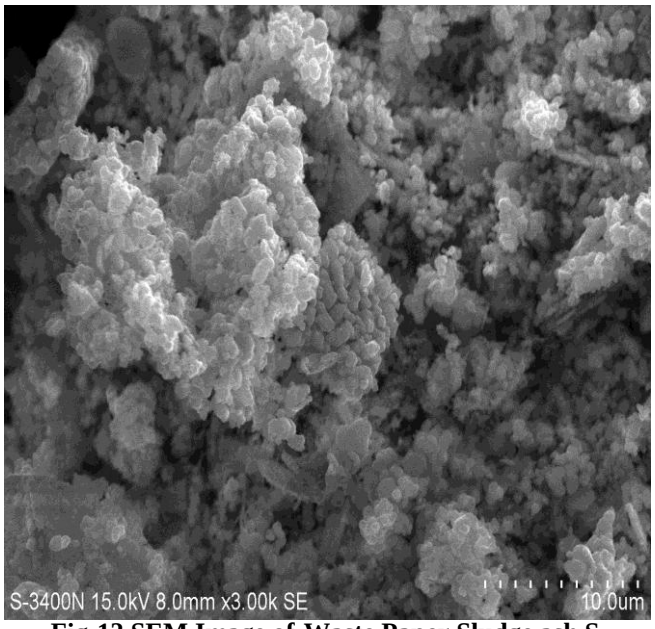


**Fig-12 SEM Image of Waste Paper Sludge ash $S_6$**

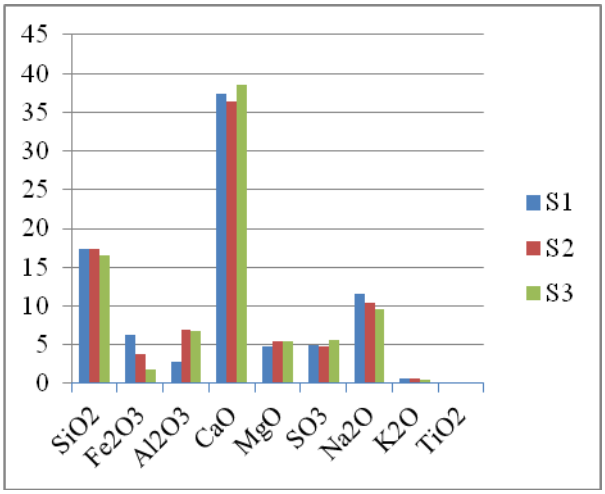


**Fig-13 Chemical composition of waste paper sludge (Pondicherry region)**

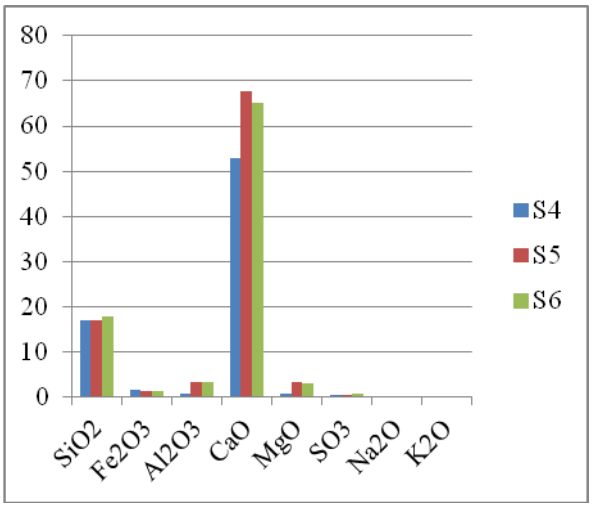


**Fig-14 Chemical composition of waste paper sludge (Tamilnadu region)**

## IV.CONCLUSION

From the Physical properties and chemical analysis reported also in various literature reviewed by the experts and researchers it is concluded that waste paper sludge exhibits good Pozzolanic property that could be used as a supplementary cementitious material in the cement industry. Waste paper sludge ash is eco friendly material it will not cause any hazardous to our society.

## V. ACKNOWLEDGEMENT

The authors would like to thank Dr.K.Sudarshan, Assistant Manager (R&D),TNPL,Karur, Dr.A.C.RameshBabu, Deputy Manager(Scientific), CARD, NLCIL, Neyveli for their support throughout this research. The authors would also like to thank CIF Laboratory (Central Instrumentation Facility) Pondicherry University, Pondicherry for their help with experiments.

