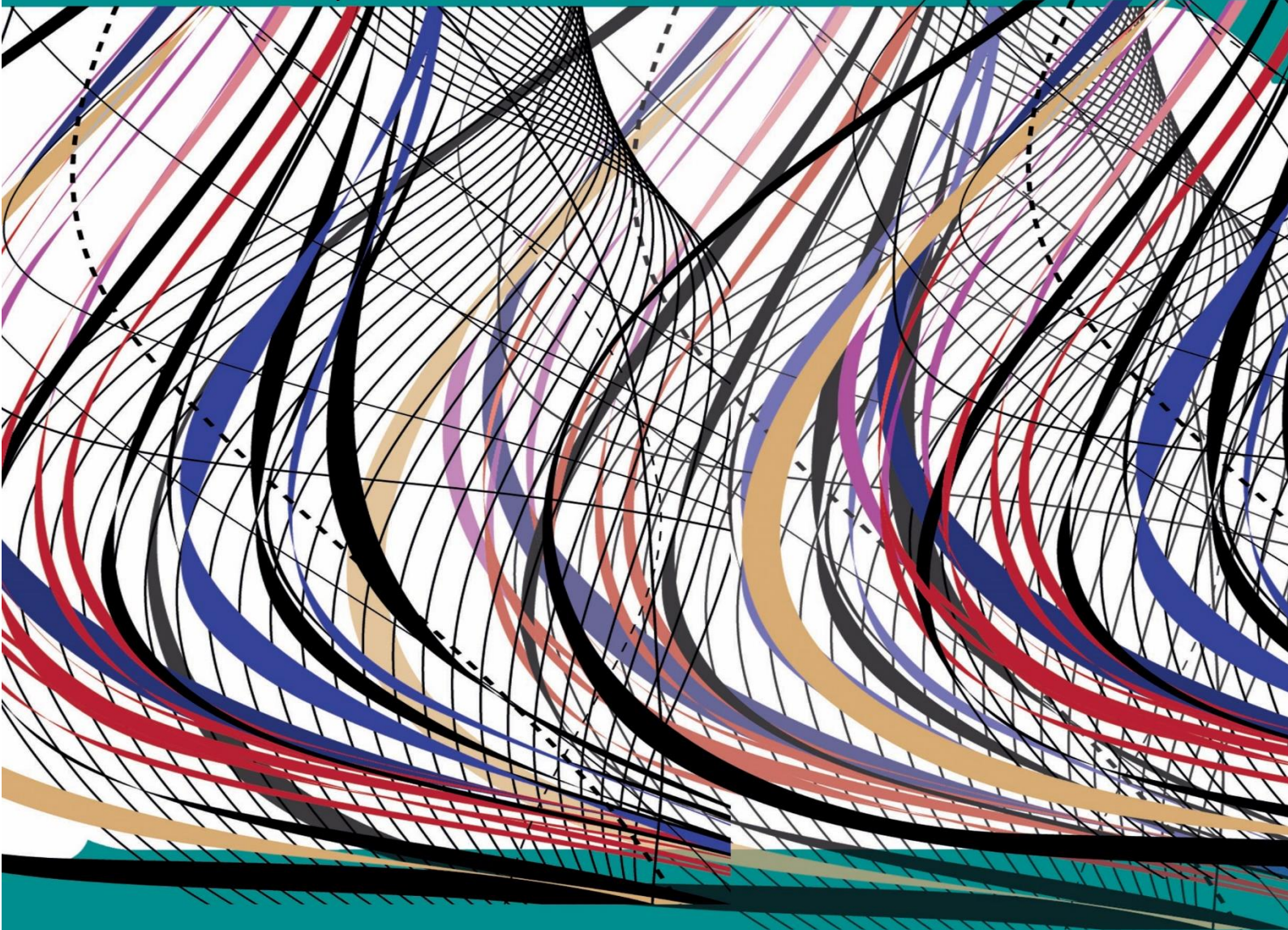


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# FOREWORD

I am pleased to put into the hands of readers Volume-6; Issue-11: Nov, 2020 of “**International Journal of Advanced Engineering, Management and Science (IJAEMS) (ISSN: 2354-1311)**”, an international journal which publishes peer reviewed quality research papers on a wide variety of topics related to Science, Technology, Management and Humanities. Looking to the keen interest shown by the authors and readers, the editorial board has decided to release print issue also, but this decision the journal issue will be available in various library also in print and online version. This will motivate authors for quick publication of their research papers. Even with these changes our objective remains the same, that is, to encourage young researchers and academicians to think innovatively and share their research findings with others for the betterment of mankind. This journal has DOI (Digital Object Identifier) also, this will improve citation of research papers.

I thank all the authors of the research papers for contributing their scholarly articles. Despite many challenges, the entire editorial board has worked tirelessly and helped me to bring out this issue of the journal well in time. They all deserve my heartfelt thanks.

Finally, I hope the readers will make good use of this valuable research material and continue to contribute their research finding for publication in this journal. Constructive comments and suggestions from our readers are welcome for further improvement of the quality and usefulness of the journal.

With warm regards.

