Treatment and Disposal of Glass-wool and Asbestos Bearing Waste-Insulation Materials from Ship Dismantling Yards in India

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Abstract

In the recent years, there have been serious efforts to perform ship recycling activity in an environmentally sound manner with the help of appropriate technology, management framework and regulatory pressure (Hong-Kong Convention by the International Maritime Organization and Regulation on Eco-friendly Ship Recycling by the European Commission). Like in India, several yards in China, Pakistan, Bangladesh and Turkey have been the important players in this sector. Approximately150 Ship-Recycling Yards (SRY) along the 12 km shoreline in Alang-Sosiya Ship Recycling Zone in the State of Gujarat on the West-Coast of India, probably the largest facility for ship breaking and recycling of metals in the world, has been breaking 300 to 400 large obsolete ships (cumulative capacity) every year.

This study presents an assessment of the waste-insulation materials (asbestos and glass-wool) collected from the yards in Alang. The waste-insulation matrixes were analyzed for their elemental, morphological, and other physico-chemical characteristics by using analytical techniques including Inductively Coupled Plasma-Atomic Emission Spectroscopy and Scanning Electron Microscopy. On the basis of analysis,a framework for management of waste insulation material has been proposed for the environmental sound management of glasswool and asbestos bearing wastes. Finally, some practical and scientifically defendable alternatives have been reported for treatment and disposal of these voluminous hazardous wastes.

Keywords: Asbestos, Glasswool, Hazardous wastes, Ship recycling, Ship dismantling, Alang

1. Introduction

Insulation materials like asbestos and glasswool have been extensively used for over millennia owing to its peculiar properties such as resistance towards heat, acids, chemicals, high flexibility and tensile strength (Thompson *et al*., 2002; Foresti *et al*, 2009). Yet, over the last few decades, the use of insulation material has drastically increased meeting the requirements of industrial installations and structures, construction sector as well as ship building industry (USGS, 2015). Asbestos and glasswool are used as insulation materials in industrial installations and structures. The management of end-of-life products bearing glasswool and asbestos in industrial installations has become a challenging task as they are humungous in amount and handling such wastes requires extreme precautionary measures and handling expertise. Most insulation wastes comes from demolition and refurbishment projects such as ship dismantling activity.

A major portion of insulation material wastes in India remains unattended and unidentified, rest of the wastes fraction, which is generated from ship dismantling sector and asbestos product manufacturing industries are disposed through landfilling as per the national regulatory norms. Keeping in mind the integrated approach of wastes management and circular economy, it is required to work on various recycling technological interventions available for asbestos wastes in order to process and convert them into some constructive material and minimize the health risk to the workforce. First, the prevailing practices of ship dismantling were studied in Alang to assess the current practices of asbestos and glasswool wastes management. Secondly, suggestions and interventions have been articulated in the form of a framework for managing asbestos and glasswool wastes generated from the SRYso that the yards will be able to demonstrate better compliance of Indian as well as International regulations.

2. Study Area

Alang-Sosiya yard was selected as the study area as it is considered as the largest graveyard of the ships in the entire country (Hiremath *et al*., 2015). It islocated in Talaja Tehsil of Bhavnagar District in Gujarat which stretches over a length of ~10 km of coastline. The yard is divided into 167 plots which have been leased to private entrepreneurs for ship recycling. The area is located between latitudes 21o22'36" N & 21o26'28.32" N and longitudes 72o10'00.4" E & 72o13'29.78" E. In a study done by Deshpande *et al*. (2012), it was found that around

350 ships are dismantled and recycled every year at Alang-Sosiya ship breaking yards. As per Gujarat Maritime Board (GMB), 2015 presently these yards have the ability to recycle about 450 ships per year producing around 4.5 million MT of re-rollable steel.

