



(RESEARCH ARTICLE)



Biothermocool: A sustainable and eco-friendly solution for managing agricultural and Thermocol waste

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Abstract

Stubble burning, the act of setting fire to leftover crop residue after harvesting, is a problem that affects many countries, including India. This practice, common in states like Punjab, Haryana, and Uttar Pradesh, contributes to severe air pollution, worsens public health, and impacts the environment. Addressing the environmental toll of stubble burning requires a shift toward more sustainable agricultural practices that mitigate these consequences. Alternative methods, which are efficient, low cost, user friendly, innovative and sustainable can help preserve soil health, reduce emissions, and protect both human health and local ecosystems. The second major concern that this research focussed on was thermocol. It is manufactured from a petroleum-based plastic compound known as polystyrene. Many of us are unaware about its adverse effects on our environment and the toxic emissions it causes when incinerated. Thermocols are not environmentally friendly and they emit chlorofluoro carbon (CFCs) when they are burnt. Biothermocool provided us with a comprehensive, cost-effective, and sustainable solution to two major waste management issues—stubble disposal and thermocol pollution. It is easy to produce, biodegradable, and holds great promise for environmental conservation and community-level waste management. Our research shows that simple innovations can bridge the gap between ecological problems and practical, scalable solutions.

Keywords: Stubble burning; Thermocol, polystyrene; Chlorofluoro carbon; Biothermocool; Biodegradable; Sustainable solutions

1. Introduction

Stubble burning is the practice of intentionally setting fire to the straw stubble that remains after grains, such as rice and wheat, have been harvested. The technique is used to quickly and cheaply clear fields. It is still widespread today. Stubble burning has been associated with increasing air pollution over the past few decades due to the particulate matter contamination it distributes into the atmosphere. In India, stubble burning generates a thick haze. These fires pose a significant health risk to individuals across all ages. In countries such as India and Pakistan, stubble burning is illegal. Enforcement is weak, allowing the practice to continue.

The unconventional practice of stubble burning continues despite repeated calls from environmental scientists for its cessation. Within just two months from 15 September to 15 November, 23505 cases of farm fires were recorded in six states, including Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Rajasthan, and Delhi.

The winter harvest season in November and December is one of the major contributors to air pollution. For reasons such as failed crop output, time and money constraints, and low market prices, farmers set fire to their crops to quickly clear their fields. In cold weather and low wind conditions, a meteorological phenomenon known as temperature inversion makes it difficult for pollutants to disperse and rise, resulting in thick smog. The toxic fumes from the

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agricultural fields when combined with already high carbon emissions in the city exacerbate air pollution in the national capital, Delhi, thereby causing adverse impacts on health and huge economic losses. (Sadan Khan, Jan 09, 2025)

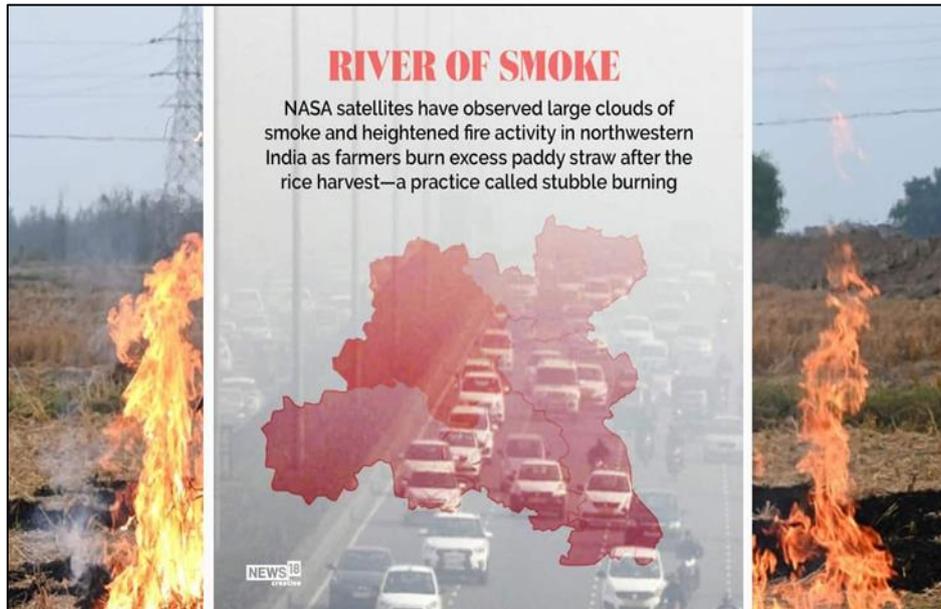


Figure 1 NASA satellites have observed large clouds of smoke and heightened fire activity in northwestern India from farmers burning crop stubble. (Moneycontrol News 2022)