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# Thermal regeneration of activated carbon saturated with nitrate ions from an artisanal furnace

Horo Koné<sup>1</sup>, Konan Edmond Kouassi<sup>2</sup>, Affoué Tindo Sylvie Konan<sup>1</sup>, Kopoin Adoubi<sup>1</sup>, Kouassi Benjamin Yao<sup>1</sup>

<sup>1</sup>Laboratoire des Procédés Industriels, de Synthèse de l'Environnement et des Energies Nouvelles (LAPISEN); Institut National Polytechnique Houphouët-Boigny, BP 1313 Yamoussoukro, Côte d'Ivoire

<sup>2</sup>Laboratoire de Thermodynamique et de Physico-Chimie du Milieu (LTPCM), UFR-SFA, Université Nangui-Abrégua, 02 BP 801 Abidjan 01, Côte d'Ivoire

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**Abstract**— The present study was initiated to help the simple and less expensive regeneration of activated carbons after saturation in rural area. In order to determine a regeneration time and the number of regeneration cycles, an adsorption test was necessary. Thus, 3h and 4 cycles of carbon regeneration are obtained after evaluation of the performance, percentage and adsorption capacity after each cycle. Regeneration percentages of 71.29, 54.05, 40.40, 28.06 % and 72.6, 69.84, 64.33, 34.98 % for respective concentrations of  $30 \pm 1.2$  mg/L and  $55 \pm 1.6$  mg/L are observed. Also, the performances of activated carbon 8.5, 10, 12, 20 g/L and capacities 24.04, 19.93, 14.9 and 10.35 mg/g 35.7, 34.12, 31.43 and 17.09 mg/g respectively for dry season and rainy season were necessary to fix the number of cycles. The artisanal furnace with its ease of installation and its maximum temperature of  $500 \pm 2^\circ\text{C}$  is suitable for the regeneration of saturated activated carbon.

**Keywords**— Regeneration, saturated activated carbon, artisanal furnace.

## I. INTRODUCTION

Sustainable development necessarily involves recycling everything we use in order to guarantee the life for future generations. It is in this perspective that researchers have taken an interest in the regeneration of activated carbon in order to protect what the forerunners used in their productions. Several regeneration methods are available. It can be extractive using a volatile organic solvent [1], a fluid such as  $\text{CO}_2$  [2] or concentrated solutions of surfactants [3], to extract the pollutants from the activated carbon. However, its implementation remains costly even if this opinion is not unanimous. Indeed, some estimates consider it much cheaper than thermal regeneration [4,5]. Regeneration can be done in the same way by vapour desorption with the use of temperatures between 105 and 140 °C [6] to just shift the adsorption equilibrium. Like the first mentioned, it is limited for

activated carbons having adsorbed volatile compounds. In addition to the two methods, thermal regeneration, which is the most common method, perfectly regenerates the activated carbon [7]. [8] reported percentages of 92-95% and 96-98% regeneration for carbons regenerated at 500°C. In addition, this method leads to a mass loss of coal in the order of 7-10%, and can reduce the porosity of the adsorbent [9]. Also, certain bacteria and enzymes are involved in the regeneration of activated carbons. In this way, bacteria or micro-organisms that can degrade the pollutant are brought into contact with the carbon [5]. This method is limited in the presence of poorly biodegradable pollutants or when concentration levels reach the inhibition or toxicity threshold [10]. Electrolytes can be used for electrochemical regeneration. [11] and [12] have used NaCl,  $\text{Na}_2\text{SO}_4$  or  $\text{NaHCO}_3$  as electrolytes, respectively. [13] in using the electrochemical route, have reported a regeneration percentage ranging from 70 to 90%

using diclofenac. However, [5] noted that the choice of NaCl electrolyte gives better results but remains limited due to the production of toxic organochlorine compounds generated. Overall, all of these methods are expensive. Indeed, [13] reported a total consumption of 3.80 kWh kgGAC-1 during the chemical regeneration of coal. In view of the additional costs associated with coal regeneration, an adaptation of one of the methods in rural areas is the objective of this study. The originality of this work lies in the use of an artisanal furnace especially for the regeneration of activated carbon saturated. Indeed, most research is focused on the production of activated carbon at lower cost in rural areas but few studies have focused on simplified and practicable regeneration in rural areas. Thus, the thermal regeneration method will be applied and the electric furnace will be replaced by a small-scale furnace that is easily feasible in rural areas.

## II. METHODOLOGY

### 2.1 Presentation of the artisanal oven

The artisanal furnace was built on the northern site of the INP-HB (Figure 4). Several materials were used in its construction. The main materials were clay, banco bricks and a metal skeleton Fig. 1A. Unlike the modern kiln the artisanal furnace was built around two chambers. The feed chamber, rectangular in shape and with a volume of 15000 cm<sup>3</sup>, was created to facilitate the supply of firewood to the kiln, which was the source of energy to operate it. As for the pyrolysis chamber in conical form and with a volume of 100480 cm<sup>3</sup>, it received the material to be carbonized. The two chambers were separated by a metal plate. In order to obtain hermetic conditions during carbonization Fig. 1B, the pyrolysis chamber was equipped with a closure.

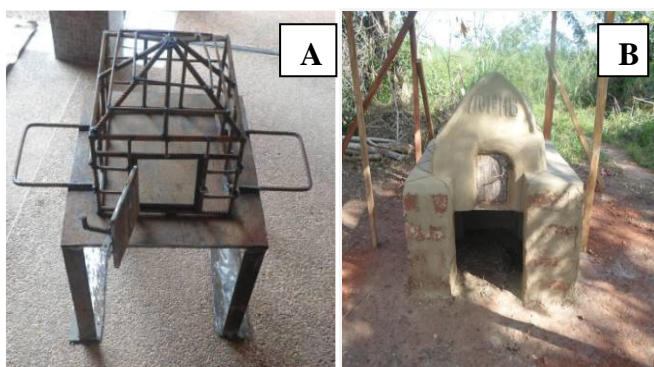


Fig. 1: Skeleton of the traditional oven (A) and the traditional oven (B)

### 2.2 Temperature evaluation

First, the oven temperatures were determined using a thermometer in time steps of 30min to 210 min. Then, from 210 min the time steps were varied from 15 min to 255 min or it became 20 min. Finally, the maximum temperature of the oven was determined by constructing the temperature versus time diagram.

