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Solid Waste Management and Air Quality Monitoring In Agricultural Food Industries: Case of AFRIFOOD / SA, Cameroon

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ABSTRACT. All human activities generates waste which gradually alters our environment. Appropriate management of these wastes is therefore essential, especially wastes from agro industries. The aim of this work was therefore to contribute to the protection of the environment by monitoring air quality and valorising rice husks in AFRIFOOD. More specifically, we identify and quantify the solid and gaseous wastes production sources. Observations and semi-structured interviews were used to identify sources of pollution; the material balance approach made it possible to quantify solid waste while the "Carbon Monoxide Meter AS8700A" and the "Air Quality Detector BR-8C" were used for the measurement of air quality (estimate of PM1; PM10; PM2.5; HCHO; TVOC). Results showed that, the main waste produced by AFRIFOOD is rice husks and at a rate of 400 tons / year; Open air burning remain the only management alternative for these wastes. The other wastes identified includes: ash from parboiling units and dust at the factory. These can all be considered as ordinary and inert waste, with little or no danger to the environment. Also, air at the plant had insignificant CO_2, HCOH, TVOC and CO concentration values, justifying the "very good" rating displayed by the meters. We suggest the valorisation of the rice husks through biochar briquettes production; that will limit environmental pollution in a long term. Results from preliminary tests done suggest that this technology can be promising. Further development is needed for large scale application.

Keywords: air, environment, waste, rice husks, biochar.

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1. Introduction

Since the early 1990s, environmental protection has become a collective concern. The issue of waste is actual and affects everyone. As a consumer, discarder, household waste collection user, and recyclable waste sorter, citizen or taxpayer, everyone can and must be a player in better waste management. Simple actions make it possible to take concrete action to improve the living environment and preserve the well-being of everyone: each citizen can throw less and throw better (Michel *et al.,* 2002).

The growth in waste production and the ever-faster development of consumer goods have deeply marked the socio-economic structure of industrialized countries. Political authorities are trying to change the way we approach products and waste by resorting to new instruments, based on financial incentives. With the exception of those kept in museums, all of our consumer goods end their lives as waste. There is no doubt that the propensity to consume and to produce wastes depends closely on the purchasing power and prosperity of a society (CUSSRT, 2008). On the other hand, access to energy, which is increasingly seen as a fundamental right, is a necessary condition for any development process. In Africa, Latin America and Asia (including India and China) wood is becoming more and more difficult to find; Two billion people around the world therefore depend on wood for their domestic energy needs. In Africa more particularly, it represents 89% of energy sources. However, these populations will not have the means to afford the so-called modern energies (based on hydrocarbons or solar energy), which means that they will soon no longer have the possibility of cooking their food. This deforestation accentuates drought, desertification as well as climate change. The best solution we found might be to recover agricultural residues or renewable biomass that cannot be valued otherwise and transform them into green charcoal briquettes that are used in the same way as charcoal (Maninder *et al.*, 2012).

In an integrated vision of sustainable development, the issue of waste must be placed in a holistic perspective of risk and resource management, which covers the entire waste life cycle, from generation to final treatment. It anticipates waste from the project stage, includes source reduction, recovery and elimination strategies and aims to control flows throughout the process leading to waste (Taelman *et al*., 2018). We must focus on production processes that generate little waste, manufacture goods with a long lifespan and optimize packaging. The use of polluting substances, in research and manufacturing processes, should be limited as far as possible,

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in order to facilitate the subsequent stages of waste treatment and recovery (CUSSRT, 2008). However, like all forms of agro-food production, rice, thanks to its multiple intrinsic potentials, requires exploration on several dimensions both at the level of primary processing into first-class products such as white rice, parboiled rice, brown rice… But also at the level of secondary processing into products intended for other uses. Since environmental protection has become a collective concern, the issue of waste is daily and affects everyone (Yoada *et al.,* 2014). As a consumer, discarder, household waste collection user, and recyclable waste sorter, citizen or taxpayer etc. everyone must be a player in better waste management. This brings us to the main aim of this work; which is to contribute to environment protection by recovering the wastes from rice processing in AFRIFOOD SA. Cameroon. The main objectives were to:

- Identify the sources of waste production in the AFRIFOOD company;
- Quantify the volumes of solid waste produced in the company;
- Quantify the greenhouse gas emissions in the immediate working environment of AFRIFOOD.