3. Literature Review

Asbestos Containing Materials (ACM) are commonly found in steam supply piping, valves, miscellaneous insulations on water pipes and other machineries, boiler casings, furnace insulations, sanitary spaces, AC ducts, refrigeration pipes, steam supply piping, exhaust piping, brake linings *etc*. and thereby extensively generated in huge quantities in ship dismantling activity. The primary routes of potential human exposure to asbestos are inhalation and ingestion. At ship dismantling yards, dermal absorption of asbestos is minimal, but dermal contact may lead to secondary ingestion or inhalation of dust (Courtice *et al*., 2011). Glass wool is generally used in ship for insulating purposes *i.e*. in engine room, heating systems, ventilation systems, electrical equipment, doors and side walls of cabins, ceilings and door panels. Glass wool emissions from all types of ships are significantly higher when compared with the other types of landfillable wastes - especially asbestos and asbestos containing materials. Transportation, storage and disposal of glass wool is the major challenge for ship breaking and recycling industry in Alang (Hiremath *et al*., 2016). American Conference of Governmental industrial Hygienists (ACGIH) has classified glass wool fibres as Category A3 (Confirmed Animal Carcinogen with Unknown Relevance to Human) under head Carcinogenicity. The Factories (Amendment) Act has laid down Permissible Limit of Exposure - Time Weighted Exposure (PLE –TWA) of 10 mg/m^3 as a Total Dust for Amorphous Silicates Since, glass wool is an amorphous silicate, a permissible limit of exposure of 10 mg/m^3 (TWA) can be adopted for glass wool as total dust. The extracted verbatim from a study namely "Product stewardship and science: Safe manufacture and use of fiber glass" authored by Hesterberg *et al*., (2012), stated that 'Certain Glass Wool Fibers (Inhalable) reasonably anticipated to be a human carcinogen. Certain Glass Wool Fibers (Inhalable) may be viewed as equivalent to '"Inhalable Biopersistent Glass Fibers" with purposeful exclusion of biosoluble and, thus, less biopersistent, glass fibers".For the present study few representative samples were collected from Alang ship recycling yard and analyzed for various properties (Figure 1).

4. Sampling and Analysis

The samples were preliminarily investigated for colour, odour, moisture and loss on ignition. For analysis of organic content in contaminated samples of asbestos and glasswool, solvent extraction method using Dichloromethane (DCM) was carried out for more than 48 hours. It was observed that the oil and grease were in around 34% in the glass wool sample and 22% in asbestos sample. Moisture content was less in the samples. The contamination of oil in samples may pose threat while disposing in to secured landfill. Quantification of oil and grease in the samples was done by using Soxhlet extraction technique. The concentrated extracted oil was quantified by gravimetric method. It was found to be very viscous and having tar like properties. In order to analyze the presence of various organic contaminants, the separation of various organic components (aliphatic, aromatic and polar compounds) was done by using silica gel column chromatography method. For morphological studies, the samples of glass wool and asbestos collected from Alang were finely ground, prepared and coated with platinum for around 200 seconds. The powder was examined in a FEG-SEM (Make: JEOL JSM-7600F, Model: JSM-7600F).For understanding the elemental composition of the insulation wastes, ICP-AES was conducted. Metal concentration, heavy metals in particular in the solution of every sample were analyzed by ICP-AES (Make: SPECTRO Analytical Instruments GmbH, Germany; Model: ARCOS).

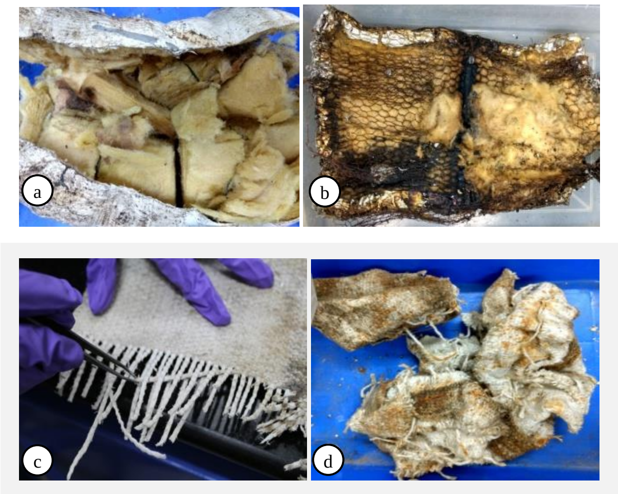

Figure 1: Insulation waste samples collected from Alang Ship Recycling Yard (a) and (b) are un-contaminated and contaminated glasswool samples, (c) and (d) are un-contaminated and contaminated asbestos sample

5. Results and Discussion

From the analysis, it was observed that the oil and grease were in around 34 % in the glass wool sample and 22% in asbestos sample. The major contaminants constituting the glasswool and asbestos bearing wastes consist of various organic compounds such as alcohols, carboxylic acids, esters and esters. Aromatic compounds such as Butane, 2,2,3-trimethyl 1,4-Pentadein-3-ol, Decane, Dodecane, 6-Trifluromethoxy-benzothizol-2-ylamine, Pentadecanoic acid, Dibutyl-octadecanoic acid, methyl ester, 1,2-benzenedicarboxylic acid *etc* were observed. One of the important finding is the presence of the "Phthalates" (Dibutyl phthalate) in the sample. The phthalates are extremely hazardous for the marine environment and are considered as potential endocrine disruptors. Many of the aromatic hydrocarbons are persistent in nature and can cause hazard to the human health and environment. Disposing such kind of wastes contaminated with organics can lead to severe hazard in the form of groundwater contamination though potential action of leachates. The SEM imaging of asbestos and glass wool are presented in Figure 2. The asbestos fibres found in the bulk samples of insulation material had the characteristic morphology and appearance of chrysotile asbestos (white asbestos) which is evident from the physical observation also.