### 2.3 Characterization of raw *Borassus aethiopum* activated carbon (BA-AC)

#### 2.3.1 Mineralogical composition

The mineralogical composition of the BA-AC concerned the level of carbon, nitrogen and hydrogen. This was concerned C, H, and N in solid Biocombustibles. As the BA-AC were not pre-dried, the moisture content was determined and calculations were made on the gross basis of the expressions below.

$$C_{\text{sec}} = C_{\text{brut}} \times 100 / (100 - T_{\text{hum}})$$

$$N_{\text{sec}} = N_{\text{brut}} \times 100 / (100 - T_{\text{hum}})$$

$$H_{\text{sec}} = (H_{\text{brut}} - 0,1119 \times T_{\text{hum}}) \times 100 / (100 - T_{\text{hum}})$$

Whith C is Carbon content, N indicate Nitrogen content, H the Hydrogen content and  $T_{\text{hum}}$  represent moisture content of the sample

For the percentage of oxygen contained in *Borassus aethiopum* activated carbon was evaluated according to the Equation 1 [14].

$$\%O = 100 - \%C - \%N - \%ash \quad (1)$$

#### 2.3.2. Determination of BA-AC texture

The textural determination of carbon led to the Nitrogen adsorption experiment at a temperature of 77K to 25 °C. To do this, a BET meter was used (Quantachrome Novamix version 11.03). Considering an initial pressure  $p_0$ , increasing pressure values were applied which allowed the corresponding equilibrium pressure  $p$  to be determined. At each applied pressure value, a volume  $V$  of gas was adsorbed. The adsorption isotherm was obtained by constructing the function  $V(\text{ads}) = f(p/p_0)$ .

Where  $V(\text{ads})$  was the volume of gas adsorbed and  $p/p_0$  the ratio of the pressure

Considering the adsorption isotherms, the BET surface area was calculated using the equation 2

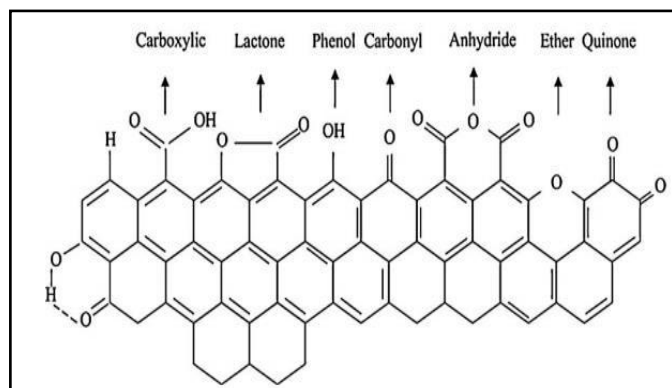
$$S_{\text{BET}} = \frac{V_m \times N_A \times a_m}{m \times V_M} \quad (2)$$

Where  $S_{\text{BET}}$  is the specific surface area (m<sup>2</sup>/g),  $N$  (A) is the Avogadro number,  $a_m$  indicates the surface area occupied by the N<sub>2</sub> molecule (0.1627 nm<sup>2</sup>/molecule of nitrogen),  $m$  is the mass of the sample (g) and  $V_M$  is the molar volume of N<sub>2</sub> at TPN (22414 cm<sup>3</sup>/mole).



### 2.3.3 Activated carbon surface chemistry

The chemical functions on the surface of the coal were determined using infrared spectroscopy to obtain the spectrum shown in Fig. 3. Referring to the different functional groupings on the coal surface a structure with acidic groupings was proposed by [15] (Fig. 2). Based on



this structure, the BA-AC structure has been proposed [15].

Fig. 2 : Fonction acide à la surface du charbon

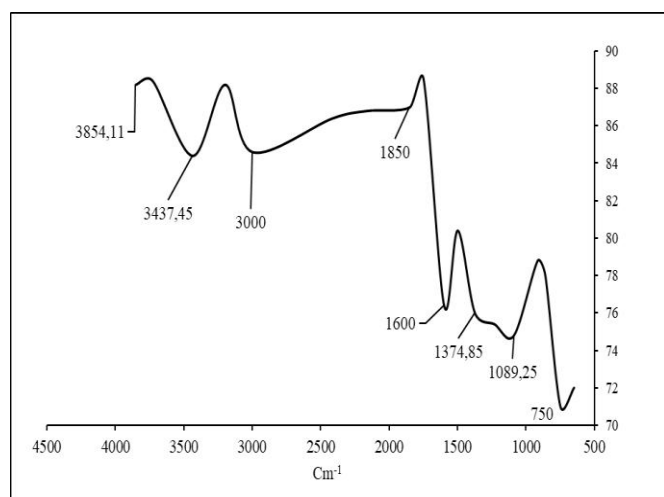


Fig. 3: Fourier infrared spectrum to be transformed

### 2.3.4 pH at zero load point

The pH at zero load was determined using the following methodology. First, 10 Erlenmeyer flasks containing 50 mL of distilled water were selected. Then, initial pH values (pHi) ranging from 2 to 12 were selected after adjustment with hydrogen chloride (0.1M) or sodium hydroxide (0.1M) solutions. To each Erlenmeyer flask, 50 mg of activated carbon was added. Then the whole was stirred for 24 h at room temperature. Finally, the new pH values were determined after 24 hours of stirring. The pH of zero charge was obtained when pHi= pHf (Konan et al., 2019).