2. Materials and Methods

2.1 Site location

This study was carried out at AFRIFOOD SA; a company created in 2012 by AFRIGROUP HOLDING Plc, *CREDIT COMMUNAUTAIRE D'AFRIQUE*, selected farmers and other businessmen, having as mission the development of second generation agriculture, in order to restore food self-sufficiency in products such as rice, corn, tomatoes, etc. It is located in the capital of the Western region (Bafoussam) whose geographical coordinates are: North latitude: 5˚ 28 '; longitude East: 10˚ 33 '; average altitude: 1450m and about 300 km from Yaoundé and 275km from Douala. This region is characterized by a Cameroonian-type highland climate, 1800mm of rainfall per year (Mpakam, 2008), ferrallitic soils, poorly evolved soils and hydromorphic soils (Tsalefack, 1999) and built on plateau basalts resulting from ancient volcanism (Tchindjang, 1996).

2.2 Identification of AFRIFOOD waste sources

Identifying waste is the first step in a business's waste management process. For this, observations were made so as to locate the main areas or sources of waste production. Each identified waste source were labelled based on the type or nature of the waste. Semi-structured interviews were conducted; it consisted of a questionnaire having general and specific questions to the management board up to employees. General questions were: what do you produce? What is the production process? How do you manage waste? While Specific questions were: Where is the waste stored? What forms of waste are produced? What is the nature of the plant's waste? What are the quantities produced during the rice processing process? What are the production frequencies of this waste? For how long in the year do you produce waste? What is the most important waste produced in the company? Furthermore, information available on the company were collected as secondary data. It consisted of collection orders; registers consulting the waste lists in the rice directories proper; or wastes from the production of rice for consumption by the company.

2.3 Classification and quantification of waste

Waste classification was done using the environmental code of decree n ° 2002-540 of April 18, 2002. After identifying the waste produced, each one was organized on a table based on its nature. The quantification through "Purchased Material Balance" consisted of estimating the annual production of waste using the company secondary data; consulted management level concerning their waste to better estimate and quantify them; and estimated the quantities of waste eliminated yearly using the balance sheet: Waste produced internally = Materials purchased - Materials sold to customers - Changes in inventory.

2.4 Quantification of greenhouse gas emissions

The Carbon Monoxide Meter AS8700A was used to measure temperature data in °C (degrees Celcuis) and °F (degrees Faraday), carbon monoxide (C0). Data was collected once per day (between 9 am and 10 am) in all the waste production areas. The Air Quality Detector was then used to measure Pm1; Pm10; Pm2.5; HCHO; TVOC and CO2. The identified waste disposal site and both devices were used at the same time.

3. Results and Discussion

3.1 Results

3.1.1 Identification of waste sources in AFRIFOOD

The various wastes that were identified at the rice mill are recorded in Table 2 according to presence rate and their nature. Rice mill waste identification is such that at each source, there was potentially production different types of waste: for example, in the parboiling sector, there were deposits of charcoal used for cooking this rice. Or in the factory, there was rice hull wastes, dust deposits and powders from the rice husking and polishing activities. In the combustion area, ashes from rice husks were found; in fact, burning was a solution for the company to quickly evacuate excess rice husks, when they were produced in inedible quantities.

3.1.2 Waste classification

We noticed that, the wastes were produced following the rice processing chain and the most abundant product was rice husk because it represents about 25%. Table 1 also shows that there are more banal products than dangerous and inert ones; the most important are rice hulls because it is one of the most waste products produced in large quantities in the rice mill. Table 1 further indicates, the relevance of our waste is assessed according to the volume of production of the latter; the more waste is produced, the more it is represented by the plus sign (+). This is why the rice husks are the most represented because of their very high relevance; then come the ash of rice husks, dust and low flour (moderately present), in last position we have stones and charcoal (weakly present).

