Management and Exploitation of Human Hair "Waste" as an Additive to Building Materials: A Review

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Abstract Recently, biological fibers have become striking topic to researchers, scientists, and engineers as substitute reinforcement, due to their cheap availability, high aspect strength, and appreciable mechanical properties. Human hair fiber (HHF) is one of the unsullied biological fibers. Its accumulation, in the form of waste heaps or in waste stream leads to many environmental problems. All in all, three to four tons of this biological fiber is thrown around like confetti in India annually; posing an environmental challenge. Nowadays, as a commercial application, human hair waste is finding its use in the field of material science. Because of the fact that human hair is strong in tension; it can be used as a fiber reinforcement material. A substantial amount of sulfur is present in human hair because of the presence of "cysteine" amino acid, a major constituent of keratin proteins. Keratin is a primary component of human hair, which is a protein, a polymer of amino acids. Protein "keratin" is incredibly strong, insoluble, and tough. A single strand of HHF can withstand a load of 100–150 gms and on removal of the deforming load, HHF is capable to regain its original position by virtue of its elasticity. This review paper outlines the current scenario of exploitation of HHF as biological composite fiber in various fields of construction. This study shows that HHF is a highly multifaceted material with noteworthy potential in several major areas such as medical applications, cosmetic industry, agriculture, construction material, and pollution control.

Keywords Human hair fiber · Construction material · Environmental challenge · Mechanical properties

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1 Introduction

To be amazed, use of biological fibers is not new to our generation but they have already been used some 3000 years ago in the ancient Egypt, in composite systems, where clay and straw were mixed in order to build the structures and walls. But recently, biological fibers have become a striking reinforcing material for polymeric composites from an ecological and economical point of view. Though there exists a number of uses of human hair, it is considered as a waste material in almost every part of the world. Its accumulation, in the form of waste heaps or in waste stream leads to many environmental problems [1].

In areas where population density is quite low, especially rural areas, the hair which is thrown away in nature decomposes very slowly taking a very long time, almost over several years, finally returning back the integral elements to their natural cycles. Those elements include carbon, sulfur, oxygen, nitrogen, etc. In highly populated areas, especially urban areas, the hair often accumulates in the solid waste streams in large amounts and as a result chokes the drainage systems, creating a serious problem.

As the degradation process is quite slow, it remains as a part of thr waste stream, engrossing large space for a long time. Eutrophication is one of the unwholesome result due to the increase in the concentration of nitrogen from the leachate of these dumps. Also, it's a widespread practice of burning of waste piles holding human hair which results in the production of toxic gases with foul order such as hydrogen sulfides, ammonia, sulfur dioxide, carbonyl sulfides, phenols, pyrroles, pyridines, and nitriles [2].

Sweat, oils, organic matter, etc., sticking to the waste hair crumble over the passage of time and ultimately become a reason for the malodorous condition, providing a space for pathogens breeding. Even the hair dust generated from the open dumps causes a lot of discomfort to the nearby mortals and can face severe respiratory problems if large amounts of inhalation occurs for a long span of time. In order to solve all the problems discussed above, the finest way is to evolve systems that can utilize the fritter away as a source.

Contribution to the economy will be an additional advantage along with the reduction in waste. Growing cognizance related to the environmental issues in the world has evoked interest of the researchers in the area of utilization of biodegradable materials. The resources of the natural or biological fibers include animals, plants, or minerals.

With the shortfall of energy supplies and ecological risk, the idiosyncratic advantage of using biological fibers include its nontoxicity, abundance in quantity, noncorrosive in nature, no irritation to the eyes, skin, or respiratory system. With all these beneficial properties, polymer composites reinforced with natural fibers have grabbed much interest as an alternative reinforcement in place of synthetic ones [3].

As a possible material resource, the fiber of human hair has a number of advantages, such as it is renewable, completely biodegradable, and most importantly it is available in bulk at a very cheap or nil cost in almost every locality. The property

of lightweight and more volume of natural fibers in comparison with the synthetic fibers helps to improve the efficiency of fuel and also reduces the emissions in the auto applications [4, 5]. Surprisingly, though human hair is thrown as waste in many parts of the world, yet there occurs large scale international trades in the products of and high quality hair.

In 2010, India exported approx. one million kg of hair and human hair products worth US $238 million, and the total global imports were valued at US $1.24 billion [6]. In India, the workers of the hair processing units involved in such trades have reported many number of cases of infections in the respiratory tract and tuberculosis as a result of decaying hair and hair dust [7, 8].

This paper assesses and explores various employment of human hair in different fields, especially as an additive to building materials, from the standpoint of expanding its exploitation as a resource along with addressing the environmental issues related with it as solid waste.

