Utilization of Sludge as Raw Material in Construction Industry

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Abstract-- **A large quantity of sludge rich in nutrients and microorganisms is generated every year from water and wastewater treatment plants, the final destination of which affects the environment. Generally, dewatered sludge is disposed of by spreading on the land or by land filling. However, space limitations on existing landfill sites and problems of waste stabilization have prompted investigation into alternative reuse techniques and disposal routes for sludge. A more reasonable approach is to view the sludge as a resource that can be recycled or reused. Many researchers have exploited the reuse of lime sludge from water treatment plant and sewage sludge ash as an inexpensive source of soil stabilizer in sub grade stabilization and soft cohesive soil respectively. Sewage sludge pellets (SSP) has replaced sand in concrete manufacturing for pavements. The use of SSP as substituting material in raw mix formulation in Portland cement manufacturing has been studied by many researchers. Experimental results showed the feasibility of the partial replacement (15 and 30%) of cement by sewage sludge ash (SSA) in mortars. This paper highlights the potential of dried sludge, sludge pellets and sludge ash in various building materials for construction.**

***Index Terms*—Landfill, sewage sludge ash, sewage sludge pellet, sludge.**

I. INTRODUCTION

From water and wastewater treatment plants, sludge is obtained as a by-product. The disposal of sludge for modern municipalities represents an ever-increasingly difficult problem. Some agricultural practices become an important reusing way for sludge. Feasibility studies on the use of sludge to produce cement, mortar, concrete, building blocks etc as a means of ultimate sludge disposal has been initiated. The application of sludge can significantly reduce the sludge disposal cost component of sewerage treatment.

The most common sewage sludge disposal alternative is the incineration. The sewage sludge ash (SSA) retained in filters can be deposited in controlled landfills or used in construction for improving some properties of building materials. The production of sewage sludge pellets (SSP) by sewage sludge thermal drying, it is shown as an appropriate management to reduce the weight of the generated waste and to stabilize physically, chemically and biologically the sewage sludge.

In this paper an attempt has been made to find out the reuse potential of sludge which itself is an end product causing much pollution. In view of the anticipated disposal problem of sludge and associated environmental concerns, recycling of sludge into useful materials is gaining due consideration as an alternative disposal option. It is actually sludge reprocessing to value-added products that holds the future key to sustainable management. Thus, the primary focus of this review is the value addition of sludge comprising recovery of different components and development of commercial products.

II. PROCESSING OF SLUDGE

1) Incineration

The most common sewage sludge disposal alternative is the incineration. Incineration can be used as means 1) to reduce the volume of the dry sludge and 2) to produce a sterile non-harmful residue that is free from volatile content. Incineration of sludge can be done by multiple hearth furnace, flash type furnace, infrared furnace and fluidized bed furnace. The sewage sludge ash (SSA) retained in filters can be deposited in controlled landfills or used in construction for improving some properties of building materials.

2) Pelletilization

In order to facilitate sewage sludge handling, a partial drying process is necessary to reduce the total volume of waste. As a result of this drying process, a worm shape particles or spherical particles are obtained; these particles are named sewage sludge pellets (SSP).

3) Atomization

Atomization aims to obtain a semi-fine, highly fluid product with residual moisture of under 5 %, consists in a rotary co-current system with a maximum evaporation capacity of 3000 kg/h. The atomization system allows 1) the reuse of sludge generated in treatment plants as a prime material in industrial processes; 2) preservation of natural spaces by avoiding the final destination of sludge in landfills, 3) the reduction of area devoted to the onsite storage of such waste, as well as substantial savings in transportation cost.

4) Dewatering

Water purification sludge is very bulky in nature and normally it is not undergoing any procedure to reduce its volume whereas sewage sludge being contaminated in nature is first anaerobically digested and then disposed off. The traditional way to get rid of drinking water sludge has been to just let the sludge drain back into the raw water source. However, it has become increasingly important to handle sludge in a more effective manner due to new regulations, legislation and environmental issues. Sludge should be first dewatered to make its handling easy.

III. POTENTIAL REUSE APPLICATION OF SLUDGE IN STRUCTURAL BUILDING MATERIALS

Potential uses of sludge in construction products include aerated concrete (as aggregate), ceramic materials (as sand and clay replacement), cement (as cement replacement /filler), fine aggregate for concrete products, and the manufacture of synthetic coarse aggregate.

