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Design Prototype of Bio-Filter to Treatment of Carbon Dioxide Gas Exhausts

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Abstract- The research aims to design and fabricate prototype of a bio-filter which used to process the emissions of CO and Co_2.That are mainly generated from the combustion of coal, oil and natural gas. These are main energy resources in our daily life whichused in different food activities as food factories and charcoal grills. The prototype consists of cylinder steel with two covers, two tubes welded on the outer face of each cover and candle of filter.Candlwas consisting of two circle walls and the space between two walls was 2cm In the experimentswere conducted on four cases frombio materialsas follows:- 1- grinded ficusgreen leaves 2-grinded green leaves after drying 3-dry sawdust, 4-Wet sawdust. Measurements were done at five times after 2, 4, 6, 8, and 10 min. from starting experiments.The moisture contents was measured to the agricultural residues (bio-materials) before and after experiments. Chemical analysis was done on the bio-material to measure the Co, Co_2 befor and after experiments. Also,Co ,Co_2 were measured in the air befor input prototype and after output. The results with bio.filter were: - with green leaves: Co_2 ratiodecreased to18% ,Codecreased to 2 %. And absorb of C ratio bygreen leaves was 4.5%.

- *With dry leaves:* Co_2 decreased to 15%, Co ratio didn't change and absorb of C ratio bydry leaves was 0.07%.
- *With wet sawdust:* Co_2 decreased 0.03% and Co ratio didn't change.
- *With dry sawdust:* Co_2 and Co didn't change. The finel conclution was the ficus green leaves is the best bio.materials to use with bio-filter.

Keywords: air purifier, air pollution, carbon capture, direct air capture.

I. Introduction

EXhaust gases emissions from cooking and food processing activities very dangerous because it contain some toxic gases as Co_2 that cusses respiratory illness, and other chronic diseases, mental-health problems, asthma and potentially cardiovascular disease and cancer. Moreover, some gases Co, N_2, O_2, H_2O, PM, HC, So_2, No_2 which produce from unfired fuel is toxic gasas.

Hence, it must keep the components of natural air at 78% nitrogen, 21% oxygen, argon 0.9%, carbon dioxide 0.0390%, and water vapor at a variable rate (Singh et al., 2018). Air pollutants can define as any substance emitted into the air from an anthropogenic, biogenic, or gynogenetic source, that is either not part of the natural atmosphere or is present in higher concentrations than the natural atmosphere, and may cause a short-term or long-term adverse effect. Air pollution caused problematic health include breathing problems, respiratory illness, changes in the lung's defenses, and worsening respiratory, and cardiovascular disease. ElAziz et al.(2015).

World Bank (2016) reported that, In fact, exposure to air pollution is now the fourth in the world. (Ministry of agricultural, 2018-2019) reported that agricultural residues are national wasted wealth and are one of the riches untapped, because of burning and disposing of in different ways. Total agricultural residues in Egypt are about 43 million tons about 8 Million ton horticultural wastes, about 4 Million tons paper waste and can produce, and about 300 thousand tons from ficus paper waste leaves as a residues per year.

Unep (2004) explained that air pollutants can be divided into anthropogenic and natural pollutants according to their sources, or primary and secondary pollutants, which stem from reactions of primary pollutants when taking the production process into account.

Carbon dioxide (Co_2) emissions have become one of the most serious issues and this environmental concern is being faced by our civilization today. The major sources of air pollution are industrial emissions, vehicular emissions, and domestic emissions. Air is very important as it provides oxygen and other gases that are essential to all life on earth. It consists of a mixture of invisible gases that surround the planet. (SEPA, 2019).

These gases can purify before exit to air by using filters or different methods. There are many types of filters can be used based on the types of materials made some filters component is bio-materials to adsorb the emission contents from the exhaust gas. Li et al. (2011) explained that several methods have been developed and used to capture Co_2 from high emission sources and store it in different conditions.

