ISSN: 2347-4688, Vol. 12, No.(1) 2024, pg. 161-169

Current Agriculture Research Journal

www.agriculturejournal.org

Stubble Burning in India: Environmental Concern and Alternative Tools

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Abstract

India is recognized as the world's second-largest agro-based economy. With 20% of the world's total rice production, India ranks second in the world behind China. Farmers in northern India, including Punjab, Haryana, and other regions, frequently burn any leftover stubble or straw in their fields after the grain harvest. So as to decrease the quantity of agricultural waste, farmers carry out this clearing technique (Parali burning) to get the fields ready for the next planting season. In India as well as other countries throughout the world, crop residue burning is an alarming issue. Every year, throughout the months of September and October, the Delhi and its nearby areas witness significant air pollution due to stubble burning after rice harvesting, which leads to chaos. Despite implementing numerous significant steps, both the Central and Delhi governments have not yet been able to resolve this issue. There are several adverse consequences of burning stubble, such as the release of potentially dangerous pollutants into the air, increased smog production, and worsened human health. Moreover, this has a detrimental effect on the nutritious value of the soil. Crop residue can be dealt with different efficient ways, even though it cannot be completely eradicated. In this regard, the present article aims to investigate optional environmental friendly disposal methods for stubble burning that India could implement. It is possible to transform stubble into something valuable in a number of ways such as the production of electricity from biomass, domestic animal feed, or even the production of necessary end products like medicines, health products, and composts. Furthermore, addition of crop leftovers into soil can also improve the physical, chemical, and biological qualities of soil in a number of ways. In North India, the majority of farmers think burning is the best option as they are unaware of various other options available to control stubble. Therefore, extensive awareness campaigns are required to inform farmers about the adverse impacts of stubble burning and the availability of other better financially viable solutions.

Article History

Received: 09 January 2024

Accepted: 14 Mar 2024

Keywords

Agriculture Waste;
Air Pollution;
Environment;
Human Health;
India, Stubble Burning.

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Doi: https://dx.doi.org/10.12944/CARJ.12.1.13

Introduction

With a long history of agriculture, India, the second most populous country in the world, produces huge amounts of food grains, including wheat and rice, for both domestic consumption and export. Among the various crops cultivated, the main contributors of crop residual are rice (43%), wheat (21%), sugarcane (19%), and oil seed crops (5%) and the majority crop residues are burnt.[1-3] It is quite challenging for the farmers to find the crops that generate reduced crop leftovers because these crops have such high returns on investment.[4] Parali or stubble is the lowest portion of rice crop that remains after the higher portion is harvested and is useless to the farmers. Farmers burn this remaining crop *i.e.* dry parali (straw), because they have to leave the fields in order to grow the new crop. Farmers in northern India, particularly in Punjab and Haryana frequently burn leftover stubble or straw in their fields.[5] However, it can be used for a variety of purposes, including the manufacture of mushrooms, mats, paper mash, liquor, excrement, and fodder for ruminant's etc.[4] One of the best strategies to manage agricultural stubble is to incorporate them into the soil which will keep the amount of organic matter in the soil intact and also improves its fertility. Addition of straw into the soil increases its productivity and replenishes nutrients that would have otherwise burned.[6] In general, adding straw to soil improves fertility and increases sequestration of carbon. However, many farmers, particularly in developing nations, cannot afford the additional labor and/or mechanized equipment needed for this technique.[6] According to the Ministry of New and Renewable Energy, India yields about 500 million tons of crop leftovers per annum. The residue thus produced is mainly utilized as fodder and fuel for various industrial and domestic uses. Still, 140 million tons remain in excess, of which 92 million tons are burned yearly.[7] In order to shorten the time duration amid harvest and sowing of the next crop, about 35 million tons of paddy crop wastes are burned by farmers annually, primarily in Punjab and Haryana. This is a low-cost method of disposing off. The burning of parali, a practice common in northwest India, has been recognized as an important contributor to the air pollution of Delhi.[8,9] Burning stubble releases hazardous greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), and nitrogen dioxide (N_2O) at very high levels, threatening the human health.[7,10] Rice straw is predominantly composed of ash (18.67%), silica (74.67%), fixed carbon (15.86%), calcium oxide (3.01%), magnesium oxide (1.75%), nitrogen dioxide (0.96%), and potassium dioxide (6.30%). It is evident that burning paddy straw, which contains these dangerous compounds, releases them into the atmosphere and subsequently contaminates the surrounding air quality.[11] It also creates hazardous clouds that lead to an emergency condition with high AQI (Air Quality Index). These gases have adverse effects not only on the environment but also on human and animal health.[12] Further, air pollution can cause irritation to skin and eyes, as well as serious neurological, cardiovascular, and respiratory conditions, asthma, chronic obstructive pulmonary disease, bronchitis, lung capacity loss, emphysema, cancer, and other health issues. It also increases mortality rates due to prolonged exposure to high pollution levels. Furthermore, stubble burning has an adverse impact on the climate, soil fertility and economic development of nation.[13,6] Burning stubble also indirectly contributes to rising global temperatures, which weakens the ozone layer.[13] As India produces a lot of crop waste, this issue of residue burning warrants attention from other countries as well mainly for two reasons: first, the organic composition of the residue makes it beneficial for society; and second, the massive amount of residue, if handled carelessly, can have negative environmental effects that may extend far beyond India.