### 2.4 Determining the regeneration time

The regeneration time required for saturated carbon was tested in the laboratory. First, 300 g of saturated activated carbon with nitrate ions was divided into 5 samples of 60 g. Then, each 60 g sample placed in a hermetically sealed container was heated in the oven at  $500 \pm 1.15$  °C for times ranging from 1h to 5h. Finally, each sample formed a column that allowed a nitrate adsorption test to be performed on two samples with different concentrations of  $30 \pm 1.2$  mg/L and  $55 \pm 1.6$  mg/L determined previously in raw lakes water respectively in dry season and rainy season. The adsorption capacities and performances of the different regenerated carbons were determined according to equations 3 and 4, respectively [16].

$$N_0 = \frac{A_i}{m} \int_0^{V_a} \left(1 - \frac{A_t}{A_0}\right) dv \quad (3)$$

$$ARE = \frac{\text{Masse of adsorbent(g)}}{V_b(L)} \quad (4)$$

Where  $N_0$  is adsorption capacities,  $V_b$  is the volume of water treated before the breakthrough point and AER is adsorbent exhaustion rate.

### 2.5 Number of regeneration cycles

Since activated carbon regeneration is not eternal, the number of regeneration cycles was further tested in laboratory. The carbon was regenerated by applying the conditions of the column that gave the best adsorption capacity when determining the regeneration time. A total of four regeneration cycles (R1, R2, R3 and R4) were carried out. The different adsorption capacities and performance of the columns after each regeneration were determined according to equations 3 and 4.

### 2.6 Evaluation of the regeneration percentage

The following method has been adopted. First, the adsorption capacity of the raw activated carbon was determined. Then the adsorption capacity of the regenerated carbon was determined. Finally, the regeneration percentages were calculated according to equation (5) [13,17].

$$\%RE = \frac{q_r}{q_c} \times 100 \quad (5)$$

where %RE is the percentage of regeneration,  $q_r$  is the adsorption capacity of the regenerated carbon and  $q_c$  is the adsorption capacity of the raw activated carbon.

### 2.7 Evaluation of carbon loss after regeneration

First, 50 g of coal was weighed and then placed in a container with a mass  $m_0$ . The container was then placed in an artisanal furnace at a temperature of  $500 \pm 1.15$  °C.

Finally, after 3 hours of regeneration, the container was removed and weighed with its contents. The loss of carbon was calculated according to equation (6).

$$\%P = \frac{m_i - m_f}{m_i} \times 100 \quad (6)$$

### 2.8 Study of column breakthrough after regeneration

The regenerated charcoal was tested by continuous adsorption of a raw lake water. Two nitrate concentrations were used ( $C_0=30 \pm 1.2$  mg/L;  $C_0=55 \pm 1.6$  mg/L). This water was used on the one hand to determine the regeneration time and on the other hand to determine the number of regeneration cycles. The logistic model indicated by equation (7) was used to determine the volumes treated at the breakthrough point  $t_{50}$ .

$$\ln\left(\frac{C_t}{C_0 - C_t}\right) = k(t - t_{50}) \quad (7)$$

With  $C_0$ : Initial concentration;  $C_t$ : concentration at a given instant and  $t_{50}$  the breakthrough time

### 2.9 Testing activated carbon on lake water to remove turbidity after regeneration

Filters were designed and then combined in series of 3, 6 and 9. All filters in a series were identical. Their characteristics are shown in Table 1 and fig. 4. The filters were mounted on a device installed at Lac Dougba in Ivory coast to conduct the tests on recycled activated carbon. For each series of columns turbidity elimination tests in the lake water were carried out after each regeneration over two dry season.

Table. 1: Filter characteristics

Characteristics	Dimensions
Outside diameter	22,5 cm
Inner diameter	20cm
Height	44.7 cm
Empty column volume	14035,8 cm <sup>3</sup>
Volume of coarse sand	1884 cm <sup>3</sup>
Volume of coal	7850 cm <sup>3</sup>
Volume of fine sand	1256 cm <sup>3</sup>

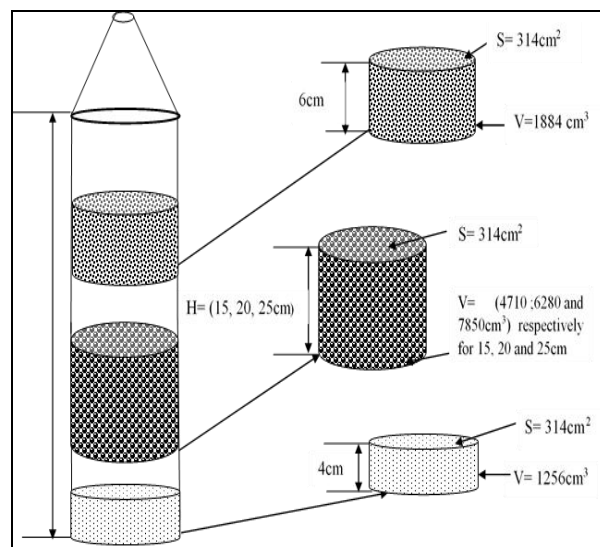


Fig. 4: Colonne test for turbidity removal

## III. RESULTS

### 3.1 Assessment of artisanal oven temperature

From Fig. 5, it can be seen that the heating temperatures of the furnace vary over time. When the furnace is fed, it gradually heats up and then reaches its maximum temperature of 500.67 °C, which remains constant for 30 min, regardless of the feed supplied to the furnace. Like the heating, the cooling of the furnace is gradual. In view of the maximum temperature obtained, this furnace can be used for the regeneration of certain saturated activated carbons. Indeed, compared to the studies of [8,18], this furnace can be used for the regeneration of some saturated activated carbons, which respectively varied the temperatures from 250 to 450 °C and 20 to 600 °C from modern furnaces in order to remove the dyes adsorbed by the coal, the artisanal furnace could replace the modern furnace. It will be limited only if the absorbed pollutant requires a destruction temperature higher than the maximum temperature of 500 °C.