Gary (2009) explained that Carbon capture and storage (CCS) involves the separation and capture of co_2 from flue gas or syn gas in the case of IGCC.CCS is a three-step process that includes:

1. LiOH absorption solution developed by NASA use the same principle but different compound

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2. Capture of Co_2 from electric generating units (or other industrial processes).
3. Compression and transport of the captured co_2 (usually in pipe lines) and under ground injection and geologic sequestration (also referred to as storage) of the co_2 into deep under ground rock formations.

Hussain et al. (2009) mentioned that the possibility to clean contaminated air with hyper accumulator plants has shown great potential. One of the most recently studied species used in phytoremediation applications is woody trees and ornamental plants. These plants can be harvested every 8 to 10 years to generate revenue, along with the added advantage of working as natural air conditioners.

Herzog et al. (2009) explained that carbon dioxide capture and storage (CCS) is the only pathway that can allow the world to continue to enjoy the benefits of using coal while drastically reducing the emissions associated with coal combustion.

To date, all commercial post-combustion Co_2 capture plants use chemical absorption processes with monoethanolamine (MEA)-based solvents. MEA has developed over 70 years ago as a general, non-selective solvent to remove acid gases, such as Co_2 and hydrogen sulfide, from natural gas streams. The amount of carbon dioxide (Co_2) in the atmosphere continues to rise and rather rapidly due to unparalleled cumulative Co_2 emissions. The percentage increased from 382 ppm in 2006 to 408 ppm in the 2018 level over time (Nasa, 2019).

Brethour et al. (2007) cleared that the agricultural residues can include about 6,000 species of cut flowers, potted flowering plants, houseplants, cut foliage, bedding plants, bulbs, cuttings for propagation, food and medicinal plants in greenhouses and outdoor-grown cut flowers and Nursery farmers produce about 9,000 species of annual and perennial plants, woody shrubs, deciduous, coniferous trees, roses, outdoor garden flowers, and Christmas trees. Ficusretusa is a kind of heavy, fast-growing, round-headed, and evergreen ornamental tree that can reach a height of 10 meters.

The research aimed to design and manufacture a locally bio-filter used to process exhaust gases produced by food factories.

II. Materials and Methods

This research was done from2019 to 2020 at Agricultural Engineering Research Institute "AEnRI" Min. Egypt to design and fabricate prototype device for treating and filtering carbon dioxide gas and carbon monoxide gas (exhaust gases) by using crop residues.

a) Design and fabricate prototype device

It was mainly consisting of:

Cylinder steel (12 cm outer diameter and 27.3 cm length) as shown in Figs (1 and2).Two covers from sheet metal 1.0mm thickness. The bottom cover has a hole 2 cm diameter in the center and the upper cover has a hole in the side. Two tubes (2.8 cm diameter and 3.8cm length) have been welded on the upper and bottom covers holes. A candle was fabricated from perforated mesh(0.5 mm) as adouble wall cylinder. The outer wall and inner wall diameters were 8 and6 cm respectively as shown in Fig.(3) It Was welded in the center of the bottom cover and Four vertical bar (5 mm diameter and 24 cm length) were welded on the inside face of the bottom cover as support of candle

b) Agriculture residues

- *Ficusretusa (Moraceae):* It is considered a plant belonging an evergreen trees with a thick shade that grows in various types of soils. It is distinguished as a huge water-loving tree. the grinded of fresh and dried ficus leaves were used in this reserch. as shown in Fig.(4)
- *Sawdust:* It is relatively abundant and inexpensive. Sawdust or wood dust is an industrial waste obtained by-products from cutting, sawing or grinding of timber in the form of fine particles. Sawdust largely consists of cellulose, it also contains soluble sugar, acids, resins, oils and waxes, and other organic substances.