Table 1
Wastes of AFRIFOOD'S rice milling factory

Waste category	Description	Pertinence	
Rice husk ash	Powdered product resulting from complete combustion of rice husks	B	++
Rice husk	Solid product resulting from paddy hulling	B	+++
Rice brown	Slightly fined product resulting from the friction movement of the huller rubber bands	B I	++
Dust	Very fined product present in air	B, D	++
Stones	Coarse material from rice farms	I	+
Powders	Solid and light deposits derived from rice farms dusts	B, D	++
Wood charcoal	Coarse material derived from burning of wood for rice parboiling	B , I	+

Key: I (inert), B (banal), D (dangerous) + (weakly present) ++ (moderately present) +++ (very present)

3.1.3 Waste quantification

A good quantification of waste starts with an estimate and an evaluation of the annual or monthly production. Indeed, the transformation of paddy into edible rice in AFRIFOOD is such that it depends on paddy supply rate coming from individuals or from the farmers themselves (Koutaba and Ndop). Thus the figure 1 represents the transformation graph of the AFRIFOOD rice mill.

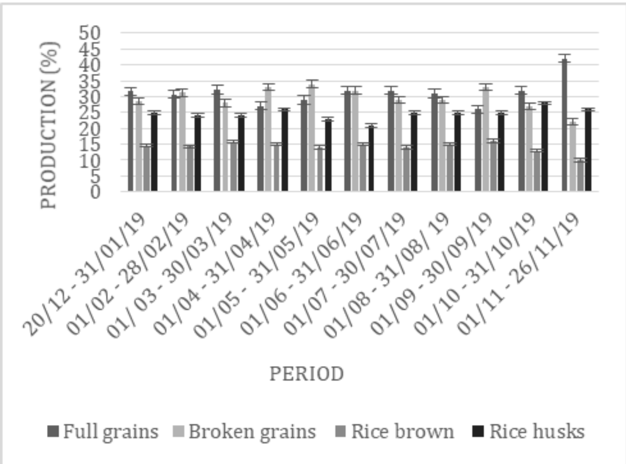

Fig. 1 Paddy rice milling in AFRIFOOD

From Fig.1, the quantities of products obtained depend essentially on the quality and efficiency of the machines; the marketing of its products also depends on consumers (households). Indeed, the high production rate of full grain rice is a function of the high demand for rice for preparing end of year celebrations. So the more intense the husking activity in the rice mill, the more the rate of waste production increases. The figure shows us the pace of waste production according to the rate of husked paddy rice in 2019.

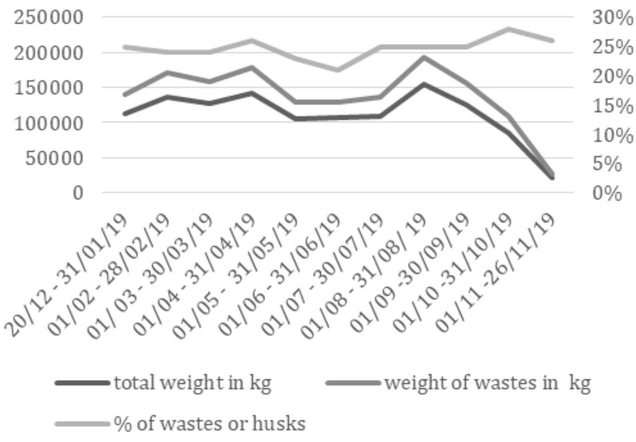

Fig. 2 Rice husk waste in AFRIFOOD

The weight represents the quantity of husked paddy in the rice mill per month and the percentage waste is the quantity of waste produced according to the weight of paddy. From fig. 2 the peak was reached in August, this is probably due to the huge quantities of paddy coming directly from the rice fields the day after post-harvest activities; which shows that at this time, the markets are favourable for rice mills like AFRIFOOD. It can be seen that the rice husk waste rate fluctuates around 25% for the entire paddy husking period; this rate is almost constant throughout the year and varies slightly depending on the paddy supply and its quality. The quality of the machines is also an important element in the transformation process because the better the machine, the lower the waste rate. Regarding the production rate of waste dust, low flour, stones, powder and charcoal, they were very poorly represented, which is why we could not have the exact data to better appreciate them.

