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ENVIRONMENTAL AND HEALTH IMPACT OF OPEN BURNING RICE STRAW (REVIEW ARTICLE)

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Abstract

Introduction: Egypt is an agricultural country and the largest rice producer in the Middle East region. It is an important strategic crop that is planted in Nile Delta area. The term rice straw describes the dry stalks of the rice crop that remains after the removal of the grain during harvesting process. Rice straw biochemical composition is the typical structure of agricultural- based lignocellulosic residue. Farmers all over the world had the habit of open burning of rice straw as a disposal method of the voluminous residues of harvested rice. This practice causes significant amount of air pollutants like gases as NO_x, CO, CO_2, fine dust ($PM_{2.5}$, and PM_{10}), that affects the air quality, leads to climatic changes and deteriorates public health. The Egyptian Ministry of Environmental Affairs had controlled this practice that has both environmental and health impacts, through installing intelligent monitors all over Egypt that give alarm in case of exceeding the limits stated by the national environmental law. Efforts had been directed towards onsite collection of rice straw and convincing farmers to recycle the straw into a wide range of products and to provide them with machines for the processing of the rice straw for free added to exploring opportunities of agro-industrial uses as household fuel, livestock bedding, papers, fertilizers, furniture and construction. Consequently, increase the commercial demand for rice straw that derived up prices resulting in the establishment of more rural activities and services. This act improved the air quality and reduced the negative impact on the environment and public health.

Key words: Rice straw, Rice husk, Black cloud and Open burning.

Introduction

1- Background:

Rice is one of the largest crops grown in Egypt and is the principal food for the majority of the country's population. Rice represents the second largest share of any crop in the world based on the report of Food and Agriculture Organization of the United Nations (FAO) (Food and Agriculture Organization of the United Nations., 2008). Rice is mainly grown in tropical and sub-tropical areas, however the Mediterranean climates may also is suitable for its production.

2- Definition and composition of rice husk and straw:

Rice husks also called "Rice Hull" (RH) are the coating on a seed or grain of rice and are generated during the first stage of rice milling, when rough rice or paddy rice is husked. The rice husk layer accounts for 20 % of the weight of paddy. It is formed from hard materials, including silica and lignin, to protect the seed during the growing season. Each kg of milled white rice results in roughly 0.28 kg of rice husk as a by-product of rice production during milling by friction and the process is called de-husking or de-hulling. De-husking was traditionally done using mortar and pestles but, in modern rice mills, it is done by passing the paddy grains between two abrasive surfaces that move at different speeds. After separating the husk from paddy, the husk is removed by suction and then transported to a storage dump outside the milling plant (Esa et al., 2013).

Rice straw (RS) refers to the dry stalks of the cereal crops rice that is poor in nitrogen and high in inorganic compounds. Rice grain is composed of an external husk layer, a bran layer and the endosperm. Rice straw is produced when harvesting paddy, the grains are separated. The stalks remain after removal of the grain during the grain harvesting process. The composition of rice straw is of fibrous nature with high content of silicon dioxide (SO^2) that resists decay when incorporated into the soil and can lead to a reduction in yield the following season because of the formation of toxic gases added to leading mortality (Bakker et al., 2013).

Rice straw (RS) is the inedible fibrous plant that is left in the field after the harvest, it is

lignocellulosic biomass produced as an agricultural side product after harvesting the main rice

product. Rice husk or straw have high silica content (Standards and Industrial Research Institute of Malaysia., 1983).

Rice straw is biochemically composed of an agricultural-based lignocellulosic residual having 30 – 45% cellulose, 20 – 25% hemicellulose, 15 – 20 % lignin, and a minor percentage of organic compounds (Sarnklong et al., 2010).

3- The practice of open burning of rice husk and straw:

The practice of rice straw open burning is caused by the necessity of a short turnover time between rice and subsequent crops. Elimination or processing of rice straw should be carried rapidly so as it does not act as a physical barrier to prepare a seedbed for the following crop. There are different practices for rice straw burning (e.g. pile burning or burning of straw that is consistently spread over the field). Open-field burning has many advantages as being effective, reliable, and inexpensive. Also the infrequent need labor and equipment and reliability under variety of weather and field conditions. Alternative methods for open burning of rice straw includes incorporation in the soil or on overall nutrient balance and long-term soil fertility, has become increasingly recognized and considered rice straw as an important natural resource and not wastes. Each of these activities has a different impact on soil fertility or the nutrient balance. The recycling of crop residues has the advantage of converting the excess waste into useful product for meeting nutrient requirement of crops, maintaining soil physical and chemical properties and improving the ecological balance of the crop production system (Goswami et al, 2019). Degradation of rice straw in the field emits significant amount of greenhouse gases, such as methane and N_2O (Launio et al., 2015).