The theory of the prototype device's operation is summed up in the passage of air which loaded with exhaust gases from the centerical hole of the lower cover of the device to the inner circumference of device candle. The exhaust gas passes from the center of the candle to the inner circumference of the device cylinder through the filter candle that filled with biomaterial that absorbs gases .The exhaust air exits from the side opening of the upper cover to the out side air without loaded by hurmful gasses as Co_2 and Co

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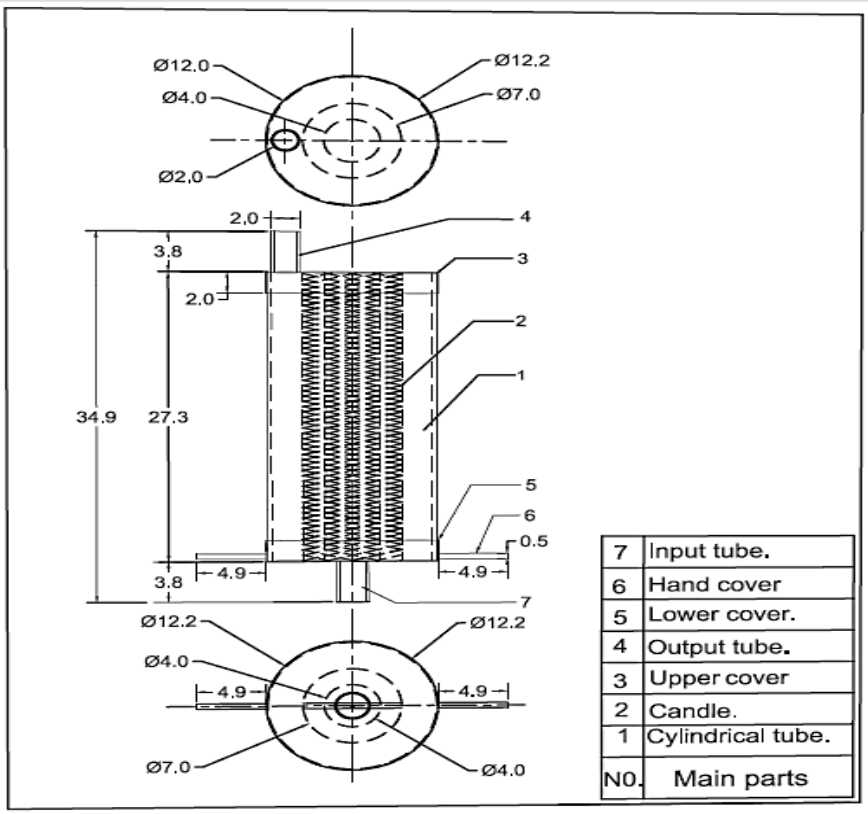
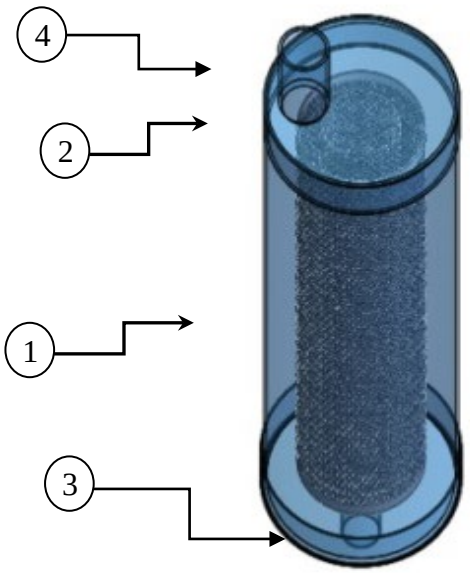