In India, stubble burning is also known as “Parali Burning” in local language. Generally harmful effects of stubble burning is loss of nutrients in the soil, pollution from smoke, including greenhouse gases and others that damage the ozone layer, damage to electrical and electronic equipment from floating threads of conductive waste, risk of fires spreading out of control. Additionally, prolonged stubble burning kills beneficial microflora and fauna in soil which reduces organic matter and destroys the carbon-nitrogen equilibrium.

A wide array of health disorders is associated with the stubble burning emission releases which have caused people to develop lung cancer and respiratory infections. The emissions also threaten the health of children who tend to have weaker organs. Not only that but the smog from the stubble burning also severely affects people with Chronic Obstructive Pulmonary Disorder as it worsens their health conditions. India also has the highest number of blind people in the world and if the smog gets in your eyes, you are more likely to develop cataracts. Additionally, people who have been exposed to smog can develop eye irritation, eye-watering, and conjunctival hyperaemia symptoms. In order to reduce pollution there needs to be severe attention to the issue involved with effective sustainable management practices enforced by the government. The Indian government has been receiving intense backlash for not reacting quickly enough to the health emergency, especially amongst the green revolution that is bringing attention to climate change concerns. Recently, The Amritsar district administration is going to introduce a 'kisan priority card' (KPC) to incentivise farmers for refraining from burning stubble and promote a sense of pride and inclusion by inviting them to participate in Government functions, allowing them to share their experiences and recognising them as valued contributors to the society. (TOI, July 2025)

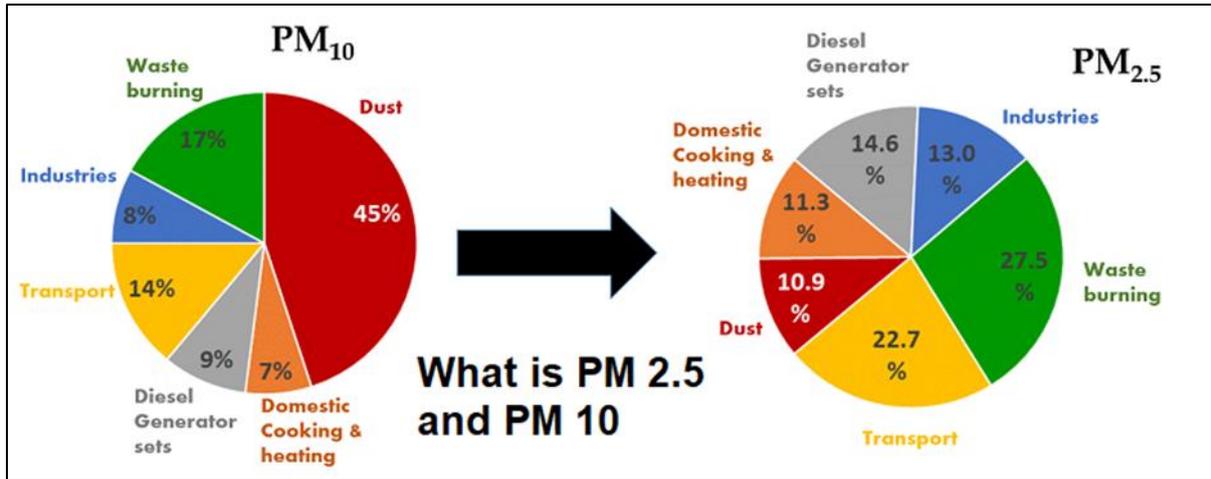


Figure 2 Difference between PM 10 and PM 2.5 (Useful information, Welcome NRI)