4- Current uses of rice straw:

Extensive efforts have been made by public authorities to explore prospects for crop residue usage on-site, for livestock feed, for composting/soil enrichment and for alternative uses (such as household fuel, livestock bedding, etc.). These prospects for off-farm industrial use have been ignored; and rice straw continues to be burned). The Egyptian government explored agro-industrial opportunities for use of rice residues for livestock feed, for the production of energy, for use as a soil substrate (for producing a range of high value crops) and within a handful

of manufacturing ventures (for board, paper, fuels, bricks for construction and service materials, etc.) (IEEP, 2012).

The magnitude of agricultural crop residues that contribute to dry biomass is about 12.33 million tons/ year, and 63.75% of this amount is produced from rice straw. Accordingly, rice straw could be a source of renewable fuel with the benefit of replacement of fossil fuels; reduction of CO^2 emissions and prevention of the pollution caused by open burning of straw (https://english.rvo.nl/sites/default/files/2013/12/Straw%20report%20AgNL%20June%202013.pdf). Bakker and his coworkers in 2013 studied the relation to the thermal conversion process of rice straw, thermo-gravimetric analysis (TGA) and differential scanning calorimetric (DSC) and concluded that it could cause some operating problems because of the presence of high contents of potassium, chlorine and silicon in the raw material. This attributed to high quantity of ashes with important sintering and slugging tendencies that negatively affect the thermal conversion systems. They suggested a process of washing rice straw with water as a pretreatment step prior to combustion process that showed improvement of undesirable inorganic compounds related to ash problems.

Table (1): Traditional uses for rice straw.

Traditional Uses	
Fuel for cooking	Combustion of straw is used as fuel but when compared to other agricultural residues as cotton stalks or rice husks, it produces more smoke making it undesirable for cooking
Building materials	Straw is combined with mud to produce building blocks and also used for thatching of roofs
Animal production	Animal bedding and animal feed but it is low quality feed
Compositing	Compositing when combined with other agricultural residues as animal manure to be returned to the field
Incorporation	Straw is returned to the field by tillage. Incorporation of fresh straw is labour- intensive or requires suitable machinery for land preparation and may result in the buildup of disease problem.

((https://english.rvo.nl/sites/default/files/2013/12/Straw%20report%20AgNL%20June%202013.pdf).)

5- Environmental impact of open burning of rice husk/ straw:

For decades, Egyptian farmers used to gather rice straw and open burn it in the field as a mean of rapid disposal. The practice has been condemned by environmentalists over the past years, and legislations were delivered for prohibition of open burning that causes environmental pollution in many countries. Environmentalists have blamed the process of open burning of rice straw for the development of thick layer of smog "black cloud" first appeared in Egypt, over the Nile Delta and Cairo in 1997, and became clearly visible to the naked eye two years later (http://english.ahram.org.eg/News/281781.aspx).

Many studies evaluates the environmental impact of open rice straw burning that is known to cause substantial amount of air pollutants that contributes to serious deterioration of the ambient air quality, climatic changes and deterioration of general population health. Table (2) Describes the estimated the emissions of greenhouse gas and other air pollutants (NO_x, CO, CO_2, fine dust) from the open burning of rice straw in Egypt. Rice is produced at a volume of more than 8 tons / hectare [ha.]. Rice straw burning showed a release of 11 tons of CO_2-equivalent per ha of land, NO_x and fine dust particles $PM_{2.5}$. Autumn season is the time of burning of rice straw when the chance of inversion conditions and the air basin's failure to adequately disperse emissions are at their maximum (Poppens and Bakker, 2010).

Table (2): Estimated emissions of greenhouse gases and other air pollutants from field burning of rice straw in Egypt.

Pollutants	Emission factor g/kg straw dry weight	Emissions Kg pollutants/ha	Emissions in CO_2 Eq. Ton CO_2 eq/ha
C O_2	1460.00	9344.0	9.34
CH_4	0.74	4.7	0.10
N_2O	0.79	5.1	1.57
CO	72.4	463.4	
NOx	3.52	22.5	
SO_2	0.15	0.9	
PM 2.5 (fine particulate matter)	12.95	82.9	
Total		9354	11

(Poppens and Bakker, 2010).