Fig. 1: Schematic diagram of prototype device



1: Cylinder tube steel 2: Cover steel 3: Input 4:Output

Fig. 2: Prototype device

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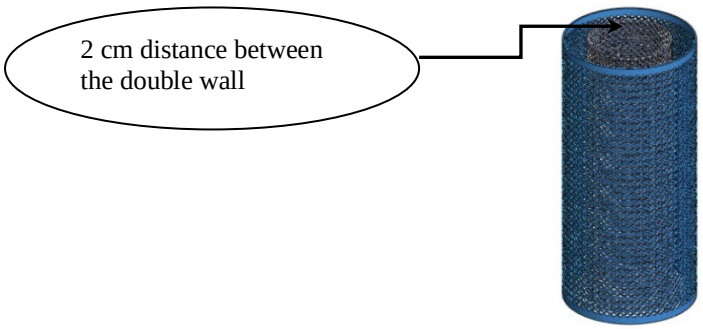


Fig. 3: A candle of filter



(A)



Green (B) Dry

Fig. 4: Ficus leaves and grinding samples

c) *Experimental procedures: It was divided into four steps*

First step; Preparing a combustion chamber for wood and wastes were resulting from its incineration: carbon dioxide and carbon monoxide. Second steps; includes preparing the residues, of; 1- Washing green ficus leaves and crinding it. 2- drying other green leaves at 70°C for 8 hours. After that grinded it to obtain the granular size less than 4.5 mm. 3- prepare sampl from the dry sawdust and other sample with high moisture by adding the suitable amount of water and determine its moisture contents.

Second step; the bio-filter was constructed to use with grinded green ficus (about 175 g) which put between the double wall of candle (Fig.5) fours step; evaluatation of the prototype device under experimental variables by randomized design in three replicates.; moisture content of ficus leaves (green and dry) and sawdust (wet and dry) and air quality with quality of bio.filter materials.



Fig. 5: Ficus leaves in candle

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d) Measurements

i. *Moisture content (MC)*

The moisture content was determined by drying different types of agricultural residues at 70 C°until the weight become constant according to the method described by the AOAC, 2000.

$$MC = \frac{mass\ of\ wet\ sample - mass\ of\ dry\ sample}{mass\ of\ wet\ sample} \times 100, wb\%$$

ii. *Exhaust gases*

The gas components measured using by the device "Auto check" model 974/5 SPTC to measure Co_2 and Co of air before and after tests.

iii. *Chemical analysis of residues*

The carbon content of ficus leaves and sawdust was determined before and after tests in the laboratory of Faculty Science, Cairo–University, Egypt.

iv. The exhaust that resulted from the combustion chamber was measured at five times, 2, 4, 6, 8, and 10 min. from the beginning of the combustion process

v. *Mathematical analysis*

The data were analyzed using excel program 2017 to obtain the best fit curve and coefficient of determination for the relationship between Co_2 and Co as a measurements with the both of residues moisture contents and operating time.

III. Results and Discussions

a) Moisture content

The results of moisture content to different bio-materials before experiments were as shown in table (1) which used as filter media.

Table 1: The moisture contents of some bio-materials.

Biological materials	Moisture content %
Green Leaves officus	53
Dry Leaves officus	34
Dry sawdust	8
Wet sawdust	42

b) Chemical analysis of bio-filter media

The results of carbon components from chemical analysis for each ficus green leaves, dry ficus leaves, wet sawdust, and dry sawdust were 44.7%, 48.17%, 98.8%, and 98.87% respectively before the experiment. and there were 49.23%, 48.24%, 81.6 % and 98.87% respectively after the experiment as shown in table (2). Noted that, the carbon component with dry sawdust was not changing and it was decreasing from 98.87% to 81.6% with wet sawdust because of increasing the moisture content in the carbon ratio dry mass is decreasing.