1) Sludge as cementitious material

The properties of sewage sludge depend on the quality of wastewater, for example industrial wastewaters containing heavy metals yield contaminated sewage sludge. This sewage sludge, contaminated by heavy metals can be stabilized and solidified using cement and pozzolans. In this cementing matrix, metals are converted into highly insoluble salts, which do not leach at appreciable rates [27-29]. On the other hand, sewage sludge together with limestone and clay can be used as raw materials for making cementicious building materials [25] and sewage sludge can also be used to produce pozzolanic materials [12-15]. In addition, pozzolanic behaviour of SSA has been checked attending to lime fixation in cement/SSA pastes by thermogravimetric techniques. On the other hand SSA/fly ash mixture has been investigated as an alternative to improve the properties of Portland cement containing SSA. Research done by Pan et al. (2003) observed that ISSA can be subjected to any possible reuse options such as fine aggregates or as filler in cement and road construction and as pozzolanic material. The use of SSP as substituting material in raw mix formulation in Portland cement manufacturing has been studied by many researchers. These pellets can be mixed with cement pastes in order to study the influence on setting time and cement hydration [20]. In addition, cement mortars were also prepared using SSP [13]. J. Monzo in his study in 2003 concluded that raw materials containing SSP have no problem to use in OPC clinker manufacturing; however studies of heavy metal retention capability of this new clinker must be carried out. Moreover, sludge can be combined with cellulose fibers in the cement matrix to create so-called hemp Crete, with high compression strength, good impact resistance, cohesion and workability. The use of sludge reduces costs because of the lower consumption of water, clay and electricity in the production process [19]. The partial replacement of Portland cement by SSA promoted an increase in the total porosity and a reduction in the absortivity values of the OPC reference mixtures. [8]. In recent studies by Huxing Chen et. Al in 2010 reveals that water purification sludge (WPS) can replace siliceous material partially upto 10%. It was found that WPS replacements <7% increased the strength of samples.

2) Sludge as biocement

The experimental results presented in this study show that the biocement made from a mixture of sludge and limestone at equal amount by weight, fired at 1000~ for 4 hours under controlled incineration, is a potential material for the production of masonry cement. Further investigation is needed to determine other qualities of the mortar based on air content and water-retention characteristics, prior to its acceptance as a suitable masonry cement. When being used as a blended cement material, the biocement can replace up to 30% by weight of ordinary Portland cement without deteriorating the strength. However, the effects of high water demand and quick setting properties on the quality of mortar must be studied. Further studies are also needed to investigate the long-term properties such as durability and chemical stability [11]

3) Sludge aggregate in mortar and concrete

The sludge containing concretes appears economically attractive given the low prices of raw industrial wastes. Wide scale application of this method can significantly improve the environmental situation in industrial regions. Utilization of sludge ash as raw materials in the production of pellet aggregates was reported by Bhatty et al. (1992), who observed a lower aggregate specific gravity and hence a better strength-to-weight ratio with no adverse effects on concrete strength. SSA has been used in mortars [9], concrete mixtures [18], in brick manufacture [4], as a fine aggregate in mortars [21], and in asphalt paving mixes [26]. J.Monzo et. al observed that control paste has shorter initial and final setting times than pastes containing SSA. In addition, an increase of both setting times is observed when percentages of SSA do. SSA improves mortar strength at early curing time. Studies conducted By R. Khanbilvar showed that the design strength is still attainable for up to 30% (by weight) ash replacement.

The pellets being round in shape enhanced the workability of concrete and resulted in dense concrete specimens. The replacement of granite with sintered sludge pellets in concrete as coarse aggregate attained a strength equivalent to that of the regular concrete [4]. SSP can be used in concrete manufacturing for pavements.

According to the chemical composition of SSP and to the chemical composition of the other components in raw material for Portland cement clinker manufacturing, 11% of SSP (dried matter) was proposed as a maximum replacing percentage in raw formulation. Dr Andrew in his case study in 2007 showed that the characterization data and trial results indicated that ISSA could be suitable for use in aerated concrete. Monzo et. al in 2003 observed that the presence of SSA in mortars prepared with various cements reduces their workability; the negative influence of SSA is similar for all cements. For high replacement levels (30%), very low workability mortars were obtained in all cases. They recommended that for the reuse of SSA in practical mortar production, addition of plasticizing agents.