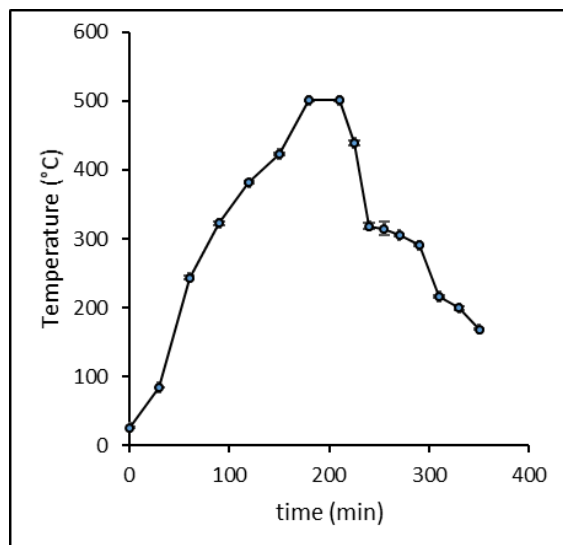


Fig. 5: Determination of the temperature of the artisanal furnace in operation

### 3.2 Some characteristics of raw BA-AC

#### 3.2.1. Elemental composition of activated carbon

The elemental analysis of the activated charcoal prepared in a traditional oven was carried out taking into account four compounds (table 3). These were carbon, nitrogen, hydrogen and oxygen. Indeed, this analysis reveals that the carbon is made up of 74 % carbon, 2.77 % hydrogen, 0.69 % nitrogen and 19.48 % oxygen. However, the percentage of 74 % carbon obtained shows that the roast wood is rich in carbon and suitable for the production of quality activated carbon [18]. This carbon percentage falls well within the range [50; 90 %] recognized by [19,20] as a means of judging the quality of a plant to produce activated carbon. Indeed, these authors believe that the carbon content of a plant must be in the range [50; 90 %] for it to be eligible for the production of activated carbon. In addition, this percentage is well above those found by [14] which are 33.48 % and 37.43 % respectively for peanut shells and coconut shells. The branches of *Borassus aethiopum* (BA) are therefore suitable for the production of quality activated carbon.

Table. 2: Elemental composition of *Borassus aethiopum* activated carbon

Elements	Percentage (%)
N	0.69
C	74
H	2.77
O	19.48

#### 3.2.2 Pore distribution and BET surface

Raw activated carbon before saturation and saturated activated carbon were characterized. The characteristics are listed in the table 3 below. Analysis of the table shows that the specific surface area of coal decreases when it is saturated. Indeed, the specific surface area of 1431.61 m<sup>2</sup>/g has increased to 83.58m<sup>2</sup>/g after saturation. This decrease is simply due to the closure of the pores of the carbon by the adsorbed pollutants. This finding is consistent with that of [8]. These authors found that after saturation of the carbon by BB9, the specific surface area decreased from 1131 m<sup>2</sup>/g to 679 m<sup>2</sup>/g. However, the saturated activated carbon is still microporous with an ash content of 12.58 % and a pHzc of 5.46. This high ash content could be linked to the deterioration of part of the carbon following the high temperature applied to calcine the pollutants adsorbed by the activated carbon. Also, the increase of the pHzc could be induced by the ashes of the pollutants calcined during regeneration. In addition, the ash of the regenerated carbon is a mixture of part of the activated carbon and the adsorbed pollutants. This finding on the transformation of part of the carbon into ash corroborates [21] assertion. He showed that regeneration makes the carbon friable due to the regeneration temperature which degrades part of the carbon into ash. The curves of adsorption/desorption of N<sub>2</sub> from raw and regenerated carbon are shown respectively in fig.6 and fig. 7. The shape of the two curves shows that the regenerated activated carbon is always microporous and mesoporous if we stick to the classification of IUPAC which is type IV.

Table. 3: Characteristics of the raw activated carbon before saturation

Parameters	BA-AC values	BA-AC regeneration values
SBET(m <sup>2</sup> /g)	1431.61	83.58
SEX(m <sup>2</sup> /g)	1432	85
Vp(nm)	1.85	1.849
Vt(nm)	0.971	4.844
Vmicr(nm)	0.279	0.199
Ash%	2.89	12.58
pHzc	5	5.46

