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ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

ABSTRACT: In recent years, the economy has started shifting from a linear business model to a circular business model among scholars and practitioners. There is a lot of wastage in the linear economy and a lot of resources are left unused. Pollution in Delhi is the major issue prevailing among the researchers. Circular economy, as a combination of reducing, reuse, recycle and recover can reduce the pollution by providing alternative strategies to control it. This paper provides a case study on pollution

of Delhi, focussing on the stubble burning. During the winter season, farmers burn the crop residue (stubble and straws) which is the main contributor to pollution. The major effect of stubble burning is on Delhi due to its geographical location. The paper aims to highlight alternatives made available in the circular economy, which not only help to reduce pollution but also prevents the wastage in agriculture. It provides an incentive to re-utilise agricultural waste in different forms.

Keywords: Innovative technologies; Stubble burn; Delhi; Pollution;
Circular Economy; Farmers; Geographical location

JEL Codes: L31, O1, O33, Q1, N5

BACKGROUND AND CONTEXT

“The Circular Economy is a blueprint for a new sustainable economy, one that has innovation and efficiency at its heart and addresses the business challenges presented by continued economics unpredictability, exponential

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population growth and our escalating demand for the world's natural resources" ----- Chris Dedicoat, President, EMEA

The concept of Circular Economy has gained importance in recent times among the scholars in connection with sustainable development. There is not a single definition of Circular economy and everyone defines and understand it differently. It is an industrial system which highlights the importance of regeneration in an innovative way. But the traditional economy is primarily in function in most of the fields.

With the growing population, our resources are continuously depleting as they are limited in nature. The main reason behind this is wastage of resources since people do not use them judiciously. This is a common tradition that once the product becomes useless, customers usually discard it. Recycling or reusing the product is not the economic priority as new products and alternatives are easily available.

The current system where wastage is common is generally known as 'take-make-dispose' model or linear model. The functioning of this model is quite simple. Companies buy raw materials, use energy for manufacturing and sell the final product to the consumers, who use it for a specific purpose and then discards it. Thus this process incurs an unnecessary loss of resources in the economy.

There is wastage at different stages of the product. Take the example of a food market. There is wastage in the production chain as food is lost due to pests or sometimes due to poor efficiency of farmers. Then there is wastage in the food supply chain in the form of leakages during transport or storage in bad condition. There is also end-of-life wastage by consumers as they just use the main food and throw the seeds like while eating mangoes, its kernel or seed is thrown. This kernel has various health benefits if used properly.

The circular economy is a step to change this end-of-life concept into restoration, stimulate the use of renewable energy, replace the use of toxic materials which does not allow the product to be reused and aims for innovative methods of production to reduce wastage. It comprises of 4Rs – Reduce, Reuse, Recycle and Recover. It focuses on achieving the objective of economic prosperity, environmental quality and social equity.


Some researchers used only 3R framework, leaving out the process of recovery. While Potting et al. (2017) used the 9R framework (as shown in Figure 1) instead of 4R framework to extend the definition of circular economy (as explained in the figure below). They explained how an economy moves from linear to circularity. It focussed on using the material

ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

of all products in some way or the other and reduce the wastage to its minimum. (J. Kirchherr et al. 2017)

Few methods that have been introduced for a circular economy are – use of biodegradable packaging instead of plastics; remanufacturing of mobile phones by giving incentives to consumers to return their old phones (it has reduced the cost of mobile phones by 50%); increased use of organic materials as these materials can be breakdown by insects which then become compost (a form of recycling). (Ellan MacArthur Foundation)

Figure 1

Circular economy		Strategies	
	Smarter product use and manufacture	R0 Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
		R1 Rethink	Make product use more intensive (e.g. by sharing product)
		R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
	Extend lifespan of product and its parts	R3 Reuse	Reuse by another consumer of discarded product which is still in good condition and fulfils its original function
		R4 Repair	Repair and maintenance of defective product so it can be used with its original function
		R5 Refurbish	Restore an old product and bring it up to date
		R6 Remanufacture	Use parts of discarded product in a new product with the same function
	Useful application of materials	R7 Repurpose	Use discarded product or its parts in a new product with a different function
		R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
R9 Recover		Incineration of material with energy recovery	
Linear economy			

Source: Potting et al. (2017, p.5)

If the waste is eliminated from the production process, then it will save the costs of production. Elimination of waste also results in less resource dependence. It encourages innovation and thus growth in the economy. Prevention of wastage of resources is beneficial for the industries, consumers and also the economy.