4) Concrete blocks with sludge

Production of various mix ratio of hollow concrete blocks from dewatered water treatment sludge used as a fine aggregate could be a profitable disposal alternative in the future [26]. The mineral composition and PSD of milled ISSA suggests that it could be used in the manufacture of aggregates for lightweight thermally insulating blocks. Sintering of ISSA produces lightweight aggregate suitable for production of lightweight blocks and concrete [6].

5) Sludge in bricks

Nuvolari (2002) tested soft-mud bricks with reduced dimensions (10x5x2.5 cm) and concluded that the maximum proportion of sludge that met minimum compressive strength standards was 10%. For the bricks manufactured with sludge ash, a concentration of up to 40% was technically feasible. Weng *et al.* (2003) reported that the benefits of using sludge or sludge ash as an additive in bricks or tiles include: the immobilization of heavy metals in the ceramic matrix, post-firing; oxidation of organic material; and the destruction of any pathogen during the firing process. Herek *et al.* (2005) and Balasubramanian *et al.* (2006) assessed the use of textile sludge in the manufacture of ceramic blocks. Both studies report that the test specimens manufactured with 10% sludge are technically adequate. Maria P. Durante Ingunza et. al (2010) observed that both the control bricks of the two manufacturing stages and those manufactured with 15 and 20% sludge, are characterized as Class II residue—nondangerous. They concluded that the maximum concentration of sludge that can be incorporated into ceramic mass, meeting both the technical and environmental requirements, is 20%. Mortar mixtures containing 10-30% of SSA as cement replacement presented compressive strength at 7 days higher than that of the reference mixture and about the same strength at the age of 28 days. The high performance concrete produced replacing 5-10% of OPC by SSA also presented axial compressive strength equivalent to that of the reference mixture at the age of 28 days. [8]

6) Sludge in soil stabilization

Sludge has gained its application in soil stabilization

Studies done by Den Fong Lin et. al showed the stabilizing potential of sludge ash for soft cohesive subgrade soils. In the improvement of swelling potential; it is possible for sludge ash to effectively reduce the swelling behaviours of A-4 soils. Test results obtained by the author demonstrated that sewage sludge ash is able to effectively improve the engineering properties of soft cohesive sub grade soil with optimum amount of sludge ash as 8% by weight. They concluded that sludge ash has the potential to replace fly ash in the application of improving soft cohesive soil while providing a wide reclamation of sewage sludge. Lime sludge from water treatment plants has found its application in transportation also. Chemical analyses performed by Jingsi Lang indicate that lime sludge has similar chemical components as commercial hydrated lime. Lime sludge was found to increase the soil deformation modulus and reduce the plastic behaviors. The existing testing data demonstrated the positive effects of lime sludge treatment in improving the soil mechanical performance properties as well as improving the durability under freeze-thaw cycles.

IV. POTENTIAL REUSE APPLICATION OF SLUDGE IN NON-STRUCTURAL BUILDING MATERIALS

1) Cement concrete flooring tiles

Balasubramanian in 2005 showed that textile effluent treatment plant sludge satisfied all the standards as per British Standards for being used in flooring tiles.

2) Solid blocks with sludge

Test results obtained by Balasubramanian indicate that solid blocks with upto 30% of sludge utilized as a substitute for cement meet the BIS specification code IS: 2185(part1) 1979. The solid blocks satisfy ASTM (C129-75) standard specifications for on-load-bearing concrete masonry units.

3) Pavement blocks with sludge

The compressive strength results indicate that the pavement blocks of 10% and 20% sludge as a substitute for cement proide more than 80% of the strength of commercial blocks with no sludge. Water adsorption of each block meets BIS requirement. [3]

V. ONGOING REASEACH

1) Imperial College of London

Shane Donatello, Chris Cheeseman, Mark Tyrer and Andy Biggs of Imperial college of London are working on the manufacture of value-added construction products containing sewage ash to allow improved resource efficiency. This involved

• Activation of the pozzolanic properties of ISSA to produce products with useful compressive strengths and other physical properties;

• Formation of 'foamed' ISSA, to make lightweight, thermally insulating aggregate and block products.