3.1.4 Quantification of greenhouse gas emissions

The results for collection of air quality assessment parameters showed that, for carbon monoxide, the meter displayed the value for temperature apart from CO value in degrees Celsius and Faraday. On the other hand, the air quality meter records several other values in addition to the CO_2 value; like PM 10, PM 2.5, PM1.0, HCOH and TVOC. Thus, figure 3 represents the evaluation of each parameter data recorded thanks to the air parameter measuring device.

From fig. 3 below, temperature varies between 26.5 ° C and 28.5 ° C for the evaluation of Pm 2.5; Pm 2.5 varies between 0.001 and 0.02; this curve is greater than the other two curves. As for the evaluation of Pm 2.5, the temperature varies between 27.5 ° C and 28.5 ° C; Pm 10 varies between 0.01 and 0.02, this curve is lower than the other two curves; its values are very low and they are slightly higher than the 10 ppm fluxes. While in the evaluation of Pm 1, temperature varies between 26.5 ° C and 28.5 ° C and Pm 2.5 varies between 0.01 and 0.02; this curve is in-between those of ppm 5 and 10. These are low values compared to those of ppm 10 and high compared to that of ppm 2.5.

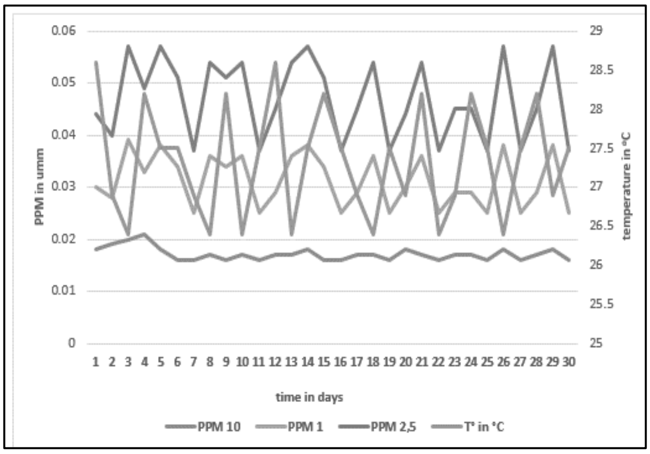

Fig. 3 Variation of PPM with respect to time

The immediate working environment of AFRIFOOD display values indicating the different data which are 0 (Zero) for the CO and CO2 in their evaluation. This result clearly demonstrates the total absence of CO and CO2 at AFRIFOOD rice mill, which visibly emanates from the purity of the air despite the presence of flour dust, or the constant hum of the machines. These values are insignificant due to the total absence of pollutants in the working environment. As for HCOH (Methanol or Formaldehyde) Assessment, there was no emission of HCHO in this environment. It was the same for TVOC (Volatile organic compounds) as its assessment revealed.

Ultimately, values of Pm 2.5 are higher than those of ppm 10 and ppm 1. So there is more production of particles with diameter 2.5 than particles with diameter 10 and 1. But Temperature doesn't greatly influences the presence of particles in the immediate working environment. The air quality parameters showed such zero because of the absence of pollution activities and as a result, the Air Quality Detector displayed "VERY GOOD" which accurately characterized the environment.

3.2 Discussion

3.2.1 Identification of waste sources

The by-products evocated during this research are identical and common to that of the AFRIFOOD rice mill; and corroborates with the work of Bodie et al (2019) who elaborated on the current trends of rice milling by-products for several applications and alternative food production systems. Some Asian and South American countries are a major source of pollution. Cyclones are often the only means used for dust removal, while the efficiency of these arrangements does not exceed 90 to 95% (Middleton and Kang, 2017). In this case, the dust emissions were between 70 and 150 mg / m3. These systems should therefore be supplemented by dust filters. The wastes derived from paddy processing as was the case in the study of dust, rice husks, and stones (of variable sizes). The parboiling system is still traditional which justifies the presence of charcoal; as in contrast to the modern steaming system.