There is a transformation from linear to circular business models in products like mobile phones, light commercial vehicle (LCV) and washing machines. The transition is observed in the product design, business models and reverse cycle skills. Earlier the importance was on primary extraction but it has now shifted to repeated use of products, components and materials. Yield improvement of around 95% (from 70%) was observed and on an average 60% time savings in pre-processing was found. Also, around 25% of savings were detected in the overall costs of production.

Agriculture is one of the main sources of income for many households in India. More than 50% of India's workforce is engaged in agriculture. Thus it plays an important role in the overall socio-economic development of the country. It generates a lot of agricultural waste in the form of crop residue. Once the crop has been harvested, some material is left on the cultivated land which is called crop residue. This includes stalks and stubble, leaves and seed pods. Instead of utilising these residues, farmers generally burn the stubble to get rid of the waste in a convenient manner.

In late September and October each year, farmers mainly in Punjab and Haryana burn an estimated 35 million tons of crop waste from their paddy fields. This practice is regarded as a low-cost straw-disposal practice and it helps to reduce the turnaround time between harvesting and sowing for the second (winter) crop. A cloud of particulates called "toxic cloud" in New Delhi Smoke is being produced from this smoke which is also visible from space and results in declarations of an air-pollution emergency in the state.

When a farmer intentionally sets a fire on the remaining of the food grains like paddy, wheat, etc., after being harvested is known as Stubble or Straw Burning or Parali in short. The practice was common among farmers until the governments restricted its use during the 1990s. This method is widely accepted as a cost-effective method, it kills slugs and other pests and it also helps to reduce nitrogen tie-up. Besides these few benefits of stubble burning, there are many harmful effects which are as follows:

1. Loss of nutrients: Organic quality of soil gets affected due to stubble burning as it damages the micro-organisms present in the upper layer of the soil. Due to the loss of 'friendly' pests, the solubility capacity of the upper layers of soil reduces. The crops become more prone to diseases as the wrath of 'enemy' pests has increased.
2. Pollution from smoke: Another adverse effect of stubble burning includes the emission of greenhouse gases (GHGs) which contributes to global warming, increased levels of particulate matter (PM) and smog. The smog results in serious health problems, loss of biodiversity of agricultural lands, and the degradation of the fertility of the soil.
3. Damage to electrical and electronic equipment from floating threads of conducting a waste
4. Risk of spread of uncontrol fire

In this respect, the current study focuses on the advantages of the circular economy taking into consideration the case of stubble burning. Our focus is primarily on the capital city of India, New Delhi. It is surrounded by states of Uttar Pradesh, Punjab and Haryana where most of the agricultural

ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

activities and thus crop residue burning takes place. Due to its geographical location, Delhi suffers maximum pollution because of stubble burning. We will explore alternative strategies available in the circular economy which will benefit Delhi by reducing pollution and economy by providing reusable resources.

POLLUTION PROBLEM IN INDIA

Air is the core element for the sustenance of life. However, going by the data and statistics, various sources have merged, posing a significant threat to air quality. Air Pollution is the greatest risk to human life, more so in India than in any other country. And with the rapid urbanisation, the country has been detrimental in many ways to its environment.

An increase in the country's population and inadequate infrastructure have left many Indian cities with unhealthy living conditions. With existing challenges posed by the COVID-19 Pandemic, worsening air quality is the leading environmental concern amongst the people of India, where many citizens bear the brunt of the toxic, unhealthy living conditions.