The high carbon-to-nitrogen content of rice straw leads to a very low biodegradability compared to other agricultural residues. This is of particular importance in case of using rice straw for anaerobic digestion to produce biogas. To fasten the degradation of organic components of straw, agricultural residues should be added. Rice straw has ash concentrations of 18 to 20 weight% (based on dry matter) and high levels of potassium and chlorine in straw leading to high possibility of ash slugging and fouling in combustion systems (Bakker et al., 2013).

A study cited by Forbes website, and conducted by The Eco Experts Company, has nominated Cairo as "the most polluted city on Earth". British energy firm Eco Experts in 2018, analysis of data from selected 48 cities in the world and also ranked Cairo as the world's most polluted city. Cairo recorded the highest pollution among the studied cities, followed by Delhi, Beijing, Moscow, Istanbul, Guangzhou, Shanghai, Buenos Aires, Paris and Los Angeles. It was speculated that, on an average day, residents breathe air loaded with particulate matter (PM) < 2.5m that is 11.7 times higher than safe level set by the World Health Organization. As regards PM10 m, the level reached an average of 284g/m3 which is the 2nd highest city and 14.2 times over the safe limit. (https://thearabweekly.com/cairo-needs-more-awareness-strict-regulations-protect-environment).

Table (3): Rank of polluted cities in the world (the highest ten cities in the world)

Rank	Country	City	Score
1	Egypt	Cairo	95.8361
2	India	Delhi	86.7024
3	China	Bejing	76.4648
4	Russia	Mosco	75.5634
5	Turkey	Istanbul	72.9714
6	China	Guangzhou	71.5192
7	China	Shanghai	71.4118
8	Argentina	Buenos Aires	68.7428
9	France	Paris	67.1649
10	USA	Los Angeles	66.0576

(https://egyptindependent.com/cairo-the-most-polluted-city-in-the-world-study/).

Incomplete combustion of rice straw in the field emits pollutants as toxic gases as carbon monoxide (CO), volatile organic compound (VOC), aerosols (Zhang et al., 2017), polycyclic aromatic hydrocarbons and fine/inhalable particles (Kim Oanh et al., 2005). Ramadan (2018) studied air pollution observed in Nile Delta region in Egypt caused by open rice straw burning, and concluded that the mean hourly flux reaches values of 32 mg^3 of CO/8hours, 241 μgm^3 of total particulate matter (TPM) for 24 hours and 155 of NO_x for 24 hours. The mean hourly flux reaches values of 32 mg^3/CO of 8 hours, 241 μgm^3 of total particulate matter (TPM) for 24 hours and 155 of NO_x for 24

hours in the Nile Delta. The aerosol composition collected in Nile delta during burning periods showed an increase in the concentration of K^+ , NO^{-3} and Cl^- ions that are inter

correlated.

6- Health hazards attributed to combustion of rice straw:

Pollutants emitted from open burning of agricultural residuals raise alarms about potential affection of general health (https://scoopempire.com/ministry-of- environment-stops-burning-rice-straw-in-a-strive-for-better-air-quality/).

The released pollutants disperse into the atmosphere and subsequent chemical and physical reaction results in adverse health effects. Torigoe and his colleagues in 2000, linked the increased asthma attacks either induces or exacerbates asthma, in children to the open rice straw burning in a prefecture in Japan.

Recently Dizaji et al., 2019 studied utilization of biomass for the generation of biogenic materials. Combustion of Rice Husk (RH) and Rice Straw (RS); have high silica content, produce high-grade biogenic silica that had shown to cause pulmonary disease resembling asbestosis, namely pleural fibrosis and possibly bronchogenic carcinoma.

Lim and his colleagues (1984) described "Rice Millers' Syndrome" among rice mill workers in Malaysian population who manifested with distinctive clinical, hematological and radiological findings. Ratnaprabha and Manjunath (2016) documented significant respiratory morbidities and pulmonary function tests deterioration among rice mill workers in Karnataka City.

Ghosh et al (2014) explained these

findings by the fact that the small particle size emitted from agricultural burning can reach the pulmonary spaces of human lungs, causing respiratory disorders that include acute bronchitis. Several reports have suggested that unprotected dust exposures in agricultural settings may lead to pulmonary fibrosis (Green et al., 1990).