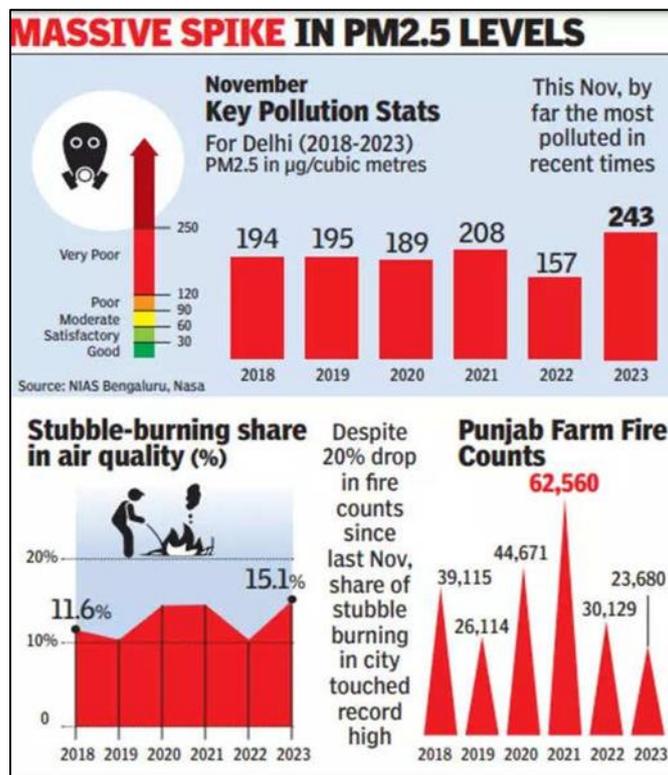


Figure 3 Massive spike in PM 2.5 levels (Amit Bhattacharya, TOI, December 1, 2023)

Prolonged exposure to particulate emissions may lead to an elevated rate of cardiovascular mortality (Saggu et al., 2018). Fine particulate matter (PM_{2.5}) has more effects on humans than the larger sizes, for the former can penetrate through the trachea into the lungs and subsequently to the bloodstream (Ghosh et al., 2019). An epidemiologic study conducted by Saggu et al. (2018) reported a decline of pulmonary and lung function especially in children exposed to a high level of particulate pollution. PM_{2.5} pollution alone accounts for about 21% of the total deaths in the southern part of Asia. Its effects range from a runny nose, coughing, and difficulty in breathing to chronic effects such as asthma and coronary diseases (Ghosh et al., 2019). A study showed that exposure to a high level of particulate emissions may lead to a decrease in the functionality of the human lungs. The effect is more austere in children as prolonged exposure may lead to asthma or chronic pulmonary diseases (Ghosh et al., 2019). Other effects of exposure to polluted air include; tuberculosis, stroke, lung cancer, cardiac arrest, and acute infections in the respiratory system (Saggu et al., 2018).