In the U.S., Air Quality Index or AQI is used as the measure of outdoor air pollution, which rates air conditions across the country. It is based on concentrations of five major pollutants: ground-level ozone, particle pollution (or particulate matter), carbon monoxide, sulphur dioxide, and nitrogen dioxide. WHO data shows that low- and middle-income countries suffer most from the highest exposures.

Some of the short-term problems caused by air pollution include sneezing and coughing, eye irritation, headaches, and dizziness. While the long term problems associated with air pollution has been linked to higher rates of cancer, heart diseases, stroke, and respiratory diseases like asthma. Particulate matter smaller than 10 micrometres (classified as PM_{10} and the even smaller $PM_{2.5}$) pose higher health risks because they can be breathed deeply into the lungs and may cross into the bloodstream. Major concerns for human health from exposure to PM_{10} include long term health problems. Few categories of people including elderly persons, children and people with chronic lung disease, influenza or asthma are highly vulnerable to the effects of particulate matter. India saw one-fourth of global deaths linked to $PM_{2.5}$ exposure in 2019.

Air pollution in India is a serious health issue. Of the most polluted cities in the world, 22 out of 30 are in India in 2019 and almost 99 per cent of Indians breathe air that is 10 times or more over the WHO safe limit. Also, 13 of the world's 20 cities with the highest annual levels of air pollution

are in India. Air pollution contributes to the premature deaths of 2 million Indians every year. One in eight deaths in India was attributable to air pollution in 2017 which is way more than those caused by diarrhoea, tuberculosis, HIV, or malaria.

India has no doubt witnessed a surge over air pollution in recent years. Moreover, the country's geographical distribution also contributes to the problem. Agricultural practices like burning crop stubble are still commonly used. Its smoke wafts over big cities like Delhi. Given that these regions are landlocked, it is difficult for the smoke to dissipate. Additionally, it often combines with traffic exhaust and factory emissions. According to the Central Pollution Control Board, of the four major Indian cities, air pollution was consistently worse in Delhi, every year over 5 years (2004–2018). Kolkata was a close second, followed by Mumbai.

Delhi- the heart of India, with the levels of PM 2.5- polluting particles, has been ranked as the most polluted capital city in the world, and the fifth most polluted city worldwide. Delhi air quality is frequently "unhealthy." In 2019, 60.5 per cent of all annual hours were rated "unhealthy" or worse. While poor air quality is common throughout the year, the winter has a much higher frequency of hours rated "unhealthy," "very unhealthy," or "hazardous." With the Air Quality Index (AQI) at 313 in November, Delhi's air quality slips to 'very poor' from 'poor'.

Moreover, Delhi's geographic location in a "bowl" near the foothills of the Himalayas creates a pollution-trapping effect in which air has only narrow outlets to escape. As emissions are generated and coastal winds blow inland, air stagnates in the city as it becomes blocked by the surrounding mountains. Notoriously polluted cities like Beijing, China and Los Angeles, USA experience similar effects.