Table 2: The ratio of carbon contents in bio-filter medias before and after treatments

Bio-materials	Before treatment	After Using bio-filter
Green Leaves officus	44.70	49.23
Dry Leaves officus	48.17	48.24
Wet sawdust	98.87	81.6
Dry sawdust	98.87	98.87

c) Influence of using bio-filter on Exhaust gases (Co_2 and Co)

i. *Influence of using bio-filter on Co_2*

First with the green leaves of ficus: The moisture content of ficus leaves after grinding it was 53% and 34% after drying it. the relationship between the Co_2 ratio which output from the prototype of bio-filter and different absorption times at different moisture content was as shown in fig.(6). At moisture content 53%: Co_2ratio were 1.15, 1.09, 1.06, 1.015, and 0.97 at different absorption times 2, 4, 6, 8 and 10 min. respectively .At moisture content 34%: Co_2ratio were 1.19, 1.15, 1.12, 1.09 and 1.04 at different times 2, 4, 6, 8, and 10 min respectively. Co_2 ratio was reduced from 1.19 to 1.04% when obserbation time was increased from 2 to 10 min respectively at moisture content 34%.also atmoisture content 53 % the Co_2ratio were decreased from 1.15 to 0.97% by increase the operating time from 2 to10 min respectively. The previous results were due to an increase in the absorption time, which leads to an increase in the biofilter's ability to absorb a greater amount of Co_2that present with the exhaust gas which passes through the prototype of the bio-filter.

The best fit curve is the polynimial to describe the effect of residues moisture conten (MC)on the Co_2using ficus leaves bio-filter at different operating times "T". The equations were:

At 34% M.C.Co_2= -0.0004(T^2) –0.0137T + 1.216 R^2=0.9930

At 53%M.C.Co_2= -0.0003(T^2) – 0.0257T + 1.195 R^2=0.9926

From the fitting Eq. It can see inversally relationship between the Co_2 content in used ficus leaves and the operating time. Therefore, the high coefficient of determination was R^2 = 0.9930 occurred at using the ficus leaves with 34% MC, while the other MC "53%" actualized about R^2 = 0.9926.

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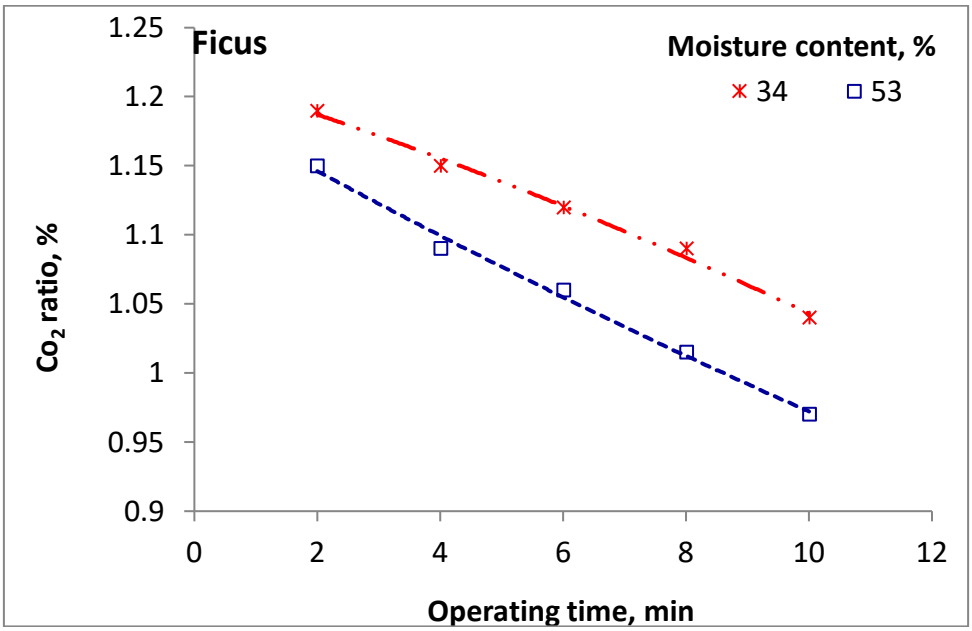


Fig. 6: The effect of using the bio-materials (Ficus leaves) on the absorption of carbon dioxide (Co_2)

Second with the sawdust: The moisture content of sawdust was 8% and 42%. The relationship between the Co_2ratio which output from the prototype of bio-filter and different absorption times at different moisture content was as shown in Fig. (7). At moisture content 42 %: Co_2ratio were decreased from1.28 %, 1.281.27%, 1.27 % and 1.27 %, at different absorption times 2, 4, 6, 8 and 10 minrespectively. At moisture content 8%: Co_2 ratio was constant at 1.28% with each different absorption times 2, 4, 6, 8 and 10 min. respectively. From previous results noted that the increase in the proportion of absorbing Co_2 was slightly with sawdust wet.