The elimination of rice husks (20%) is the number one problem in rice mills; an economical solution for recovering its residues is pyrolysis (carbonization), making it possible to produce energy by steam boilers or lean gas for gas engine units. Apart from rice hulls, all other by-products are either used locally for livestock feed or exported. After pyrolysis of the rice husks, about 18% of the starting material remains in the form of ash. Ashes on the other hand, are obtained by burning rice husks; burning was the only means the company used to get rid of excess rice hulls; nothing surprising when bulky waste are found. This ash can be used on sites for soil amendment (Kirsten et al., 2016).

3.2.2 Classification of waste

According to article R.541 of CCI France of the book Classification of waste / environmental code, agricultural waste belongs to class 02 and thus rice mill wastes fall under this classification. Also, according to the Environmental Code, industrial waste is classified according to its more or less polluting characteristics and two categories are distinguished:

- Ordinary industrial waste which consists of non-hazardous and non-inert waste;
- Inert industrial waste which are not susceptible to significant physical, chemical or biological evolution. Their deposits are often the cause of illegal dumping.

3.2.3 Quantification of waste

Among the wastes produced by AFRIFOOD, much attention was given to rice hulls because of its abundance and therefore easily measurable. This hulls which derives from paddy constitute around 20 to 25% of waste during processing and around 50% of waste produced in large quantities. This result is not different from that obtained by Bienvenido and Arvin (2019) which states that the proportions by weight of the different parts of the grain are as follows: husks: 20%, pericarp and aleuronic layer: 8%, germ: 2%, albumen: 70%.

However, the quantification of other wastes such as dust and powders, ashes and charcoal is linked to intense activity or not (Thongsanit et al., 2015). Since activities that produce these wastes are not intense, their quantification is not evident. For instance, the presence of charcoal linked to the repeated activity of parboiling the rice; due to the inappropriate traditional parboiling system. The rice brown considered as last by-product of the process is directly packaged and stored in 50kg bags intended for marketing for animal nutrition.

3.2.4 Quantification of greenhouse gas emissions

Considering that most of the wastes were ordinary and inert, it was an advantage for the result obtained; as it revealed that the nature of waste can positively or negatively influence air quality in a working environment. This is why Murad and Pereira (2011) provide an overview of the equipment and methods used to monitor air quality in order to assess potential pollution problems, as well as effective prevention and control measures. Then, according to the WHO (2005), the data on particles (or particulate matter: PM) in the air and their effects on public health are uniform and show adverse effects on human health. In fact, the information and recommendation threshold is 50 µg / m^3 (FR) on average over 24 hours and the limit values for the protection of human health are 50 µg / m^3 (EU) on daily average not to be exceed more than 35 days per year for ppm 10 emissions. For ppm 2.5, the target value for the protection of human health is 20 µg / m^3 (FR) as an annual average and 10 mg / m^3 or 10 000 µg / m^3 (FR) for the daily maximum of the 8-hour moving average for carbon monoxide (CO).

Meanwhile, Ken et al (2004) advocates that air pollution management aims to eliminate, or reduce to acceptable levels, gaseous airborne pollutants, airborne particles as well as physical and biological agents which in the atmosphere can be harmful to human, animals or plants, societal economic interest materials and the environment.

4. Conclusion

In light of this study's results, it emerges that for a good management of waste and the working environment of a company like AFRIFOOD, it is first necessary to identify its waste; rice husks are the most common and easily visible waste. Other wastes in the form of charcoal, rice brown and dust made up of fine particles were also identified which derives from rice husking activity at the mill and are almost all ordinary and inert wastes not too dangerous for the environment. The air quality in the factory is particularly very good and this is due to the almost total absence of greenhouse gases which are often responsible for the degradation of air quality; because parboiling of the rice did not coincide with the rainy season during the study period. The factory only uses electricity to run its machines; therefore no gas production.

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