## REFERENCES


1. Monte, MC.; Fuente, E.; Blanco, A. & Negro, C. (2009). Waste management from pulp and paper production in the European Union. Waste Management, Vol. 29, pp. 293–308.
2. Valeria Corinaldesi, Gabriele Fava, and Maria Letizia Ruello (2010). Paper Mill Sludge Ash as Supplementary Cementitious Material.
3. R. Srinivasan, K. Sathiya and M. Palanisamy (2010). Experimental Investigation In Developing Low Cost Concrete From Paper Industry Waste.
4. Hiroji ishimoto, Takeshi Origuchi, Masahiro Yasuda,2000" Use of paper making sludge as new material " Journal Of Materials In civil engineering.
5. A.M. Md Nazar , N.F. Abas, a , M.A. Othuman Mydin. Study on the Utilization of Paper Mill Sludge as Partial Cement Replacement in Concrete. MATEC Web of Conferences 10, 02001 (2014).
6. E. Mozaffari , J.M. Kinuthia, J. Bai, S. Wild. An investigation into the strength development of Wastepaper Sludge Ash blended with Ground Granulated Blastfurnace Slag, Cement and Concrete Research 39 (2009) 942–949
7. E. Mozaffari , M. O_Farrell, J.M. Kinuthia, S. Wild. Improving strength development of wastepaper sludge ash by wet-milling. Cement & Concrete Composites 28 (2006) 144–152
8. P. Segui , J.E. Aubert , B. Husson, M. Measson. Characterization of wastepaper sludge ash for its valorization as a component of hydraulic binders. Applied Clay Science 57 (2012) 79–85
9. Raúl Fernández , Belén Nebreda , Raquel Vigil de la Villa , Rosario García , Moisés Frías . Mineralogical and chemical evolution of hydrated phases in the pozzolanic reaction of calcined paper sludge. Cement & Concrete Composites 32 (2010) 775–782
10. Gregor J.G. Gluth , Christian Lehmann, Katrin Rübner, Hans-Carsten Kühne. Reaction products and strength development of wastepaper sludge ash and the influence of alkalis. Cement & Concrete Composites 45 (2014) 82–88
11. Jungil Son, Hyun-Joong Kim, Phil-Woo Lee. Role of Paper Sludge Particle Size and Extrusion Temperature on Performance of Paper Sludge–Thermoplastic Polymer Composites. Journal of Applied Polymer Science, Vol. 82, 2709–2718 (2001).
12. Andrew M Dunster,2007" Paper sludge and paper sludge ash in Portland cement manufacture ."BREWRT 177 / WR0115.
13. I.Vegas, J. Urreta, M. Frías, O. Rodríguez, S. Ferreiro, B. Nebreda, R. García, R. Vigil. Engineering Properties Of Cement Mortars Containing Thermally Activated Paper Sludge
14. Moisés Frías, Iñigo Vegas,Raquel Vigil de la Villa and Rosario García Giménez. Recycling of Waste Paper Sludge in Cements: Characterization and Behavior of New Eco-Efficient Matrices
15. M. Frı´as, M. I. Sa´nchez de Rojas, O. Rodrı´guez, R. Garcı´a Jime´nez and R. Vigil de la Villa. Characterisation of calcined paper sludge as an environmentally friendly source of metakaolin for manufacture of cementitious materials. Advances in Cement Research, 2008, 20, No. 1, January, 23–30
16. Gabriele Fava; Maria Letizia Ruello; and Valeria Corinaldesi. Paper Mill Sludge Ash as Supplementary Cementitious Material, J. Mater. Civ. Eng., 2011, 23(6): 772-776
17. Mavroulidou M., Boulouki G. And Unsworth C. Incorporating Waste Paper Sludge Ash As Partial Cement Replacement In Concrete. Proceedings of the 13th International Conference of Environmental Science and Technology Athens, Greece, 5-7 September 2013.
18. Pradeep Kumar Rana, Radha Raman Dash and Ratan Indu Ganguly. Geopolymer From Industrial Wastes: A Construction Material For 22nd Century, Advanced Composites for Aerospace, Marine, and Land Applications

a. Vegas, J. Urreta , M. Frías , R. García, Freeze–thaw resistance of blended cements containing calcined paper sludge, Construction and Building Materials 23 (2009) 2862–2868

19. Siti Shahidah Sharipudin, Ahmad Ruslan Mohd Ridzuan. Influence of Waste Paper Sludge Ash (WPSA) and Fine Recycled Concrete Aggregate (FRCA) on the Compressive Strength Characteristic of Foamed Concrete. Advanced Materials Research Vol 626 (2013) pp 376-380.
20. Raquel Vigil de la Villa, Moisés Frías, María Isabel Sánchez de Rojas, Iñigo Vegas, Rosario García. Mineralogical and morphological changes of calcined paper sludge at different temperatures and retention in furnace. Applied Clay Science 36 (2007) 279–286.
21. Ridzuan A.R.M, Khairulniza A.A, Fadzil M. A. and Nurliza J. Morphology and Physical Analysis of Waste Paper Sludge Ash (WPSA) Polymeric Mortar. Advanced Materials Research Vol. 701 (2013) pp 275-279.
22. M. Frías**,** O. Rodríguez, M.I. Sánchez de Rojas, S. Ferreiro, B. Nebreda and J. Olmeda. New Construction Materials: Calcined Paper Sludges as Active Additions. Materials Science Forum Vols 636-637 (2010) pp 1222-1227
23. J.Pera, J.Ambroise, National Institute of Applied Sciences, France, Properties of Calcined Paper sludge.
24. Norbaizurah Rahman, Andri Kusbiantoro, Nabilah Mamat, Khairunisa Muthusamy and Mohd Mustafa Al Bakri Abdullah. Roles of Calcium in Geopolymer Containing Paper Mill Sludge Ash, Materials Science Forum ISSN: 1662-9752, Vol. 917, pp 311-315.
25. Seon Ah Roh and Sang Done Kim, Sulphation Characteristics of Paper Sludge Ash, The Canadian Journal Of Chemical Engineering- Volume 85, April 2007
26. M. Mavroulidou, Use of waste paper sludge ash as a calcium-based stabiliser for clay soils, Waste Management & Research 2018,Vol.36(11),1066– 1072
27. Pera, J., Amrouz, A., 1998. Development of highly reactive metakaolin form paper sludge. Advance Cement Based Materials 7, 49–56.