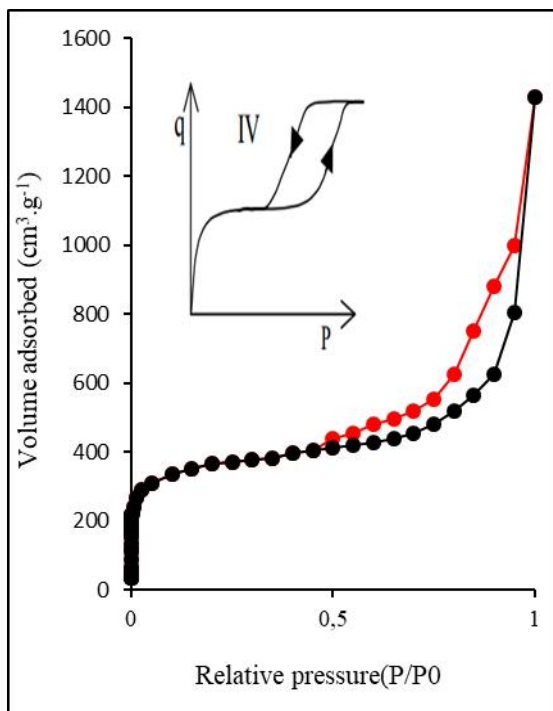


Fig. 6: Adsorption and desorption curve of raw BA-BC

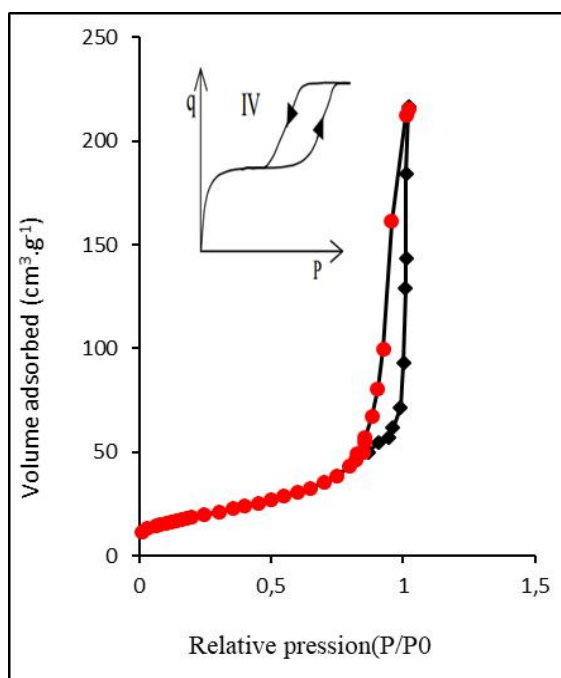


Fig.7: Adsorption and desorption curve of saturated activated carbon from BA-BC

### 3.2.3 BA-AC chemical surface

The analysis of the infrared spectrum provided the information shown in table 1. Borassus aethiopum activated carbon (BA-AC) contains O-H functional groups corresponding to the  $723\text{cm}^{-1}$  and  $750\text{cm}^{-1}$  elongation

vibrations. So, referring to the claims of [22-23], the possible chemical compounds would be the aromatic compounds. As for the C-H functional group, it appeared at wavelengths  $1200\text{ cm}^{-1}$  and  $3000\text{ cm}^{-1}$ . Then in agreement with [15-24], the possible chemical compounds are quinones. Also, chemical compounds such as carboxylic acids and esters are present. This presence is deduced from the presence of C=O functional groups detected at  $1300$ ,  $3500\text{-}4000\text{ cm}^{-1}$  and  $1600\text{-}1800\text{ cm}^{-1}$  elongation vibrations in agreement with [15-25]. Finally, at intervals of  $1330\text{-}1530\text{ cm}^{-1}$  and  $1000\text{-}1220\text{ cm}^{-1}$  indicating the presence of N-H and C-OH functional groups respectively. Thus, according to [15], nitro groups and phenolic groups are present. All functional groups detected are summaries in table 3. Referring to the structure proposed by [15] and the functional groupings found on the surface of the BA-AC, a possible structure of the BA-AC is proposed Fig. 8.

Table. 4: Functional groups and chemical compounds

Elongation vibrations (cm-1)	Functional groupings	Possible chemical compounds
723, 750	O-H	Aromatic compounds
1200 ; 3000	C-H	Quinones
1300 ; 3500-4000	C=O	Esters
1600-1800 ;	C=O	Carboxylic acids
1330-1530	N-H	Nitro group
1000-1220	C-OH	Phenolic groups

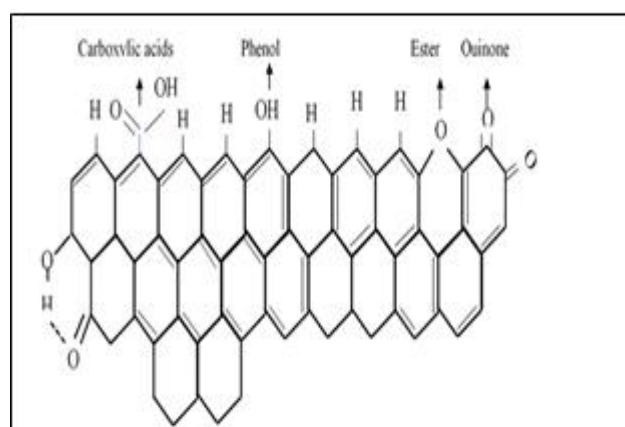


Fig. 8: possible structure of BA-AC with acids groups



### 3.2.4 Crystalline form of activated carbon

The Raman spectrum fig. 9 is used to determine the degree of crystallization of the material. In general, two peaks D and G appear on the Raman spectrum. The G peak, which expresses the graphite content, and the D peak, which expresses the diamond content, appear respectively at wavelengths between  $1350\text{--}1355\text{ cm}^{-1}$  and  $1570\text{--}1585\text{ cm}^{-1}$  [26]. According to [26-27] it is possible to know the textural property of a coal by making the  $I_D/I_G$  ratio. In this study, the Raman spectrum shown in Figure 2 has two peaks. The first peak D appeared at wavelength  $1348.99\text{ cm}^{-1}$  with intensity 8566.19 a.u. and the second peak appeared at wavelength  $1591.21\text{ cm}^{-1}$  with intensity 9342.15 a.u. By determining the coefficient of the  $I_D/I_G$  ratio the value of 0.917 is obtained. According to [28,29] a high  $I_D/I_G$  ratio value implies an organized male carbon structure and a defective activated carbon. Then according to [26] which obtained  $I_D/I_G$  ratios ranging from 0.55 to 0.70, *Borassus aethiopum* carbon has high graphitization [30-31]. Also, the G peak obtained at the wavelength of  $1591.27\text{ cm}^{-1}$  as noted by [32], the coal has an ordered structure.