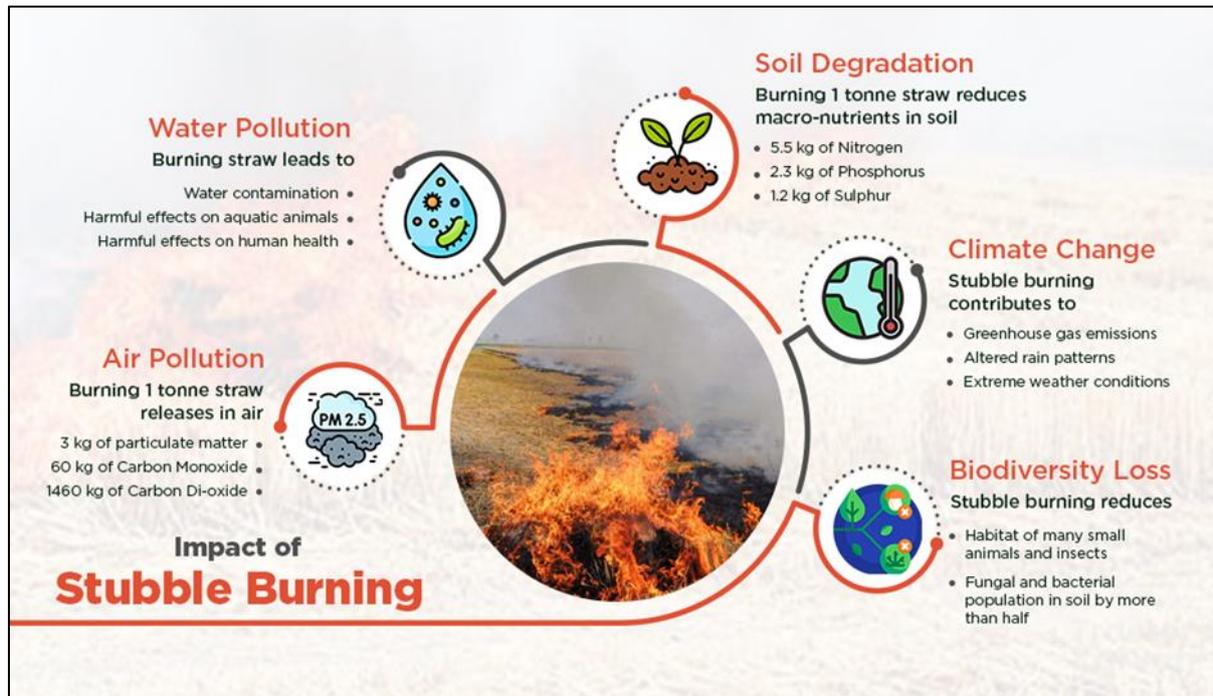


Figure 4 Impact of Stubble burning (Neesha Rathod, February 2025)

Stubble burning isn't just an issue in India. Countries like China, Thailand, Indonesia, and the United States have faced it as well. Farmers often burn crop residue because it is the fastest and cheapest way to clear their fields for the next planting season. Tight farming schedules and a lack of affordable alternatives make this method appealing. Moreover, many farmers are unaware of the long-term harm stubble burning causes to the environment and health. India's efforts to curb stubble burning are still in the early stages compared to the structured and collaborative approaches seen globally. However, while India is grappling with this issue, other countries have successfully tackled agricultural waste burning through effective policies, technology, and community action. (Khaitan Bioenergy Blogs)

A recent study in 2020 showed that India created 600-700 million tonnes of crop residue and is choking cities. People in India are awaiting sustainable management to reduce the pollution. After 1 tonne of crop residue is burnt in a field there is a release of 1,400 kg of carbon dioxide (CO₂), 58 kg of Carbon Monoxide (CO), 11 kg of particulate matter, 4.9 kg of nitrogen oxides (NO_x), and 1.2 kg of Sulphur dioxide (SO₂). Stubble burning also depletes groundwater and the lack of attention to the issue has led Indian civilians to feel hopeless for effective government interventional responses. (Stubble burning, Wikipedia)

The solutions to reduce the pollution from stubble burning involve mitigating crop farming, adhering to diversification of agriculture, adopting the paddy straw farming technique, and making biomass pellets. Agriculture residues can have other uses, such as in particle board and biofuel, though these uses can still cause problems like erosion and nutrient loss. Spraying an enzyme, which decomposes the stubble into useful fertiliser, improves the soil, avoids air pollution and prevents carbon dioxide emissions. Several companies worldwide use leftover agricultural waste to make new products. Agricultural waste can serve as raw materials for new applications, such as paper and board, bio-based oils, leather, catering disposables, fuel and plastic. Another important way to manage the agricultural waste from stubble burning would be to detoxify the soil after it has been burned and using aerobic and anaerobic techniques that recycle organic matter. (Stubble burning, Wikipedia)

Our research was initiated in response to this pressing environmental concern. In our quest for sustainable solutions, we explored various alternative methods of stubble utilization, such as Biofuel Production, Bioethanol Extraction, Composting and Vermicomposting, etc. Although these methods are promising, they often face challenges related to cost, scalability, maintenance, and technical requirements. This led us to search for an alternative that is low-cost, easy to implement, and environmentally friendly. Through our exploration, we discovered **Biothermocol**—a highly innovative material created by combining agricultural waste (like stubble and cut grass) with mycelium fungus, that was safe and productive use of stubble, eliminating the need for burning, low cost, eco-friendly, sustainable, user friendly and very easy to handle and prepare.