2) ITM University, Gurgaon

Research work is undergoing by Vaishali Sahu (Research Scholar) on finding the reuse potential of drinking water and sewage sludge as raw material in construction industry. Sludge from water treatment plant (HUDA, Gurgaon) was collected, oven dried for 24 hours and was used to prepare mortar with 5, 10 and 15% replacement of cement with sludge to study the compressive strength for 3, 7 and 28 days of curing. Similarly it is planned to collect sludge from sewage treatment plant (MCG and HUDA, Gurgaon) also and to find the applications of water purification and sewage sludge in various structural and nonstructural building materials without converting the sludge into ash or pellets which is not feasible in India due to its high cost and high level of pollution.

VI. CONCLUSIONS

Te following conclusions can be drawn from the above study:

Using sludge as a fertilizer is not permissible if harmful microorganisms are present.

Final disposal in landfill sites is not the solution due to space constraint.

It is feasible to use water purification sludge (WPS) as a substitute of siliceous material in cement production. Up to 7% of WPS can be utilized.

Sewage sludge ash can replaces 30% of cement. On the other hand incineration of sludge causes air pollution and is uneconomical in countries like India. Need of the time is to utilized sludge as it is rather than converting it into ash.

Maximum of 20% sewage sludge can be utilized for soft mud bricks.

For mortar it is feasible to utilized 30% of sludge from water and sewage treatment plants.

In soil stabilization process water purification sludge can be used up to 10%

When sludge is used for building blocks, with increase in percentage of sludge the compressive strength is found to be decreasing.

Sludge can find the alternative as its reuse in structural and non-structural building materials

VII. REFERENCES

[1] Alleman J.E. Berman N.A. "Constructive sludge management: biobrick", *J. Envirom. Eng. Div. ASCE,* 110, (1984) 301-11.

[2] Al Sayed M.H., Madany I.M. Buali A.R.M., "Use of sewage sludge ash in asphaltic paving mixes in hot regions" *Constr. Build. Mater.*, 9, (1995) 19 23.

[3] Balasubramanian J., P.C. Sabumon, John U. Lazar, R. Ilagovan, "Reuse of textile effluent plant sludge in building materials", Journal of Waste Management, 26(200), pg 22-28

[4] Bhatty J.I., Reid J.K. "Compressive strength of municipal sludge ash mortars", *ACI Mater.,* 86, (1989) 394-400.

[5] Chang J., Lin T, Ko M., Liaw D. "Stabilization/solidification of sludges containing heavy metals by using cements and waste pozzolans" *J. Envirom. Sci. Health, A* 34(5), (1999) 1143-1160.

[6] Cheeseman, C. and Virdi, G.S. 'Resources, Conversation and Recycling' 45 (2005) 18-30.

[7] Dr Andrew M Dunster,BRE, Case Study_Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material, 2007

[8] Fontes, M.C. Barbosa, R.D. Toledo Filho, J.P. Gonçalves, "Use of Recycled Materials in Buildings and Structures", November 2004, Barcelona, Potentiality of Sewage Sludge Ash as Mineral Additive in Cement Mortar and High Performance Concrete, C.M.A.

[9] HuXing Chen, Xianwei, HengJie Dai, "Reuse of water purification sludge as raw material in cement production", Journal of Cement & Concrete Composites 32 (2010) 436–439.

[10] Innovative civil engineering material from sewage sludge: biocement and its use as blended cement material By Joo-Hwa Tay and Knan-Yeow Show *Journal of Materials in Civil Engineering,* Vol. 6, No. 1, February, 1994

[11] Joo-Hwa Tay**,** "Bricks manufactured from sludge", *Journal of Environmental Engineering,* Vol. 113, No. 2, April, 1987. ©ASCE, ISSN 0733-9372/87/0002-0278/$01.00. Paper No. 21374. 278.