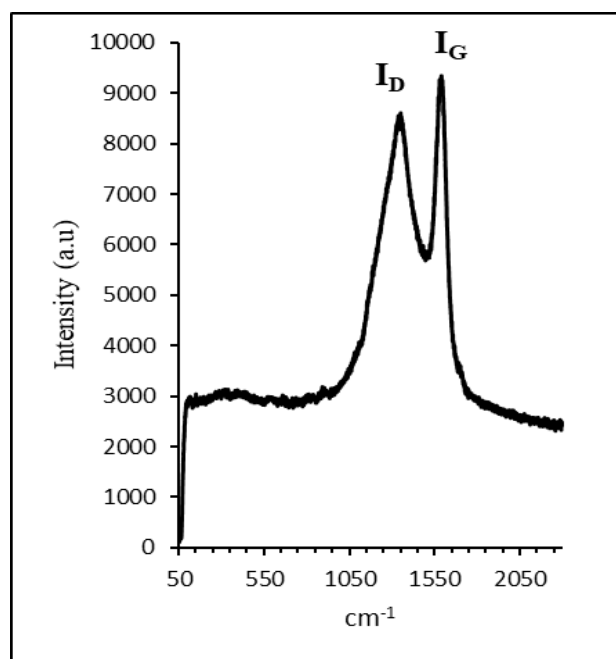


Fig. 9: Raman spectrum of BA-AC

### 3.2.5. Diffraction du charbon actif BA-AC

The diffraction of *Borassus aethiopum* carbon activated with copper sulfate resulted in Fig. 10. Observing the diffractogram, one finds  $\text{Cu}_{1.8}\text{S}$  digenite and tenorite ( $\text{CuO}$ ). The presence of these two elements in the coal makes it possible to understand that, despite the fact that the washing water of the coal gave zero values to

the atomic absorption spectrometer, copper is present in the coal. The presence of digenite and tenorite are related to the copper present in the copper sulphate solution used to impregnate the activated carbon. Indeed, during activation the heated copper gives tenorite ( $\text{CuO}$ ) of which digenite ( $\text{Cu}_{1.8}\text{S}$ ) is the intermediate step. This finding corroborates that of [33] who obtained copper oxide ( $\text{CuO}$ ) nanostructures by heating metallic copper.

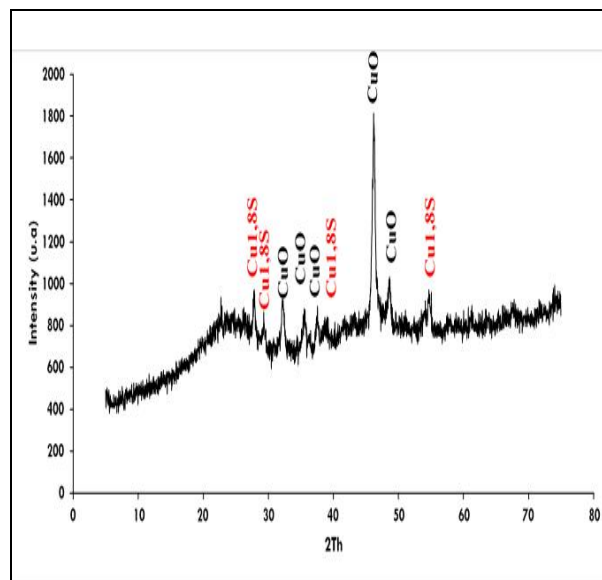


Fig. 10: Spectre of BA-AC XRD

### 3. 3 Regeneration time

In order to retain the residence time required for BA-AC in the furnace in order to acquire a good part of its adsorbent power the fig. 11 A and Fig. 11 B are obtained. To ensure the effectiveness of regeneration, a nitrate adsorption test in synthetic solution was used to determine the adsorption capacities and performance of the regenerated activated carbon at different times. As mentioned [16], between two activated carbons, the best performing one has the lowest AER value. Therefore, by comparing the adsorbent exhaustion rate (AER) 20, 12, 8.5, 12 and 15 of the carbons at the respective regeneration times of 1h, 2h, 3h, 4h and 5h, and the different adsorption capacities, 3h was selected. Figure 11 A shows that the AERs decreased steadily with increasing time to reach a minimum of  $8.57\text{ g/L}$  from three hours' regeneration time before gradually increasing to reach  $15\text{ g/L}$  at a regeneration time of 5h. Also, the adsorption capacities which are  $8.56$ ,  $15.6$ ,  $19.15$ ,  $14.83$  and  $10.53\text{ mg/g}$  for  $C_0=30\pm 1.2\text{ mg/L}$  as initial concentration and  $20.43$ ,  $32.05$ ,  $35.47$ ,  $27.06$  and  $23.95\text{ mg/g}$  for  $C_0=55\pm 1.6\text{ mg/L}$  corresponding respectively to times 1, 2, 3, 4, and 5 h. In view of the AER and adsorption capacities which are

better at the 3h regeneration time, this time was chosen as the appropriate time for the whole study.