While researching this solution of Biothermocool, we also explored the environmental hazards posed by thermocol, a material commonly used for packaging due to its lightweight and cushioning properties. However, thermocol is rarely recycled and has become a significant contributor to environmental pollution. One of its most critical drawbacks is its non-biodegradability—it can take hundreds of years to decompose, thereby persisting in the environment for generations. Improper disposal often leads to air and water pollution, as thermocol is either dumped into landfills and water bodies or openly burned, releasing toxic fumes such as styrene and benzene. These gases are carcinogenic and harmful to human health, contributing to air toxicity and respiratory problems. Moreover, thermocol's lightweight and bulky nature makes it economically unviable for large-scale recycling, leading to inefficient waste management. It also poses a serious threat to wildlife, as animals frequently ingest thermocol particles, mistaking them for food—resulting in fatal digestive blockages and malnutrition.

Thermocol, also known as expanded polystyrene foam (EPS), has become ubiquitous in our daily lives, primarily due to its lightweight and insulating properties. However, its widespread use has led to significant environmental concerns and challenges. Naturally decomposing thermocol is not as damaging to the environment as the incinerated ones. However, most thermocol do not decompose naturally and have to be burnt as part of waste management process. Upon burning, Styrofoam does not dissolve completely and leaves a molten residual matter. When cooled, the molten residue hardened and emits obnoxiously pungent vapours. Recycling thermocol is also very difficult as it has a very complicated production process and it will cost more to recycle thermocol than to produce it. The best way to manage thermocol is by limiting its production and ensuring efficient management of thermocol wastes.

The use of thermocol is bad for our environment. It is a carcinogen, non-biodegradable, contaminates the food and drinks, It affects the health of workers who work in thermocol manufacturing plants, Replete with pollutants, etc. While thermocol offers practical benefits in various industries, its environmental repercussions cannot be ignored. (Yvonne Sim, The Local Brand)

These alarming drawbacks emphasize the urgent need for sustainable alternatives like Biothermocool. By addressing both the harmful practice of stubble burning and the environmental risks of thermocol waste, Biothermocool emerges as a sustainable innovation that not only reduces environmental burden but also repurposes two major waste streams effectively. Our solution centric research on stubble burning and thermocol wastes helped us to recognize the urgent need for an integrated and sustainable solution, we aimed to develop an innovative material—Biothermocool in our Biology laboratory.

2. Methodology

To create Biothermocool, we carried out a practical experiment in the laboratory using readily available waste materials. Cut grass collected from our school playground served as the primary agricultural residue, while mycelium fungus was easily available of very low cost to act as a natural binding and growing agent. The combination of these two materials enabled the formation of a biodegradable, lightweight structure that mimics the properties of conventional thermocol. This hands-on process not only demonstrated the feasibility of converting waste into a useful product but also aligned with our goal of promoting sustainable and eco-friendly practices and also SDG 12 Responsible Consumption and Production and 13 Climate Action.

Making biothermocool is a great option for stubble burning as it is simpler, safer, and more practical compared to biofuel or biogas production. The process involves using agricultural waste like stubble to create an eco-friendly alternative to thermocol, which is non-toxic and biodegradable. It can be done with basic materials and equipment available in schools, making

it manageable for young students. Additionally, it raises awareness about sustainable waste management and offers hands-on learning opportunities while contributing to solving the stubble burning issue in an innovative and accessible way.

2.1. Material used

- Cut grasses (Stubble)
- Spawn (fungal mycelium)
- Water,
- Molds for shaping the blocks
- Grinder
- Stirrer

Cut grass waste was collected, cleaned, and processed to obtain cellulose-rich fibers. These fibers were often broken down into smaller particles to enhance their surface area and increase their susceptibility to fungal colonisation. Fungal spores or mycelium culture were introduced to the substrate. The mycelium starts to grow, feeding on the cellulose present in the cut grass waste. It binds the particles together, forming a cohesive matrix. The mycelium-infused substrate was placed into molds of desired shapes and sizes. Under controlled conditions of temperature and humidity, the mycelium continued to grow and solidify, filling the mold cavity. After the mycelium had adequately colonized the substrate, the composite material was dehydrated to stop fungal growth. This drying process strengthened the material and enhanced its structural integrity. The biodegradable thermocol was trimmed, cut and shaped as needed for various applications. (Abhijeet Shirke)

All materials used are of low cost, easily available and user friendly. We tried many iterative cycles to come to a standard method by using cut grass of our school playground and mycelium in various concentrations and kept at different temperatures. With many repetitions we have got excellent result. The blocks of thermocols are made and stored. Indian scientists at ICAR (Indian Council of Agricultural Research) have also developed a similar Biothermocol which is an environmentally friendly alternative that can effectively replace traditional roof ceilings and other packaging material.