2 Review of Natural Fiber {hhf}

Choudhry and Pandey [9] founded in their studies that composites show a higher flexural modulus, flexural strength, and Izod impact strength with 3–5% by weight of human hair fiber when compared with non reinforced polymer. Also, they found that the flexural strength, Izod impact strength and flexural modulus decreases if the proportion of HHF is increased to 10–15% by weight. Ganiron [10] examined the effects of HHF additives in comp. strength of the mixture of asphalt cement and found that the load-bearing capability of cement asphalt mixture has greatly improved when the percent of HHF is taken in between 6 and 8% by weight of bitumen. Also, he founded that this percentage can be increased if proper gradation is done and the content of bitumen added is also increased simultaneously.

Fueghelman [11] investigated the structure and mechanical properties of alpha keratin fibers like human hair, wool, and others and deduced that HHF possesses the greatest tensile strength when compared to other fibers. He also unclosed the exceptional features of HHF such as low rate of degradation, distinct chemical composition, great tensile strength, elastic recovery, thermal insulation, scaly surface, and unique kind of interactions with oils and water which has made it possible to use this fiber diversely. Figure 1 shows the human hair waste collected from a barber shop.

3 Applications of Human Hair

The uses of human hair depend on many parameters such as length, curliness or straightness, color, contamination, and hair damage. These all variation occurs due to the difference in the culture, hairstyles, ethnicity, and the various practices of hair care in different regions.

Fig. 1 Human hair

3.1 Cosmetic, Theater, and Fashion Industry

Hair Extensions, Wigs, Eyelashes, Beards, Moustaches, and other cosmetic accessories: This is a standout among the oldest and right now the biggest of the human hair based ventures, with an always expanding scale because of worldwide extension of the design business. The ones from 1400 BC Egypt, are the most established wigs known, and some of them are still unblemished today even after 3400 years [12]. This application prevalently utilizes great quality, hair with good length of practically all hues.

Check material for hair care commodity: Human hair samples are utilized as test stuff for new definitions of oils, shampoos, conditioners, colors, etc. These tests utilize hair of various hues, scope of curliness, and distinctive damage levels.

Manufacturing Cosmetic Brushes: Scaly surface of hair can hold the particles of cosmetic powder and apply it consistently on any surface or skin. Hence, hair of mortals has been used for making the brushes [13, 14].

3.2 Cultivation Industry

Vermin Control: Various problems related to vermin as well as issues arising from animals in the farms have been addressed by the use of human hair, although by various mechanisms. In Mauritius [15] human hair has been used to repulse rabbits, in USA [16] for deer and in India [17] for wild boar and rodents.

Also in India [18, 19] human hair is used to dissuade the rhinoceros beetles. Different methods and techniques involving the utilization of human hair in farms/fields help farmers to save their crops from pests and also this is more economical than the usage of pesticides.

As Mulch/Fertilizer: Human hair, a natural fiber, contains noteworthy nitrogen content which is approximately 16% since it is prevalently made up of such proteins which are nitrogen bounded. Likewise, human hair additionally contains carbon, sulfur, and 20 different components basic for plants [20]. In a few networks in India, human hair has been utilized specifically as manure for some products of the soil crops like vegetable and fruits and also in the production of natural manure [21, 22].

3.3 Pollution Check and Indemnification

Water–Oil Separation and Remediation for Oil Spill: Human hair fiber possesses a valuable property of differential affinity toward water and oils. Its surface has a lower affinity for water when compared to oils [23]. This property of hair fibers is very helpful in water–oil separation. Figure 2 shows the usage of hair fibers along with the feathers to fight against the oil spill in Philippines [24].

Removing Pollutants such as heavy metals, Aldehydes, Phenols, and Dyes from Water: Human hair has a tendency to absorb various chemicals from the aqueous solutions. Investigations demonstrate that human hair can assimilate natural toxins, for example, formaldehyde [25], phenol [26], and various heavy metals like copper{Cu}, mercury{Hg}, silver{Ag}, cadmium{Cd} from aqueous solutions [27, 28].

Fig. 2 In Philippines, Human hair and Feathers used to fight the oil spill

3.4 Biomedical Pharmaceuticals and Applications

Medicaments: Protein of human hair ordinarily contain 20 basic amino acids, all of which can be extricated on complete hydrolysis of human hair [29]. A portion of the amino acids acquired in great yield from human hair are, L-leucine, L-cysteine, L-valine, and L-isoleucine. L-cysteine and its synthetic subsidiaries are utilized in numerous beauty care products and pharmaceutical plans.

Ethnomedicinal Applications: A few societies have been utilizing human hair for planning customary medicines. Carbonized fibers of human hair have been utilized in customary Chinese medicine [30] for treating wounds, hemorrhage, scars, and burns.

It is additionally utilized in veterinary drug to quit bleeding and to advance urination [31]. In country networks in Chhattisgarh, India [22], hair fiery debris is applied to open injuries for prompt relief from discomfort just as long haul recuperation.

As a Suture in Surgery: Human hair has adequately high quality for it to be used as suture in many medical surgeries. It is moderately simple to tie hitches with human hair and it is also noninfectious (in light of its moderate decay rate and high similarity with the human body). In Europe, its utilization as suture was known in the medieval times [32]. Due to the flexibility, high strength, and elasticity, it is quite easy to make the stitches on the skin with the fibers of human hair and there is no fear of any kind of infections also.

