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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 which used 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. Candidate was consisting of two circle walls and the space between two walls was 2 cm. In the experiments were conducted on four cases from bio materials as follows:- grinded ficus, green and dry leaves ; wet and dry sawdust . Measurements were done at five times after start emittion; 2, 4, 6, 8, and 10 min. The moisture contents of the agricultural residues (bio-materials) was estimated before and after experiments. Leaves chemical analysis was done to determine the CO, CO_2 before and after experiments. Also, CO, CO_2 were measured in the air before input prototype and after output. The concluded results at using bio-filter were: - with green leaves: CO_2 ratio decreased to 18% , CO decreased to 2 %. Then the absorb of "C" ratio by green leaves was 4.5%. - With dry leaves: CO_2 decreased to 15 %, CO ratio didn't change .And absorb of "C" ratio by dry leaves was 0.07%. - With wet sawdust: CO_2 decreased to 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 can use in bio-filter.

Keywords: Air treatment, air pollution,carbon capture, direct air capture.

1. 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 The characters case must revision as Co, correct to CO, and els .....which produce from unfired fuel is toxic gasses.

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 gynogenic 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, Abd El-Aziz et al. (2015).

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

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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 syngas 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

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 underground injection and geologic sequestration (also referred to as storage) of the CO_2 into deep underground 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.

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.

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. Ficus retusa is a kind of heavy, fast-growing, round-headed, and evergreen ornamental tree that can reach a height of 10 meters.

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 ratio increased from 382 ppm in 2006 to 408 ppm in the 2018 level over time (Nasa, 2019).

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

2. Experimental

This research was done from 2019 to 2020 at Agricultural Engineering Research Institute "AEnRI". Egypt .

Prototype device

It was mainly consisting of: cylinde steel (12 cm outer diameter and 27.3 cm length) as shown in Figs (1 and 2). Two covers from sheet metal 1.0 mm thickness. The bottom cover has a hole with 2 cm diameter in the center and the upper cover has a same diameter in the side. Two tubes (2.8 cm diameter and 3.8 cm length) have been welded on the upper and bottom covers holes. A candidate was fabricated from perforated mesh (0.5 mish) as a double wall cylinder. The outer wall and inner wall diameters were 7 and 4 cm respectively as shown in Fig. (3). It was welded in the center of the bottom cover . Four vertical bar (5 mm diameter and 24 cm length) were welded on the inside face of the bottom cover as support of candle.

Agricultural residues (Bio-materials)

***Ficus retusa (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 prepared and used as shown in Fig.(4)

***Sawdust**: It is relatively abundant and inexpensive. Sawdust or wood dust is an industrial waste obtained as a 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 centrically 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 outside air without loaded by harmful gasses as CO_2 and CO.

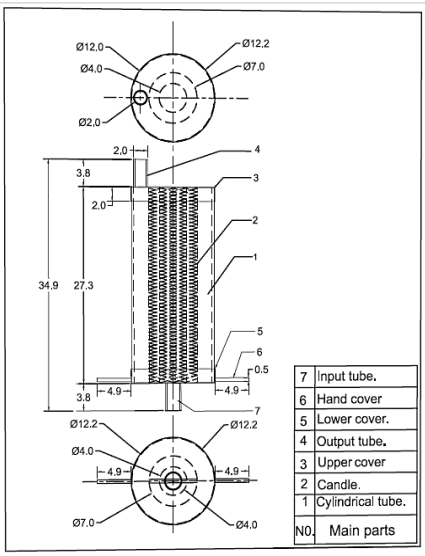
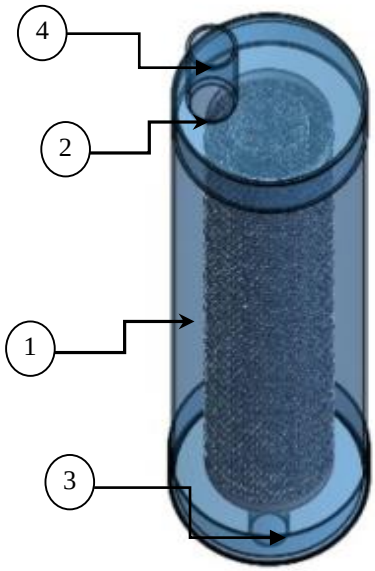


Fig. 1. Schematic diagram of prototype device



1: Cylinder tube steel 2: Cover steel 3:Input 4:Output
Fig. 2. Prototype device

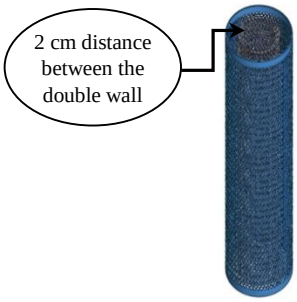


Fig. 3. A Candidate of filter

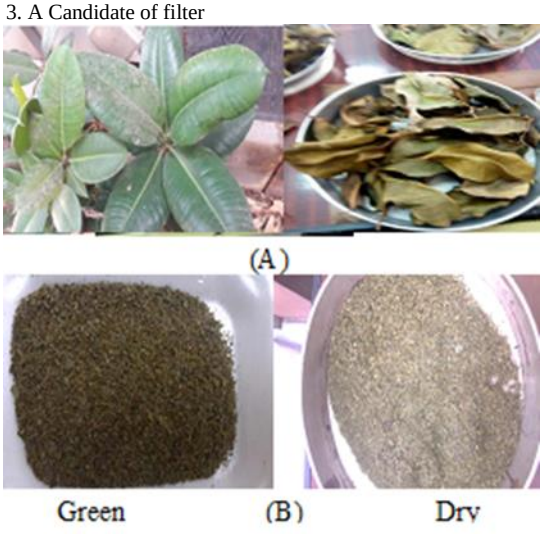


Fig 4. Ficus leaves and grinding samples

Experimental procedures

It was divided into four steps. 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 grinding 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 sample from the dry sawdust and other sample with high moisture by adding the suitable amount of water and determine its moisture contents

Third; the bio-filter was constructed to use with grinded green ficus (about 175 g) which put between the double wall of candle (Fig.5)

Fourth step; evaluation 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).