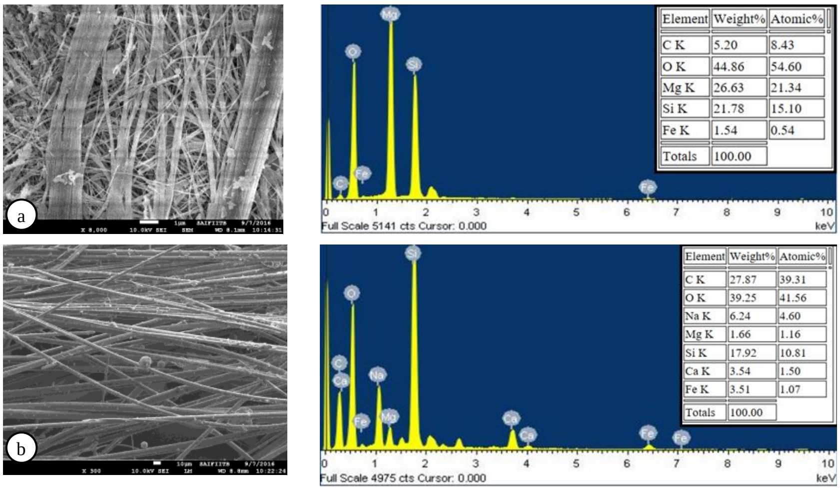

Figure 2: SEM microphotographs and EDAX analysis of asbestos (a) and glasswool (b) bearing wastes

The very fine fibres (fibrils), when viewed at higher magnification, showed the characteristic tubular structure associated with chrysotile fibrils. Individual fibres analyzed by energy dispersive X-ray (EDX) analysis showed chemistry similar to a reference standard of chrysotile studied in literature (Bonneau *et al*., 1986; Anastasiadou, 2007). The analysis carried out showed that the type of asbestos "chrysotile". Chrysotile asbestos fibres can be a matter of great concern if these fibres are into atmosphere due to dismantling activity at SRY. EDS (Energy Dispersive Spectroscopy) analysis showed the presence of oxygen, magnesium and silicon as the major element having percentage of 57%, 21%, 15% respectively. Magnesium and Silicon are the major elements found in the asbestos sample, which was further confirmed by ICP-AES analysis. The FEG-SEM image of glasswool is also showing its characteristic morphology. The major elements constituting glassfibres are C, O, Na, Si, Fe and Mg.The chemical composition of the majority of glass fibers (and glass spheres) in all samples is consistent with slag wool, a synthetic fiber commonly used in building materials like ceiling tiles EDS analysis showed the presence of oxygen, magnesium and silicon as the major element having percentage of 57%, 21%, 15% respectively. The ICP AES analysis of the contaminated sample of glasswool showed the presence of heavy metals in trace qunatities such as Nickel, Cadmium and Lead.

6. Challenges in sustainable management of insulation wastes

The major challenging task in management of insulation wastes at SRY reportedly is handling of the ACM and ACW and glass-wool wastes.There has to be more concerted efforts for minimizing the exposure of hazardous asbestos and glasswool fibres to the workforce at SRYs. Storage of these so-called "high volume less toxic wastes" at yards is anotherimportant aspect of waste insulation material management. The storage of huge quantity of wastes and the associated health hazards cannot be ignored. Proper labeling, packing and transportation is also one of the important elements of the environmentally sound management of these voluminous wastes. Lack of infrastructural facility at SRYs is the root cause of the hazards arising due to ship dismantling activity. Also, there is lack of proper classification system for management and final disposal of waste insulation material. As it is evident from the field visits and sample analysis, insulation wastes generated from different sources have different characteristic features. All wastes streams cannot be treated by adopting one single method. The management of these wastes requires a well-defined classification system so that their disposal or/and reuse technology can be designed accordingly. Presently there is no inventorization of waste insulation materials available at the Alang dismantling yards. Recycling potential of these waste materials is an un-explored area of research. Management strategies are to be framed as presently landfilling is the only disposal option being followed at SRYs in Alang