[12] Morales G. "Utilization of sewage sludge as raw material for production of pozzolanic material" Proceedings of the 10th Congress on Chemistry of Cement, 3ii, (1998) 1112-1115

[13] Maria P. Durante Ingunza1, Anaxsandra C. L. Duarte and Rubens M. Nascimento, "Use of Sewage Sludge as Raw Material in the Manufacture of Soft-Mud Bricks", Journal of Materials in Civil Engineering, Vol. 23, No. 6, June 1, 2011. Monzó J., Payá J., Borrachero M.V. and Córcoles A. "Use of sewage sludge ash (SSA)-cement admixtures in mortars", *Cem. Concr. Res.*, 26,(9), (1996) 1389-1398.

[14] Monzó J., Paya J., Borrachero MV., Bellver A., Peris-Mora E., "Study of cement-based mortars containing spanish ground sewage sludge ash" Waste materials in construction. Proceedings of the International Conference on the Environmental and Technical Implications of Construction with Alternative Materials Wascon 97. Edt Goumans JJJM., Senden G.J., Vand der Sloot H:A: (1997) 349-354

[15] Monzó J., Paya J., and Borrachero MV: "Experimental basic aspects for reusing sewage sludge ash (SSA) in concrete production" Exploiting wastes in concrete. Proceeding of Creating with Concrete, Eds Dhir R:K:, Jappy T.G. (1999) 47-56

[16] Monzo. J, J. Paya , M.V. Borrachero, I. Girbe, Reuse of sewage sludge ashes (SSA) in cement mixtures:the effect of SSA on the workability of cement mortars, Journal of waste management, 23 (2003) 373–381.

[17] Monzo J., Paya J., Borrahcero M.V. Girbés I., "Reuse of sewage sludge ashes (SSA) in cement mixtures: The effect of SSA on the workability of cement mortars", *Waste Management*, 23(2003) 373-381

[18] Pai-Haung Shih , Juu-En Chang , Hsing-Cheng Lu, Li-Choung Chiang, "Reuse of heavy metal-containing sludges in cement production", Cement and Concrete Research 35 (2005) 2110 – 2115.

[19] R. Eires, S. Jalali, Not conventional materials for a sustainable construction: a bioconstruction system reinforced with cellulose fibers, in: Portuguese Materials Society Meeting-12 International Materials Symposium, 2005.

[20] R.P. Singh and M. Agrawal "Potential benefits and risks of land application of sewage sludge', Journal of Waste Management, Volume 28, Issue 2,2008, pg 347-358

[21] Satinder K. Brar et.al, Value Addition of Wastewater Sludge: Future Course in Sludge Reutilization, Practice periodical of hazardous, toxic, and radioactive waste management © ASCE / January 2009 / 59.

[22] Shane Donatello, Chris Cheeseman, Mark Tyrer and Andy Biggs Sustainable construction products containing sewage sludge ash Department of Civil and Environmental Engineering, South Kensington campus, Imperial College London, SW7 2AZ. *Akristos Ltd., Innovation Centre 1, Keele University Business Park, Keele, Staffordshire, ST5 5NB.

[23] Tay J.H. "Sludge ash as filler for portland cement concrete", Journal of Environmental Engineering, ASCE, 113, (1987) 345-51.

[24] Tay J.H. Show K.Y. "Clay blended sludge as lightweight aggregate concrete material", Journal of Environmental Engineering, ASCE, 117, (1991) 834-44.

[25] Tay J. Show K. "Manufacture of cement from sewage sludge" *J. of Mat. in Civil Eng.* V5, (1993) 19-29

[26] Thaniya Kaosol, Reuse Water Treatment Sludge for Hollow Concrete Block Manufacture**,** Energy Research Journal 1 (2): 131-134, 2010, ISSN 1949-0151, © 2010 Science Publications.

[27] Valls S., Vázquez E., Kuchinov V. "Stabilization of wet sewage sludge in civil engineering" Recycling and reuse of sewage sludge, R.K. Dhir, M.C.Limbachiya, M.J. McCarthy Eds. Thomas Telford, London, (2001) 239-251,

[28] Yague A, Valls S., Vazquez E., Kuchinow V., "Use of dry sludge from waste water treatment plants as an additive in prefabricated concrete bricks", *Mat Const.,* 52 (2002) 31-41

[29] Yang G.C.C. Kao K.L., *J. Hazard. Mater.* 36, (1994) 81-88.