Fig. 5. Ficus leaves in candle

Measurements

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.

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

Exhaust gases

The gas components measured using device "Auto check" model 974/5 SPTC to measure CO_2 and CO of air before and after tests.

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.

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

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.

3. Results and discussions

Moisture content

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

Table (1) The moisture contents of some bio-materials.

biological materials	Moisture content %
Green Leaves of ficus	53
Dry Leaves of ficus	34
Dry sawdust	8
Wet sawdust	42

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. Thus there were 49.23%, 48.24%, 81.6 % and 98.87% respectively after the experiment as shown in table (2). The data 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 of ficus	44.70	49.23
Dry Leaves of ficus	48.17	48.24
Wet sawdust	98.87	81.6
Dry sawdust	98.87	98.87

Influence of using bio-filter on exhaust gases (CO_2 and CO)

Influence of using bio-filter on CO_2

The relationship between the CO_2 ratio which output from the prototype of bio-filter and different absorption times at different moisture content was shown in Fig. (6).At moisture content of 53%: CO_2 ratio were 1.15 , 1.09, 1.06, 1.015 ,and 0.97 at different absorption times of 2, 4, 6, 8 and 10 min. respectively .At moisture content of 34%: CO_2 ratio were 1.19, 1.15, 1.12, 1.09 and 1.04 at different times

of 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 at moisture content of 53%: the CO_2 ratio were decreased from 1.15 to 0.97 % by increase the operating time from 2 to 10 min respectively. The previous results were due to an increase in the absorption time, which leads to an increase in the bio-filter's ability to absorb a greater amount of CO_2 that present with the exhaust gas which passes through the prototype of the bio-filter.

The best fit curve is the polynomial to describe the effect of residues moisture content (MC) on the CO_2 using ficus leaves bio-filter at different operating times "T". The equations and its coefficients of determination were:

At 34% M.C. $CO_2 = -0.0004(T2) - 0.0137T + 1.216$
R2 = 0.9930

At 53% M.C. $CO_2 = -0.0003(T2) - 0.0257T + 1.195$
$R^2 = 0.9926$

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 $R^2 = 0.9926$.

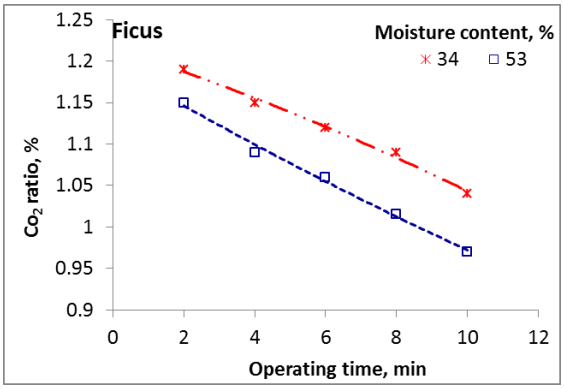


Fig.6: The effect of using the bio-materials (Ficus leaves) on the absorption of carbon dioxide (CO_2)

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. (7).At moisture content of 42 %: CO_2 ratio were decreased of 1.28 %,1.28 1.27%,1.27 % and 1.27 %, at different absorption times 2, 4, 6, 8 and 10 min respectively. At moisture content of 8%: CO ratio was constant at 1.28% with each different absorption times 2, 4, 6, 8 and 10 min. respectively. From previous results it noted that the increase in the proportion of absorbing CO_2 was slightly with sawdust wet.

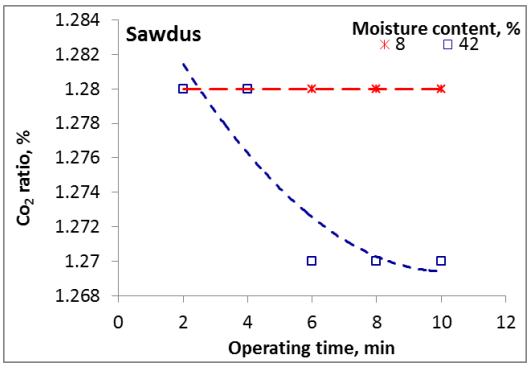


Fig. 7: The effect of using the bio materials (sawdust) on the absorption of carbon-dioxide (CO_2).

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 min respectively.

At moisture content 34%: Co ratio was constant at 1.72% with different obsorbation times 2, 4, 6, 8, and 10 min respectively .

The moisture content of sawdust was 8% and 42%. The relationship between the Co_2 ratio which output from the prototype of bio-filter and different absorption times at different moisture content.

At moisture content of 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 of 8%: Co ratio was constant at 1.28% with increasing the absorption times increased from 2 to 10 min respectively.2, 4, 6, 8 and 10 min. respectively.

4. Conclusions

The research concluded that using the bio-filter filled with green leaves 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 leaves CO_2 decreased 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 final conclusion was the ficus green leaves is the best bio-materials used with bio-filter.

5. Revision the punctuation as the first citation

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