Problems Due to Parali Burning

Following are some of the problems that could arise from burning parali:

Air Pollution and Emission of Greenhouse Gases

Burning crop residue releases greenhouse gases as well as other aerosols and trace gases that are radioactively and chemically significant. The emission of these toxic gases can be significantly greater than the Central Pollution Control Board's recommended standard level of emissions.[11] Burning rice straw is expected to release 70% of the carbon in the straw as CO_2, 7% as CO, and 0.66% as CH_4. However, 2.09% of the nitrogen in the straw is released as N_2O directly in the atmosphere which leads to global warming.[14] Moreover, burning agricultural waste releases a significant amount

of air-polluting particulate matter. The majority of the pollutants included in biomass smoke in significant concentrations are known or suspected carcinogens, which when inhaled, can cause a wide range of respiratory disorders.[15] Ash and smoke clouds can form an obstinate, non-clearing cloud that can travel over a thousand kilometres. Burning husks frequently could lead to the development of smog and brown clouds, which have an impact on the climate, atmospheric visibility, and local air quality.[5] India's air pollution levels remain alarmingly high, even though, after so many recent improvements in air quality. Out of the 30 cities in the world with the highest pollution levels, 22 are in India.[15]

Nutritional Deficiencies

Approximately 90% of the nitrogen, 50% of the sulphur, 25% of the phosphorus, and 20% of the potassium from crop leftovers are released into the atmosphere as gases and particulates when the residue is burned, along with other valuable nutrients.[16] About 400 kilograms of carbon, 25 kilograms of potassium, 5.5 kilograms of nitrogen, 2.3 kilograms of phosphorous, and 1.2 kilograms of sulphur are found in one tonne of rice straw; hence, burning rice straw releases these nutrients into the atmosphere along with other 50–70% of the micronutrients that are absorbed by the paddy crop.[14]

Loss of Soil Fertility

The majority of farmers believe that burning is a quick, simple, and affordable procedure as it destroys all undesirable plants, shrubs, and husks.[5] Some people think that fire could replenish the soil's nutrients. However, the soil becomes less productive when husks are burned on the ground as it destroys the nutrients.[17] Burning stubble transfers heat into the soil, which causes the soil to lose moisture and beneficial bacteria, thus adversely affecting the soil. Burning paddy straw raises the temperature of soil to 33.8 to 42.2 degrees Celsius up to one centimetre of soil.[18] Natural nutrients and microbes that aid in the renewal of the soil are thus destroyed.[19] Crops are now more vulnerable to disease as a result of the loss of "friendly" pests, leading to an increased wrath of "enemy" pests.[5] It is customary to use these leftovers, such as parali, to improve soil fertility and stabilize the soil. However, burning surplus crops is a usual exercise in several nations, particularly in Asia, due to their large quantity. But, burning these residuals has negative effects on the environment and requires some technical support for a safe burn in the environment.