3.5 Fabrics

In China, cotton, yak hair, and human hair are utilized to make interlining fabric for jackets and coats [33]. Individuals have customarily been making textures by blending human hair with nettle fiber, cotton, and yak hair in Arunachal Pradesh, India [34]. Elasticity, high thermal insulation, and great tensile strength make it possible to use human hair for different variety of fabrics.

3.6 As a Composite Stuff

Framed Objects and furniture: A UK-based business person, Ronald Thompson [35], has built up a technique for making up composite materials which incorporates first meshing human hair fiber into a web or tangle and after that including a basic added substance like sap or adaptable polymer (ideally a biodegradable or recyclable material). This composite possesses high strength and can be utilized for the making of framed or molded structures like mannequins and furniture. A composite comparable with unwoven hair has likewise been utilized for making perishable eyeglasses [36].

Hybrids for Superconducting Systems: Superconducting power types of gear frequently utilize fiber-glass-based amalgams for cryogenic protections. Michael et al. [37] have revealed that composite cover of human hair (and a few other biological fibers) with epoxy pitch shows dielectric breakdown properties reasonable for protection in cryogenic frameworks. A significant decrease in production cost can be seen in cryogenic equipments when these composites are used in place of glass fiber composites used currently.

4 Additive to Construction Materials

Investigation shows that reinforcement of human hair fiber enhances the capacity of thermal insulation as well as the structural strength of the structures made up of clays [38, 39]. Albeit such earth-based developments are presently diminishing in country territories, they are picking up significance in feasible design or sustainable architecture. In hinterlands of Madhya Pradesh and Uttar Pradesh, India [40], Syria [41], European countries [42], and in Bangladesh [43], fibers of human hair and clay mixture together with other binders are employed in lining ovens, plastering walls of the house, making wheels, etc.

Because of high friction coefficient and great tensile strength, human hair fiber has been utilized in reinforcing earth-based constructions. The expansion of hair fundamentally decreases cracking and drags out the life of the hair reinforced structures. Human hair fiber reinforcement even reduces the cracks which are resulted due to the plastic shrinkage in cement mortar composite by approximately 92% [44]. Also this reinforcement boosts up the compressive strength of cement concrete and fly ash concrete by more than three times [45]. The exalted pressure-bearing structures like bridges and petroleum walls utilize the property of improved strength and enhanced fracture resilience of hair reinforced fly ash concrete and cement concrete. The most interesting fact is that any kind of human hair can be utilized in the reinforcement in building material. The versatile property of the Human hair fortified in black-top asphalt may create better remain on traffic stacking by a similar principal component of exchanging the high power forces conferred by the wheel burdens at the surface to bring down dimensions of the subgrade that can suit without misshaping. The investigation by Ganiron [10] demonstrates that on adding human hair and cement to black-top asphalt blend, an extraordinarily increment in the quality of the blend is observed and in this manner making it a decent material for the development of street asphalt. Including of both human hair and cement to black-top asphalt blend enhances the heap bearing limit of the blend.

5 Conclusion

This investigation has shown that fibers of human hair have a substantial number of employments in zones running from farming to drugs to engineering/building industries. Subsisting trade in natural fiber, "human hair," which has advanced around a portion of these utilizations over hundreds of years, gives a few critical lessons. Additionally, numerous new fields are being investigated in scientific research. Huge scale implementation of these utilizations, in any case, requires a few social, environmental, and financial contemplations. This trade has given jobs in numerous parts of the world however has likewise caused worries about the moral accumulation of hair, ecological and well-being security at the human hair processing businesses, and item security for shoppers. The aggregation of human hair fibers can be based on various diverse methods run by both fiscal and nonfiscal factors. In light of a foundational way to deal with the total esteem expansion ties from accumulation to utilization, the vast majority of these worries can be addressed. There is a vast scope for the growing use of human hair fiber as its present percent usage is exceptionally low. Because of its exceptional properties and universal accessibility, human hair fiber can contribute essentially in numerous basic regions of public significance, for example, agriculture, medication, building materials, and contamination control. In order to reduce the human hair waste and to solve the problems due to its accumulation as a waste, there is a need to develop standards and legislations along with building support schemes for several utilizations according to their market scope, entrepreneurial needs, and environmental scope. Alongside, the public must also be informed about its profitable properties and secure practices of aggregation and usage. Because of its high tensile strength, elastic and crack reducing properties, and many more, its exploitation in the field of engineering specifically as an additive to the building material will be very beneficial. Due to its excellent properties and universal availability, human hair fiber can contribute basically in various fundamental areas of open centrality, for instance, horticulture, medicine, building materials, and pollution control. With the help from different stakeholders, it is conceivable to create total use frameworks for human hair fiber, which will lessen solid waste and issues related to environment, generate noteworthy socioeconomic advantages for individuals, and diminish pressure on other fossil fuels and exhaustible materials.

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