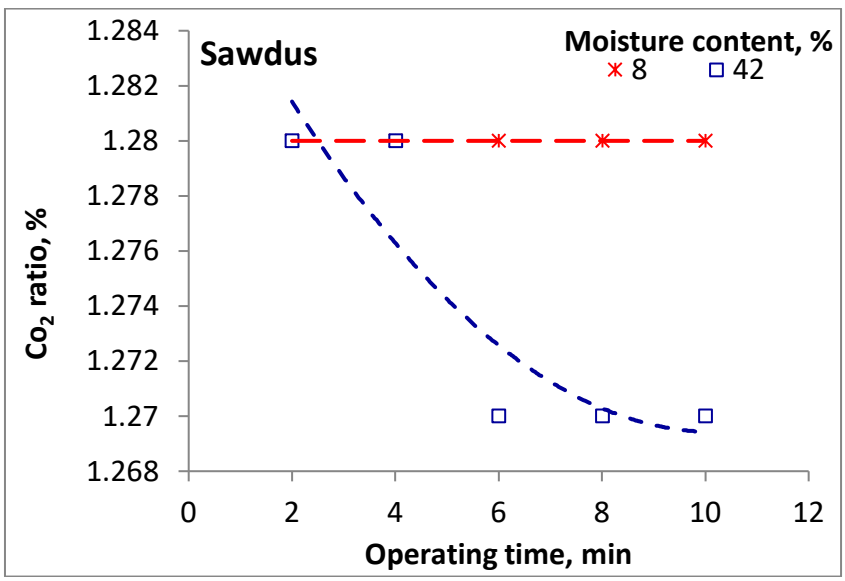


Fig. 7: The effect of using the bio materials (sawdust) on the absorpation of carbon-dioxide (Co_2)

ii. *Influence of using bio-filter on Co*

- *First with the green leaves of ficus:* The moisture content officus leaves after grinding was 53% and 34% after drying it. The relationship between the Co ratio which output from the prototype of bio-filter and different absorption times at different moisture content .
- *At moisture content 53%:* Co ratio were decreased from 1.72 % , 1.72 % ,1.72%, 1.72%and 1.69 %at different absorption times 2, 4, 6, 8 and 10 minrespectively.
- *At moisture content 34%:* Co ratio was constant at 1.72% with different obsorbation times 2, 4, 6, 8, and 10 min respectively.

Second with the sawdust: The moisture content of sawdust was 8% and 42%. The relationship between the Co_2 ratio which output from the prototype of bio-filter

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and different absorption times at different moisture content.

- *At moisture content 42 %:* Co ratio were limited for decreasing from 1.28% to 1.27% at different absorption times 2, 4, 6, 8 and 10 min. respectively.
- *At moisture content 8%:* Co ratio was constant at 1.28% with increasing the absorption times from 2, 4, 6, 8 and 10 min. respectively.

IV. Conclusions

The research concluded that the bio. filter were: - with green leaves decreased Co_2 ratio to18% and Co to 2 % and absorb the C ratio by leaves about 4.5%. while with dry green leaves Co_2decreased to 15 % and didn't effect on Co ratio. - with wet sawdust don't effect on Co ratio but decreased Co_2 0.03% while dry sawdust didn't effect on Co_2 and Co. the finel conclution was the ficus green leaves is the best bio. materials used with bio-filter

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