Smoke and Soot Particles

The smoke released due to husk burning, pollutes the air and produces a haze of pollutants that induces a "toxic atmosphere" in Delhi. An analysis of crop residue burning revealed that it released an estimated 0.25 million tons of sulphur oxides, 9 million tons of carbon monoxide, 149 million tons of carbon dioxide, and 1.28 million tons of particulate matter. An investigation conducted by Singh (2015) confirmed that burning crop leftovers in a highly polluted area of Punjab further increased particulate matter concentration.[20] Moreover, according to a study by Sidhu (2015), when monitoring is done during crop waste burning, the quantity of these gases and particulate matter exceeds the permitted amount.[21]

Harm on Health

Burning stubble produces a substantial amount of particulate matter and gaseous contaminants like sulphur oxides, nitrogen oxides, carbon monoxide, carbon dioxide, and methane etc. The ozone layer is weakened by carbon monoxide and carbon dioxide, which directs UV light that can be fatal to skin toward Earth.[4] Burning residue can lead to health risks such as bronchial asthma, asthma, acute respiratory infections (ARI), and eye irritation.[22] Due to the increase in smog, 84.5% of the people had heart difficulties, 76.8% suffered from eye irritation, 44.8% reported nose discomfort, 45.5% complained about throat irritation, wheezing issues increased by 18.0%, while cough issues increased by 41.6%.[12] Prolonged exposure to high level of pollution also increases mortality rate.[18] Different age groups are affected differently by the particulate matter generated during burning. Children have an increased risk of Acute Respiratory Infections (ARIs) because of their elevated respiratory rates.[11] A study conducted by Gupta (2018) further confirmed the impact of particulate matter (PM) released during burning on various physiological parameters in children.[23] When paddy straw burns and releases toxic gases like carbon monoxide, the blood's ability to absorb oxygen is decreased, leading to respiratory issues. Similarly, carbon dioxide emissions irritate

the eyes, while nitrogen and sulphur oxides have direct adverse effects on the blood, skin, lungs, and respiratory systems, all of which can lead to diseases including cancer.[11, 24]

Effect on Aquatic Ecosystem

The main gas responsible for the greenhouse effect among the various gases emitted during stubble burning is carbon dioxide, whose concentration is gradually rising day by day. Since carbon dioxide is the most oxidized and thermodynamically stable form of the element, it is difficult to convert it into other compounds. The only feasible method to get rid of it can be to collect and store it. Although, the oceans are the main sink for carbon dioxide emissions, carbon dioxide increases the acidity of the oceans, which affected the aquatic ecosystems.[25]

Alternatives of Stubble Burning

Burning stubble causes numerous threats to the environment. Therefore, it is beneficial to implement alternative straw management solutions including both technological and non-technological solutions as given below

As Animal Feed (Fodder)

Utilizing agricultural leftovers for animal feed is among the most popular and advantageous uses. However, Rice stubble is not used mainly as feedstock because it contains very high silica content and has relatively low lignin concentration. Compared to lignin, silica is harder for cattle to digest and has little nutritional value.[10,6] It must be appropriately processed by various units to make it fit for consumption of cattle. For example, it is possible to turn paddy straw into pellets that are used as feed for cattle.[26] In northern India, however, animal feed is primarily derived from wheat and maize straw. On the other hand, despite having a high silica concentration, rice straw is the most popular in the southern region of the nation, possibly due to lack of other feed sources. In southern India, rice husk is ground into a fine powder and fed to animals, mostly cattle.[15]

Composting

Composting is another application for crop leftovers. When combined with other organic waste, it generates nutrient-rich compost which contains nitrogen (2%), phosphorus (1.5%) and potassium (1.4-1.6%).[6] Vermicomposting, a popular composting technique, produces compost with the help of earthworms and significantly improves soil productivity. Vermicompost is a finely divided, stable material with great porosity and good water-holding capacity. It contains high concentration of nutrients, which the plants may readily absorb.[6] It acts as a natural organic fertilizer to enhance the physio-chemical and biological qualities of the soil and can entirely replace the use of agricultural chemicals like fertilizer and pesticides.[15,19] Because of the increased microbial activity in the soil, these methods also aid in increased nutrient uptake and active nutrient cycling.[19] Recently, a microbial cocktail named pusa decomposer was developed by the Indian Agricultural Research Institute that can decompose the agricultural leftovers into compost through accelerated decomposition. In order to promote speedy decomposition, a liquid formulation made with decomposer capsules is sprayed onto the field with stubbles after fermentation. The microbial agents in the capsule or solution break down the straw's molecules, soften it, and release nutrients into the field. According to reports, the degrading process takes about 25 days for completion and doesn't cost more than Rs 1000 per acre.[7]