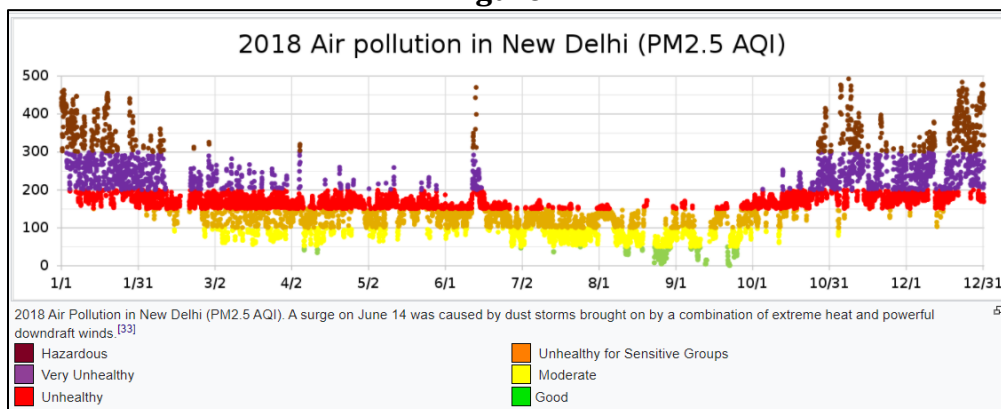
If we consider the entire winter season (Nov-Feb), as was done in the ARAI-TERI 2018 study on source apportionment, crop burning indeed accounts for roughly 4% of Delhi's air pollution. But this average figure, which the environment minister possibly relied on, hides significant daily differences, and also misses out on the impact of crop burning in October, when stubble burning is quite high. During the peak stubble burning phase, crop burning accounts for more than 50% of Delhi's air pollution, according to data from System of Air Quality and Weather Forecasting And Research (SAFAR).

About 30% of $PM_{2.5}$ concentration is contributed by sources outside the city due to Stubble Burning. It India has been cited as a major cause of air pollution in Delhi in winter season in Punjab and Haryana in northwest

ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

India. In Delhi, winter months are often more than 3 times as polluted as summer months. This difference between seasons is typically attributable to weather conditions rather than emissions. In the winter, wind conditions slow down by a third as compared to summertime conditions. Without powerful winds to disperse pollution, pollutants are more likely to accumulate. Winters in Delhi are also relatively dry, with little rain between October and May. Without rain and humidity, particles and gases are less likely to coagulate (merge to form larger particles) and thus fall to the ground due to gravity.

Figure 2



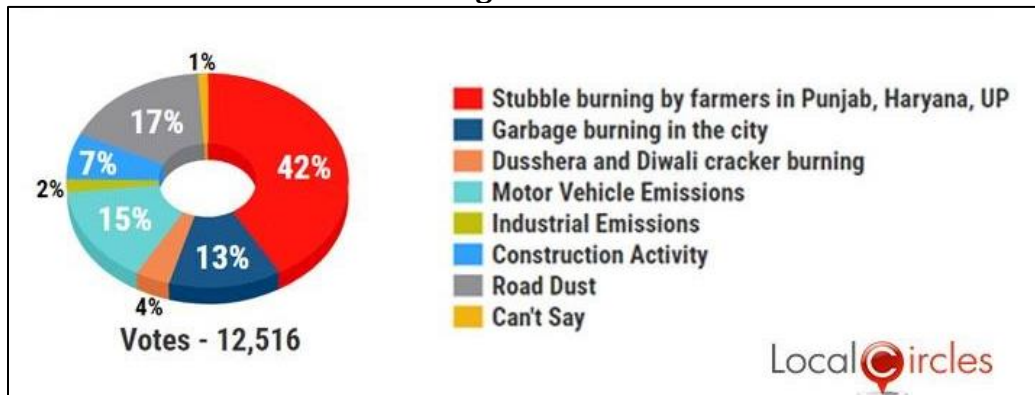
Source: "New Delhi's Air Pollution Went Off the Scale This Week". 15 June 2018.

Studies have explored that meteorological conditions have compounding effects on air pollution. It was also found that the air quality of both indoor air and outdoor air got deteriorated during winters. The average contribution of stubble burning to the concentration of PM_{2.5} in Delhi-NCR during peak phase has increased from 10% in 2019 to over 15% this year with Punjab reporting an increase of 48% in fire incidents while these declined by 28% in Haryana. This can be seen in Figure 2 above.