7. Integrated management of insulation wastes

There is enough literature available that validate the ill effects of air borne asbestos fibres (WHO, 2014; Wu *et al*., 2015). In order to avoid the deleterious health impacts to the workforce potentially exposed to fibres, there is a stern need to use some in-situ technology to reduce the friability of the fibres or combination of both of these. Many primitive methods such as wet stripping can be employed for reducing the friability of insulation material particularly asbestos. The most commonly used wetting agents are surfactants (Myers, 1974; Batdorf, 1994; Pucillo, 1999; Block *et al*., 2000; Arpin, 1982). Application of composition containing a cellulosic polymer such as hydroxy-propyl cellulose on asbestos-containing material and allowing the cellulosic polymer containing composition to penetrate and wet the asbestos-containing material before the mechanical removal was studied and patented by Erzinger(1987). These compositions may also contain auxiliary ingredients such as dyes or other coloring agents, thickening agents, inert gelling agents, preservatives, wetting agents, humectants, surfactants, solvents, pH adjusting agents *etc*. A framework for the strategicscientific management of insulation wastes material generated from ship dismantling yards is presented in Figure 3. This logical diagram may prove to act as guidance protocol for sustainable management of these insulation wastes.

7.1 Categorising the wastes and management at Ship Breaking yards

The wastes insulation material generated from different locations during ship dismantling can be broadly classified on the basis of their friable nature. “Friability” can be referred to as the tendency of the insulation material (particularly asbestos) to get pulverized by hand pressure (15 U.S. Code § 2642). If the wastes are friable, it should be properly wetted by water along with any surface active agent such as surfactant solution in order to ensure complete wetting. Further, the insulation wastes has to be labeled, packed and sealed in closed container and ultimate disposal should be done in secured landfills after treating them with cementitious material. Thus, disposal of these wastes should be done after converting them into asolidified block/matrix/monolith structures in order to have a better environmental acceptance. The dismantling of installations should be executed under controlled condition with all the precautionary measures. If the insulation wastes are contaminated with organic pollutants, it has to be pre-treated with suitable agents such as adsorbents or surfactant washing prior to subjecting it to s/s treatment. The final disposal can take place after converting the wastes into solidified matrix like in previous case. If the wastes are non-friable and non-contaminated it can be recycled by selling it in the market. However, this is only applicable to glasswool. Any type of recycling and reuse of ACMW (Asbestos Containing Material Wastes) is strictly prohibited by Basel convention and other regulatory bodies.

7.2 Directly reusable insulation wastes

The un-contaminated samples of glasswool wastes can be sold to the market as insulation material. The current practice of managing such wastes in Alang is disposing them in landfills. However, this cannot be considered as a sustainable practice of managing wastes because glasswool wastes occupies a huge space in the landfills also the handling of wastes is difficult. Asbestos containing wastes is usually not recommended to be recycled in any case as per Basel convention.

7.3 Pre-Treatment of insulation wastes prior to disposal and their recycling potential

The direct land spreading and/or indiscriminate dumping of contaminated insulation material wastes in the landfills without stabilization may cause soil and groundwater pollution. As evident from the analysis, many samples can be contaminated with oil and grease. It is thus not recommendable to dump the wastes into landfills without providing them any kind of pre-treatment. The ICP-AES analysis indicated the high concentration of metals in the sample, which is also one of the major environmental concerns. The treatment method could vary according to the requirement. The most commonly used treatment in Solidification and stabilization is adding adsorbent in the wastes. However, the landfilling of hazardous wastes having high concentration of organics is not recommendable due to microbial action of bacterial species such as *T. thioxidansis*, which after certain time can cause bacterial degradation of wastes (Knight *et al*., 2004). But this method could still be an economically workable approach in some cases (Eaton *et al*., 1987).Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl compounds (PCBs), organotins, oil and grease pollution are reportedly the major contaminants found in the ship breaking industry (Hossain *et al*., 2016) and there occurs a high probability of cross-contamination in insulation wastes. Non-volatile organics, such as PCB are not very mobile in the environment, not volatilize from the waste and create no air emission troubles, so encapsulation of these contaminants in binder matrix diminish their leachability even further (Weitzman, 1990). Further, the organic compounds may interfere in hydration reaction of cement mix by forming a layer around contaminant particles. There is adsorption of the retarding compounds on hydration products, predominantly calcium silicate hydrate, the adsorption of these compounds forms an impervious covering on the calcium silicate hydrate (C-S-H) and restrain further hydration by obstructing transport of water into the cement grain (Trussell and Spence, 1994). In order to overcome this very problem, addition of certain type of adsorbents during S/S of organic constituents in hazardous wastes had been recommended by many researchers for different kind of waste streams. Various adsorbents including activated carbon, organophilic clays and zeolites have been evaluated for the adsorption of retarding organics in mixed waste matrix prior to cement based solidification (Pollard *et al*., 1991; Montgomery, 1990). These adsorbents can be used as pretreatment of contaminated glasswool and asbestos bearing wastes prior to their solidification/stabilization or can be added as additive in cement mix, which include metal oxide, clays, natural materials (zeolites, fly ash, organic polymers, etc.), and activated carbon (Paria and Yuet, 2006).