Bran Oil and Ethanol Production

Bran oil is made from rice stubble and is beneficial & healthy for humans.[5] One of the popular and abundant lignocellulosic waste products used to produce bioethanol is rice straw. It contains a high concentration of cellulose and hemicelluloses, which are easily hydrolyzed to produce fermentable sugars. However, because of its complex nature and high lignin and ash content, the process of turning rice straw into ethanol has a number of drawbacks and limitations. Therefore, in order to remove an undesired portion, the proper pre-treatment technique must be chosen. A biological method of converting rice straw into fermentable sugars through the use of hydrolyzing enzymes is currently the most appealing option because of environmental considerations.[27] The use of rice straw for ethanol production not only solves the problem of managing it on the field, but it also improves the socioeconomic standing of rural residents, reduces pollution by preventing burning, and offers a cleaner source of renewable fuel.[28]

Biogas Production

Biogas production from biomass, including rice straw is one of the most alluring, energy-efficient, non-toxic, and environmentally friendly renewable source of energy that is nearly carbon neutral and offers zero waste solutions for handling organic waste.[24] Using grinders, rice straw gets chopped to small pieces and combined with other waste materials in digesters to produce biogas.[11,15] This gas can be upgraded to be injected into natural gas gridlines or used as fuel for vehicles. It can also be used as a fuel for cooking or heating, or it could be converted to electrical and heat energy using a combined heat and power (CHP) unit. It is advantageous for farmers and other stakeholders to use biogas production with less initial investment because it doesn't require high temperatures like gasification requires, and it's an easy process. Furthermore, the digestate that is produced as a byproduct has a high nutritional content similar to that of organic fertilizers, which can help to increase crop productivity while lowering the need for chemical fertilizers.[24]

Biofuel Production

Paddy straw can also be used to make biofuel. During manufacturing, straw is roasted at a high temperature, generating a gas that produces oil, while other gasses, like CH_4 and CO_2, are extracted from it. Cars and other vehicles can use this oil as fuel.[11] This is a viable option for managing agricultural stubble which contributes to a cleaner air and a more environmentally friendly atmosphere by directly preventing the discharge of harmful pollutants from burning stubble and indirectly lowering the use of fossil fuel-based energy. As they have a smaller carbon footprint than fossil fuels, biofuels have recently attracted attention from all across the world.[6] In addition to the many benefits of generating biofuel from crop residues that have already been mentioned, there are some drawbacks as well. For example, (i) energy requirement for collecting and distributing the biofuel, (ii) degradation of the soil due to soil erosion, etc.[29]

Paper and Handicraft Making

Rice stubble is used to make paper and temporary utensils. It can also be utilized to create decorative handcrafted products.[5] For manufacturing paper, paddy straw and wheat straw both are used in the ratio of 40:60. The sludge left over from the production of paper might be utilized to generate electricity by using the process of biomethanization.[10,15] Some paper mills are currently using this process of biomethanization which fulfills around 60% of their energy requirements. As, paper and pulp board are frequently made using paddy straw as a raw material, it aids in preventing the trees from being cut down for the paper industry.[30,11] It's possible that this management technique could serve as a substitute for deforestation. Although, very little straw is needed for this procedure, it might be taken into consideration along with other options.[11]

Chopping and Spreading Straw

The addition of straw in the soil is an important substitute for burning stubble as it preserves the soil's organic matter and nutrient content.[11] Paddy crop residues can be efficiently managed by farmers by using a variety of agricultural machinery, such as: Rotavator (for preparing the land and assimilating crop stubble into the soil); Happy Seeder (for planting crops in standing stubble); Zero Till Seed Drill (for preparing the land and directly planting seeds in the previous crop stubble); Baler (for gathering straw and forming paddy stubble bales); Paddy Straw Chopper (for chopping paddy stubble into pieces that are easily mixed with soil); and Reaper Binder (for harvesting paddy stubble and forming into bundles).[17,31] By utilizing these various tools and techniques, farmers can be benefitted due to increase in crop yields and lower fertilizer costs, which in turn boost their economy. Out of these various tools and techniques, the Happy Seeder is the most effective technique available right now for preventing crop burning.[15,18] Happy seeder performs triplet work by sowing wheat seeds, chopping the standing straw and its mulching into the soil, which maintains the soil's water content.[11] Additionally, using the happy seeder can save up to 80% on labor for residue collection and sowing, 50% less herbicide use, and 20% to 25% less irrigation is required. Currently, 11,000 happy seeders are in use in northern India, with Punjab accounting for about 80% of these.[15]