The major sources of pollution include industrial pollution, vehicular pollution, stubble burning and fireworks. Emissions come from vehicles, manufacturing and construction industries, electricity generation whereas in rural areas, much of the pollution stems from biomass burning for cooking and keeping warm. Another driver of pollution in Delhi is the unfavourable meteorological conditions. In autumn and winter months, large scale crop residue burning in agriculture fields – a cheaper alternative to mechanical tilling – is a major source of smoke, smog and particulate pollution. Besides agricultural burning, there are other sources of burning as well such as trash burning, roadside burning, landfill burning, brick kilns. Urbanisation is also one of the important contributors to the pollution which ultimately have an adverse effect on humans. In figure 3 below, it can be seen that for the current year (2020) different sources of

pollution have respective shares in their contribution to air pollution. As is visible, stubble burning by farmers in Punjab, Haryana and UP contributes maximum (around 42%) to the pollution followed by road dust whose contribution is only 17%.

Figure 3



Source: <https://www.localcircles.com/a/press/page/delhi-ncr-air-pollution-survey#.X8CrEWgzZPY>

STRATEGIES TO CONTROL DELHI POLLUTION

As Delhi and National Capital Region got engulfed by the toxic smog with pollution levels breaching permissible standards limits by multiple time in winters. The Air Quality Index in many parts of the city has slipped into the 'severe' category with a score of 448 on a scale of 500 against the permissible limit of 100 micrograms per cubic metre. As per the doctors, it is a state of emergency and has declared the condition as a public health crisis. The government also tend to take various measures to curb the problem of air pollution caused by stubble burning during the season. Moreover, in Delhi, winter months are often more than 3 times as polluted as summer months.

Most Indian cities greatly exceed acceptable levels of suspended particulate matter. This may be because of refuse and biomass burning, vehicles, power plant emissions, industrial sources. The Indian air quality monitoring stations reported lower levels of PM10 and suspended particulate matter during monsoon months possibly due to wet deposition and air scrubbing by rainfall. Higher levels of particulates were observed during winter months possibly due to lower mixing heights and more calm conditions. In other words, India's air quality worsens in winter months and improves with the onset of the monsoon season. All this resulted in declaring an air pollution emergency.

ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

Consequently, in 2015, the Government of India, together with IIT Kanpur launched the National Air Quality Index. In 2019, India launched 'The National Clean Air Programme' with the tentative national target of 20%-30% reduction in PM_{2.5} and PM₁₀ concentrations by 2024, considering 2017 as the base year for comparison. Also, the NGT (National Green Tribunal) instituted a fine of Rs. 2,00,000 on the Delhi Government for failing to file an action plan providing incentives and infrastructural assistance to farmers to stop them from burning crop residue to prevent air pollution.

There are various measures taken by the authorities to tackle air pollution in Delhi:

Odd-Even Policy on Vehicles: The policy was first introduced in January 2016 when the quality of air had nosedived and was re-introduced in April in the same year. As per the rule, between 8 am and 8 pm private, non-commercial vehicles are allowed out on the roads on alternate days – odd days if the vehicle's license plate ends in an odd number, and even days if it ends in an even number.

Delhi Authorities Enhancing Parking Fees by Four Times: In a bid to discourage people from taking out their cars and reduce vehicular emissions, the Delhi authorities including Municipal Corporations of Delhi, Delhi Development Authority, Delhi Metro Rail Corporation hiked the parking fees by four times.

Ban on Civil Construction: The construction dust has off late been recognised as one of the major sources of pollution in Delhi. It can cause health complications like asthma, chronic obstructive pulmonary diseases, silicosis, etc. Amidst the current crisis, the Delhi government has imposed a ban on construction and demolition activities.

National Green Tribunal Restricts Industrial Activities and Bans Waste Burning in Delhi: All the industrial activities, entry of trucks and all the construction-related activities have been put to hold by the government.

Red Light on, Engine off Campaign: The Delhi government has also kick-started its 'Red Light On, Gaadi Off' anti-pollution campaign for which it has deployed 2,500 environment marshals at 100 traffic signals across the city to generate awareness and curb vehicular pollution.