The prevalence of respiratory morbidity was quite high in the areas and among workers in rice mill workers that accounted for 40.73% with obstructive and restrictive respiratory morbidity being 24.60% and 16.13%, respectively (Rana et al., 2018).

Shortening lives of Egyptians by 1.85 years was attributed to air pollution according to a study published in the Journal of Environmental Science and Technology Letters in 2018. According to Egypt Independent recent report, 42,000 Egyptians die yearly from diseases related to poor air quality (https://scoopempire.com/ministry-of-environment-stops-burning-rice-straw-in-a-strive-for-better-air-quality/)

7- Egypt's Ministry of Environment act for solving the problem:

Efforts were carried out to eradicate Greater Cairo pollutants by the Egyptian Ministry of State for Environmental Affairs that convince farmers to recycle the straw into a wide range of products and to provide them with machines for the processing of the rice straw for free (https://egyptindependent.com/cairo-the-most-polluted-city-in-the-world-study/).

In Egypt rice straw was collected on place to be redirected to be utilized in furniture manufacturing and animal fodder. Executives have publicized that in 2019, about 1,900 tons of rice straw collected from 156 districts were reused as artificial organic fertilizers, food for livestock, bricks and furniture (https://www.egypttoday.com/Article/1/74565/No-burning-anymore-Rice-Straw-collected-for-recycling).

Awareness national campaign delivered by the Ministry of Environment was directed to a number of governorates in Lower Egypt including Sharkia, Gharbia, Dakhlia, Qalyoubia, Beheria, and Kafr El Sheikh, where the rice farming is predominant (https://www.reuters.com/article/us-health-airpollution-cairo/egyptian-pollution-plan-signals-the-last-straw-cloud-idUSKCN-1N42HG).

Egypt started executing essential alterations in the infrastructure and

legislations to improve air quality and banning rice burning is considered as one of the most important steps to improve air quality to maintain safe and healthy environment of the Nile Delta and all over Egypt.

Egypt's Ministry of Environment started enhancing efforts for collecting rice straws to be directed to "other industrial applications" as well as enforced legislative efforts for banning open burning straw residues. Egypt has been taking major procedures to become more environmentally friendly (https://egyptianstreets.com/2019/09/08/__trashed-12/).

By the end of the year 2019, the Ministry of Environment installed two stations for air monitoring Sohag governorate (Upper Egypt) will be installed the. The first monitoring station was fixed on the administration building of Sohag University located at the east of the Nile, under the National Network for Industrial Emission Monitoring (NNIEM). The total number of air monitoring stations at the national level reached 100 stations (https://egyptianstreets.com/2019/06/29/egypt-establishes-first-air-pollutant-monitoring-station-in-el-sohag/). Through different branches of the Environmental Affairs Agency, the Environment Ministry remotely controls the emissions through electronically monitors that are connected to the NNIEM, to ensure complying with the national limits set by the environmental law. These monitors also give warnings in case that these emissions exceed the permitted levels of pollution (https://ww.egyptindependent.com/egypt-installs-100-air-quality-monitoring-stations-nationwide-minister/). The plan of the Ministry of Environment focuses on Upper Egypt, leading to the establishment of monitoring stations in the provinces of Qena, Minya and Luxor to monitor the air pollutants and achieve the environmental targets of the 2030 Agenda for Sustainable Development (https://egyptianstreets.com/2019/06/29/egypt-establishes-first-air-pollutant-monitoring-station-in-el-sohag/).

Egypt is considered as one of the fewest countries in the Middle East, Africa and Asia that pays such attention to air monitoring and has large number of air quality monitoring stations distributed all-over the country for ensuring safe environment (https://egyptianstreets.com/2019/09/08/__trashed-12/).

Conclusion:

The conventional practice of open burning of rice straw as a fast disposal method is now prohibited by the Ministry of Environment in Egypt, for the sake of environmental and health protection and also proper maintenance of soil organic matter and erosion control.

Governmental policies should be directed towards improving opportunities for alternative uses of rice straw and expanding the biotechnology industry. Rice straw is a valuable biomass resource that should be properly used. This will increase the commercial demand for rice straw and consequently its price.

Continuous air monitoring is regularly checked all over Egyptian governorates for detecting any warning emissions that will be instantly managed. This act will mitigate the surrounding environment and the public health to achieve the target set by the 2030 Agenda for Sustainable Development.

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