Power Generation

This residue can be used to make biomass pellets, which can then be used to generate electricity in biomass-based power plants. It is expected that the use of agricultural wastes alone can replace 25% of the coal used to generate electricity, hence reducing the need for imported coal. This also contributes to

the employment of 5000 people for the building of the biomass pellet plant and about 200,000 permanent jobs in the transportation and collection of straw, the production of straw pellets. However, this is not an environment friendly option because it releases various harmful gases into the atmosphere.[11]

Diversification of Agriculture

Agricultural sustainability requires the adoption of the concept of diversification. Crop diversification, including polycultures, agroforestry, crop rotation, and others, ought to be prioritized by the government, especially with the alarming rates of air pollution, poor soil quality, and groundwater depletion.[7] The rice-wheat cropping method is not sustainable since it depletes water supplies and pollutes the environment. Maize, sugarcane and other crops can be cultivated in addition to these. It enhances the soil's ability to retain nutrients, moisture, and fertility.[11]

Education and Awareness among Farmers

According to a survey done in 2015 by Kumar *et al*., 90% of farmers burn their stubble despite being aware of the negative health effects. This could be because of a shortage of labor, a lack of government incentives, or even the farmers' ignorance of more affordable and ecologically friendly options.[32] Therefore, in order to educate the farmers about the negative effects of burning and the advantages of adopting various crop stubble management alternatives, numerous awareness campaigns and programs are needed.[6] The government awareness campaigns should concentrate more on educating people about complementary and alternative methods of managing crop residue rather than burning crop residue. The government should promote information via radio, TV, and the internet.[33] Alternative methods such as kisan camps, training sessions, and workshops, are also employed in order to educate farmers about alternate uses for crop residues in order to prevent burning.[13] The government and organizations that support agriculture should launch a widespread propaganda campaign to inform farmers about this initiative.[33]

Incentives to Farmers/Government schemes and policies

The following are some of the schemes and policies implemented by the central and state governments in order to lessen stubble burning and its negative effects on the environment, human health, and soil properties:

- In August 2007, the Indian government introduced Rashtriya Krishi Vikas Yogna (RKVY), a state plan scheme of additional central assistance. A few informative training program demonstrations were set up in Uttar Pradesh. The necessary training for producing biocompost and bio-converting agricultural waste has been provided to many farmers, helping them to reap the financial rewards.[4,19]
- In order to generate electricity, the Indian government has advised National Thermal Power Corporation (NTPC) to mix crop residue (roughly 10%) with coal. For every tonne of crop residue, the farmers received a financial return of about Rs. 5,500.[4,19]
- To promote mechanization for crop residue management, the Indian government introduced a 166 million US dollar subsidy in 2018. The central government reportedly spent 75 million US dollars in a single year to implement a program that encouraged the use of agricultural mechanization for in-situ crop residue management in Punjab, Haryana, Uttar Pradesh, and Delhi. The program aimed to reach 0.8 million hectares of land where happy seeders or zero tillage were adopted in North West Indian states.[14]
- Farmers can be encouraged to use rotavators, happy seeders, and super straw management systems by offering an adequate subsidy for the purchase of these devices.[4,11,13] The Punjab government recently launched a two-year plan that entails spending Rs. 665 crore to provide individual farmers with a 50% discount and cooperative organizations and groups with an 80% subsidy on straw management machinery. This amount of subsidy is insufficient, because, prior to the government's strict ban on burning, a rotavator cost was nearly about Rs 60,000/-. But now, even after a 50% subsidy, this machine still costs Rs 65,000/- making it an extremely expensive for farmers to buy. Consequently, the only simplest and least expensive method to get rid of the rice straw is residue burning. Therefore, sufficient incentives are needed to motivate farmers to pursue other feasible options. The government has to provide

farmers with machines that are affordable, practical, and easy to use in order to minimize stubble burning.[11]