Green Delhi App: The AAP chief also announced a 'Yudh Pradushan Ke Virudh' campaign, which intends to reduce pollution levels in Delhi to make it a cleaner and greener place for residents. As part of the campaign, the government will be using a technology developed by Pusa Agriculture Institute, to curb the menace of stubble burning.

There is a need to implement the solutions and alternatives to the stubble burning problem. And for the same, new and innovative technologies and machines can prove to be a major boon for the removal of the crop residue of agriculture, that is for straw and stubble. Some of these machines are:

Turbo Happy Seeder (THS), Rotavator, Straw Baler, Paddy Straw Chopper cum spreader and Reaper Binder. But these machines are costly and are thus mainly used by only rich farmers. State governments should come forward and provide better subsidy to farmers so that they can use these machines.

Farmers have expressed willingness to use Turbo Happy Seeder as it has reduced labour and time of farmers. This machine helps to uproot the stubble and also sow seeds in the area cleared, which is then used as mulch in the fields. But it is very costly as farmers are required to spend around Rs. 1,000 on rent and some extra money on diesel. A single machine can cover 10 acres in a day. Thus suitability and availability are the major problems. Also, farmers faced difficulty in sowing and germination of wheat seeds was also lowered when happy seeder was used. Most of the machines were dumped only after 2 years of use.

Straw Baler: It helps to compress crop residue into compact bales which can be then easily moved out of the field. It was successful in initial days as baler owners used to provide their services free of cost and would earn by selling the bales to biomass factories, paper mills and cardboard factories nearby. But this machine also failed as balers started charging price because the machine took an hour for every acre.

Paddy Straw Chopper cum Spreader: It is used to chop leftover paddy straw into pieces and spreads it around the field. Both these actions are performed in a single operation, making it easy and time-consuming for farmers.

Besides new technologies stubble can also be converted into biochar, which can further be burned in a kiln to be used as fertilizer in the fields. It is a renewable source which is much effective and environment friendly alternative. The biogas generated from this process can also be used as fuel or can be converted to electricity. This process is called biomass gasification. The problem is air blown gasifier needs to be set up which has some fixed cost. Also, there needs to be demand for this biogas, otherwise, there is no profit for the farmers.

Also, long-duration paddy varieties can be replaced with short-duration paddy varieties (like Pusa Basmati – 1509 and PR-126) to reduce stubble

ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

burning. This will give enough time for the stubble to decompose and avoid its burning. This is because these varieties will then be harvested in the third week of September, which will extend the time between the end of rice season and the start of wheat season.

Further, the demand of paddy straw and stubble can be increased by the state government. People should be made aware of the traditional way of using paddy straw and stubble as fodder and as a part of feed mixture preparations. It is also used as cattle feed, compost, roofing in rural areas, biomass energy, mushroom cultivation, packing materials, fuel, paper, bio-ethanol and industrial production. This will incentivise farmers to not burn stubble but to remove them using some methods and sell them in the markets. The government can even set up fodder and feed markets for its effective implementation.

As we talk about stubble burning, we need to remind ourselves about agriculture being a regenerative process, one which recycles. Agriculture residues can have huge economic value if utilized properly such, as making particle board, use in mushroom cultivation, use in cover crops, cattle feed, use as biofertilizer.

What we need is to utilise every product in the process and return it to the soil in one form or another. From 35 million tonnes of stubble (parali), we can obtain 21 million tonnes of high-grade organic fertiliser. The total amount of nitrogen, phosphorous, potassium and sulphur in the 23 million tonnes of parali annually burnt in Northwest India is about seven lakh tonnes, valued at Rs 1,000 crore. This apart, organic carbon is also destroyed during stubble burning. Thus, parali offers an important source for meeting the nutrient requirements of crops and improving soil health. These nutrients also reduce the risk of cancers in Punjab by reducing the levels of carcinogens in soil.

And for the same, the government is set to use a technology developed by Pusa Agriculture Institute, to curb the menace of stubble burning.