3. Result

Following multiple iterative cycles of experiments using cut grass (stubble) collected from our school playground and fungal mycelium spawn, we successfully developed Biothermocol sheets and blocks with desirable texture, strength and structural integrity. All materials used—cut grass, mycelium, water, molds, grinder, and stirrer—were low-cost, easily available, and user-friendly, making the process accessible and practical for wider application. Various concentrations of mycelium were tested under controlled conditions to identify the optimal growth environment and binding effectiveness.

After conducting several cycles with variations in temperature and composition, we found that the ideal conditions for mycelium growth and binding occurred at a temperature range of 25°C to 30°C, with an incubation period of three weeks. Under these conditions, the mycelium effectively colonized the cut grass, forming a firm, lightweight, and biodegradable block with structural properties comparable to synthetic thermocol. The final Biothermocol blocks were formed using molds, dried, and stored successfully, demonstrating excellent consistency, durability, and eco-friendliness. These results validate the potential of Biothermocol as a sustainable, dual-purpose solution to manage both stubble and thermocol waste effectively.



Figure 5 Cut grass and Mycelium fungus growing in a mold



Figure 6 Biothermocol kept for drying

The outcomes of our trials strongly affirm that this method yielded highly effective and consistent results. Among the various approaches we tested, the combination of cut grass and mycelium incubated under controlled conditions

consistently produced compact, durable, and lightweight Biothermocool blocks. The material showed excellent integrity and cohesion, making it a reliable substitute for conventional thermocol. The process not only ensured efficient bonding of natural fibers but also allowed for easy shaping and handling. These observations confirm that our method is both scientifically sound and environmentally practical, offering a powerful alternative for waste management and sustainable material development.



4. Conclusion

As global concern for environmental sustainability grows, the development of innovative and eco-friendly materials becomes imperative. Stubble burning in India is a complex problem, but it is not unsolvable. By learning from countries that have successfully addressed agricultural waste burning, India can adopt better policies, engage communities, and make use of advanced technologies. International aid can accelerate this process, bringing funding, knowledge, and resources to support sustainable practices.

Farmers play a crucial role in this transition. Empowering them with tools, financial incentives, and awareness is essential to creating a system where stubble burning becomes unnecessary. With collaborative efforts from the government, private sector, and global partners, India can overcome this challenge and set an example for sustainable agriculture worldwide.

The development of Biothermocool using cut grass (stubble) and mycelium stands out as a significant and timely innovation in the face of growing environmental challenges. This eco-friendly material not only serves as a biodegradable alternative to synthetic thermocol but also provides a sustainable solution to the widespread issue of stubble burning. By repurposing agricultural residue and harmful packaging waste, our research addresses two major global problems—air pollution from stubble burning and plastic pollution from thermocol—through a single, cost-effective, and easily replicable process. The simplicity of materials and method ensures that this solution is accessible at the grassroots level, offering immense potential for environmental, economic, and social impact.

To take this innovation forward on a larger scale, government support and startup collaboration can play a pivotal role. The government can aid by providing funding, infrastructure, and policy incentives for sustainable alternatives, while startups can drive innovation, manufacturing, and distribution through scalable business models. By including Biothermocool in green procurement policies, eco-packaging guidelines, and startup incubation programs, this project can be transformed into a national-level initiative. Promoting such solutions can not only empower rural communities and farmers with additional income opportunities but also help India move closer to its climate goals and circular economy targets. With collective effort, Biothermocool can become a symbol of innovation rooted in sustainability and social responsibility.

Let's work together to ensure cleaner air, healthier communities and a better planet for future generations.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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