- The Punjab and Haryana governments were subsequently asked by the Supreme Court to give small and marginal farmers Rs. 1000/- per quintal for the purpose of managing stubble. Accordingly, Punjab farmers may get Rs. 2560/- per acre, with an average stubble output of 25.6 quintals per acre.[14] The Haryana Government has also started a State plan scheme for managing crop residue for the year 2023-24. The State Government has agreed to offer an incentive of Rs. 1000/- per acre admissible to in-situ & ex-situ management of paddy crop residue in order to motivate the farmers.
- Recently, the government of Punjab provided 2400 tractors equipped with happy seeders to simultaneously sow wheat crop seeds and trim paddy stubbles, but these were not readily available or suitable for all regions.[14]

Stringent Laws and Enforcement Mechanism

Higher authorities passed a number of laws to discourage stubble burning and to promote safe, varied uses of residues.[14,19] In accordance with the Air Prevention and Control of Pollution Act, 1981 and the Code of Criminal Procedure, 1973, burning crop residue is strictly prohibited by the Indian government. The government can regulate the burning of crop residue by using remote sensing to monitor the situation.[34] Further, the government outlawed residue burning entirely in 2019 as well as fined farmers who continued practice and even put some of them in jail.[14] Despite the consequences, many farmers continue to burn their stubble because they believe paying the fine is less expensive than paying for other options.[17] Therefore, in order to tackle this issue, strict government regulations and enforcement mechanisms are needed. Government should deploy a monitoring investigation team to crosscheck the violators and should increase the amount of penalties and duration of imprisonment.

Market for Straw

There are several well-known paddy stubble marketing chains. The type of paddy grown and the harvesting technique used will determine the paddy straw's route through the marketing chain.[35] Despite their small size, the mapped modern marketing chains can be helpful to protect the farmers from this hazardous behaviour by providing them with assurance regarding the procurement of residue.[11]

Recommendations

In addition to the various alternatives of parali burning, some of the recommendations to tackle this issue of crop residue burning are:

- There should be strict implementation of Government Policies against stubble burning.
- A monitoring investigation team should be deployed to crosscheck the violators.
- Further research and development of new devices and chemicals are required to completely decompose the stubble at origin.
- Subsidies given to farmers for machineries should be monitored properly.
- Government should create a supply chain ecosystem with a dense network of straw banks.
- To encourage greater participation in the biomass supply chain, the demand for biomass might be raised.
- Government should implement price regulation for products derived from agricultural leftovers.
- It is necessary to map and publish a database of end customers and their annual demand for crop residues.
- A digital network might be created for interlinking farmers, straw banks, end consumers, and other stakeholders so that they can exchange agricultural waste.

Conclusion

The harmful consequences of stubble burning on the environment and human life have made it one of the most controversial issues of today. Farmers, experts, and government officials have identified a number of reasons for residue burning. One of the main causes of parali burning in India is insufficient time between harvesting the rice crop and planting the following wheat crop. Because of this, government agencies and agricultural institutions frequently advise farmers to plant rice in nurseries ten days earlier than they had previously done. Moreover, these practices of burning stubble are highly detrimental to the environment, human health, and soil health. Crop residue burning destroys soil health by eliminating beneficial soil microorganisms and harms human health and environment through air pollution causing

different respiratory, eye, and pulmonary diseases and other health issues. Farmers can use straw for a variety of purposes, such as livestock feed, soil incorporation, mulching, biochar preparation, biothermal plant production, paper industries, and more. One of the best technologies that provide a significant substitute for burning stubble is the happy seeder. Additionally, government initiatives including crop residue storage, more labour availability, and transportation infrastructure support should be implemented. It is highly advised to investigate the viability of alternatives in terms of their applicability to that particular demography, their effectiveness in consuming the amount of crop residue produced, and how feasible it is to implement them. Government and agriculture assistance organizations should launch a massive propaganda campaign to educate farmers about it. Therefore, in order to minimize the problem of stubble burning in India, efficient enforcement, adequate human resources, and focusing on the sources of pollution at ground level are equally important as financial resources. Farmers need to handle their agricultural waste by using any of the above described methods instead of burning in order to protect the environment.

Acknowledgement
No Acknowledgement

Funding
The authors received no financial support for publication of this article.

Conflict of Interest
The authors declare no conflict of interest.

Data Availability Statement
Not Applicable

Ethics approval statement
Not Applicable

Author's Contribution
Malvika Kadian: Investigation, Conceptualisation, Resources, Writing: original draft preparation, review and editing. Savita Nagoria: Visualization, Writing: review and editing. Sweety Monga: Resources, Writing: review and editing. Meera: Supervision, Writing: review and editing.

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