8. Conclusions and Recommendations

Segregation and classification:Insulation wastes mainly in the form of asbestos and glasswool are either dumped directly into landfills or cement based solidification/stabilization is being adopted as a pre-treatment technology prior to their final disposal. Based on the properties, these wastes can potentially be reused and recycled for their beneficial utilization for other constructive purposes. Practically, this approach could only be possible if we have a well-defined classification system of Asbestos Containing Products (ACPs), Asbestos Containing Material (ACM) and Asbestos Containing Wastes (ACW). At present, there are no such criteria for classifying and designating the insulation material wastes as “recyclable”. Henceforth, a strategic framework has to be developed to decide whether the waste is recyclable/ reusable or not? This classification would not only help in determining the reusability and recyclability potential of the wastes but also in a correct identification of landfills for the environmentally safe disposal of ACW and other insulation material wastes in India. Contamination: As seen in the above Figure 1, the presence of contaminants particularly organic contaminants, oil and grease etc. clearly act as abarrier for the recycling as these may degrade properties of the recycled products and limit their range of potential applicability. Systematic demolition activity of ships: The systematic dismantling activity will ensure that the insulation wastes are not getting cross contaminated and can be reused. Occupational Health and Safety: Provisions for use of Personal Protective Equipment (PPE) and proper infrastructural facilities.

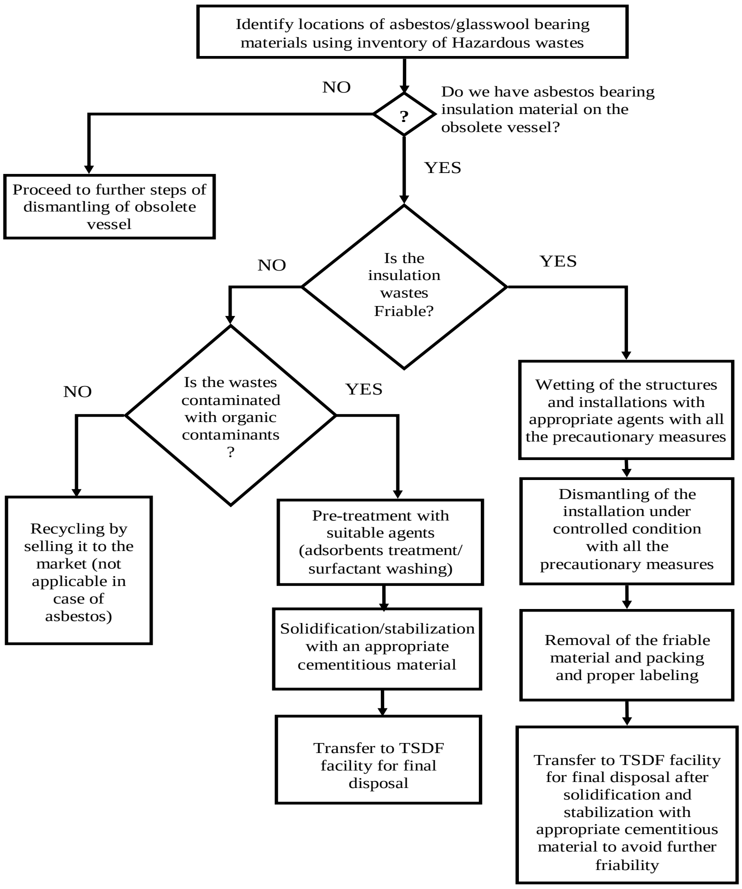

Figure 3 Framework for management of insulation wastes material generated from ship dismantling yards

should be strengthened at the SRYs at Alang ship dismantling yards. Reuse and Recycle: Provisions for re-using the non-contaminated insulation wastes in order to avoid disposal cost and Carbon footprint assessment. The carbon footprint analysis of the recycling activity versus virgin material usage for manufacturing various products can aid in justifying the recycling action of the insulation wastesThe framework for management of asbestos and glasswool bearing wastes aspresented in Figure3 will provide an easy understanding forthe steps that should be followed for the environmentally sound recycling of the obsolete vessels having inbuilt asbestos and glass wool insulation materials

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