PUSA Bio-Decomposer (The Hindu)*

Pusa bio-decomposer is a solution developed by the scientists at the Indian Agricultural Research Institute, Pusa, which can turn crop residue into manure in 15 to 20 days and therefore, can prevent stubble burning

- The decomposers are in the form of capsules made by extracting fungi strains that help the paddy straw to decompose at a much faster rate than usual.
- The fungi help to produce the essential enzymes for the degradation process.

Decomposer Mixture

- It involves making a liquid formulation using decomposer capsules and fermenting it over 8-10 days and then spraying the mixture on fields with crop stubble to ensure speedy bio-decomposition of the stubble.
- The farmers can prepare 25 litres of the liquid mixture with 4 capsules, jaggery and chickpea flour. The mixture is sufficient to cover 1 hectare of land.

Time to Decompose

- It takes around 20 days for the degradation process to be completed.
- Under usual circumstances, shredded and watered paddy straw, which is mixed with soil, takes at least 45 days to decompose.
- It does not give enough time for farmers to prepare fields for the wheat crop on time.

Benefits

- The decomposer improves the fertility and productivity of the soil as the stubble works as manure and compost for the crops and lesser fertiliser consumption is required in the future.
- The soil loses its richness due to stubble burning and it also destroys the useful bacteria and fungi in the soil, apart from causing harm to the environment.
- It is an efficient and effective, cheaper, doable and practical technique to stop stubble burning.
- It is an eco-friendly and environmentally useful technology and will contribute to achieving Swachh Bharat Mission.

CONCLUSION

As is seen, pollution is a big problem in India, especially in Delhi. This pollution problem surges in the winter season from the month of November to February. During this period, the concentration of $PM_{2.5}$ increases which is harmful to economic health.

Many reasons are observed as the cause of this deadly pollution. Some of them are vehicular pollution, industrial pollution, fireworks, stubble burning and many more. During the winter season, farmers burn the crop residue before the harvesting season which contributes to pollution and becomes the major source of it, leaving all other factors behind.

ROLE OF INNOVATIVE TECHNOLOGIES TO BOOST CIRCULAR ECONOMY: A CASE OF CONTROLLING DELHI POLLUTION CAUSED BY STUBBLE BURN

Instead of burning, if farmers shift to alternative strategies which leads to reusing the stubble and straws, then it will be beneficial for both the farmers and the economy. Thus, the shift from a linear economy (where the focus is only on the main agricultural product) to the circular economy is necessary, so that the waste can be used for economic gains. Using this model to prevent stubble burning, the economy can gain from less pollution and more resources.

Many policies were made by the government in the past like the National Policy for Management of Crop Residues to protect the parali. Since then, crop residue management has helped make the soil more fertile, thereby resulting in savings of Rs 2,000/hectare from the farmer's manure cost. Burning crop residue is a crime under Section 188 of the IPC and the Air (Prevention and Control of Pollution) Act, 1981. However, the government's implementation lacks strength.

To tackle this issue, the Delhi government had launched a widespread campaign to curb air pollution, with an action plan that would include preparing bio-chemicals and spraying them across 800 hectares of farmland in the rural belt of the capital where farmers burn crop stubble. The Delhi government will set up a centralised system to produce bio-chemicals at Najafgarh's Kharkhari Nahar village under the supervision of scientists from the Indian Agricultural Research Institute (IARI), which recently developed a low-cost solution to stop farmers from setting fire to paddy stubble.

In order to keep in check pollution from stubble burning which is not under the control of the Delhi government, it was decided that it would work with neighbouring states and agencies so that the poor air quality could be curbed in winters in advance.

The state needs to step in and engage already-existing mechanisms like the MGNREGA for this purpose. To do this, the Centre needs to allow states to include activities like harvesting and composting in MGNREGA. This has been a longstanding demand of many states. Stubble (parali) can be mixed with cow dung and few natural enzymes under MGNREGA to generate high-grade compost, and also reduce air pollution in North India.

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