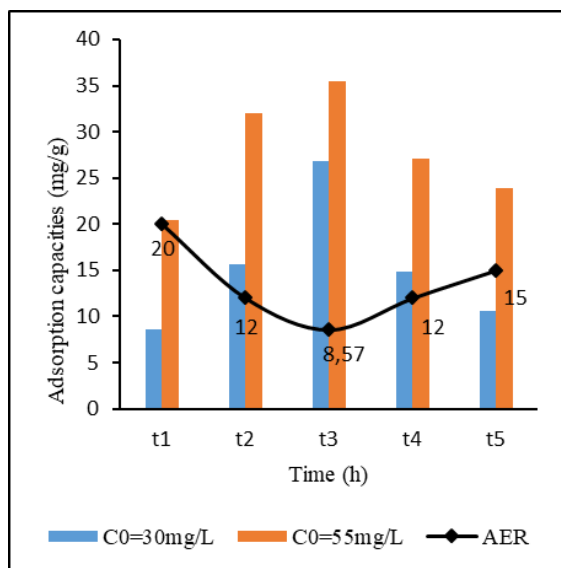


Fig. 11A: Comparative development of each AER adsorption capacities during the determination of the regeneration time

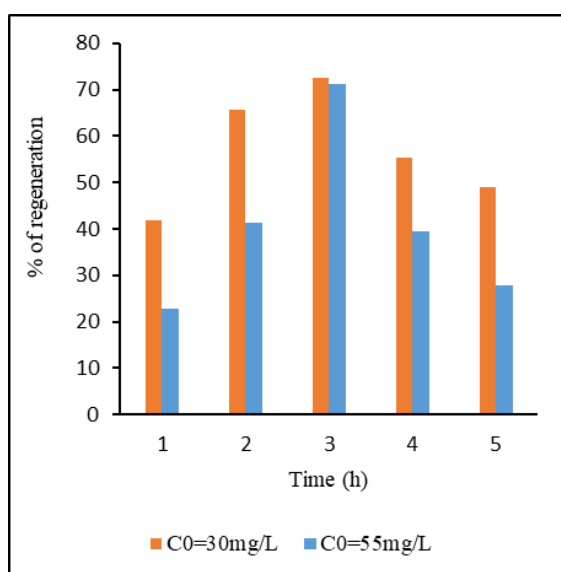


Fig. 11B: Comparative regeneration percentage during the determination of the regeneration time during the determination of the regeneration time

### 3.4 Number of regeneration cycles

Table 5A and table 5B show the evolution of the adsorption capacities and the AERs obtained after each regeneration cycle and figs (12A and 12B) show respectively the regeneration adsorptions capacities and regeneration percentages. According to Table V and Figure 9 the adsorbent exhaustion rate (AER) increase while the adsorption capacities gradually decrease from

the first regeneration cycle to the fourth regeneration cycle. Adsorbent exhaustion rate (AER) values of 8.5, 10, 12 and 20 respectively for regeneration cycles 1,2,3 and 4 were obtained. This loss of performance of the carbon after each regeneration results in a loss of adsorption capacity of 24.04, 19.93, 14.9 and 10.35 mg/g for dry season ( $30 \pm 1.2$  mg/L) and 35.7, 34.12, 31.43 and 17.09 mg/g for rainy season ( $55 \pm 1.6$  mg/L). The table. 4 and figures 13 show that the AER and adsorption capacities are in the opposite order. [16,34] made similar remarks. In addition,[34] reported capacities of 2.9 106 and 3.34 106 for AERs of 2.1 and 1.8 respectively. As for [16], they obtained adsorption capacities of 3.72, 4.64 and 4.79 against EARs of 2.7, 2.1 and 2 respectively. This decrease in capacity was noted by [13]. In addition, [13,21] showed that activated carbon loses its adsorptive capacity during regeneration. Thus, [13] proposed a maximum of 5 regenerations. Activated carbon losses ranged from 9.54 % to 23.58 % in the search for regeneration time. In the phase of determining the number of regeneration cycles, activated carbon losses varied from 8 % to 17.02 %. The general observation is that Activated carbon losses increase with the number of regeneration cycles and the length of residence time. These losses are generally beyond the loss range set by [7] which is 7 to 10 % when using a modern furnace. These losses over the regeneration cycles would be related to the use of an artisanal furnace and to a deterioration of the activated carbon over the regeneration cycles. Indeed, [21] showed that activated carbon becomes more friable more it is regenerated. Therefore, he recommends that the number of regeneration cycles at less than 5.

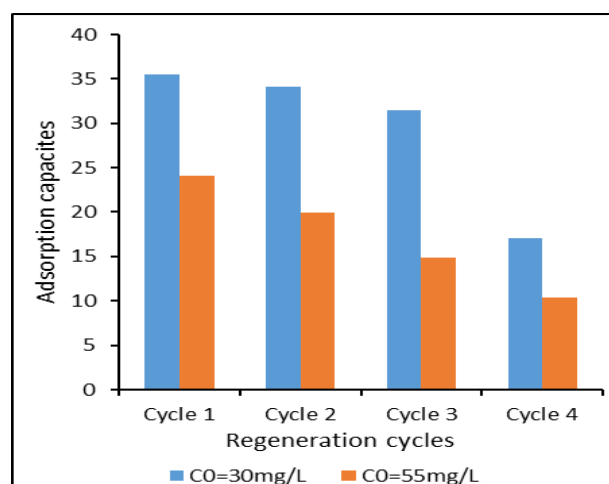


Fig. 12A: Variation of adsorption capacity as a function of regeneration cycles

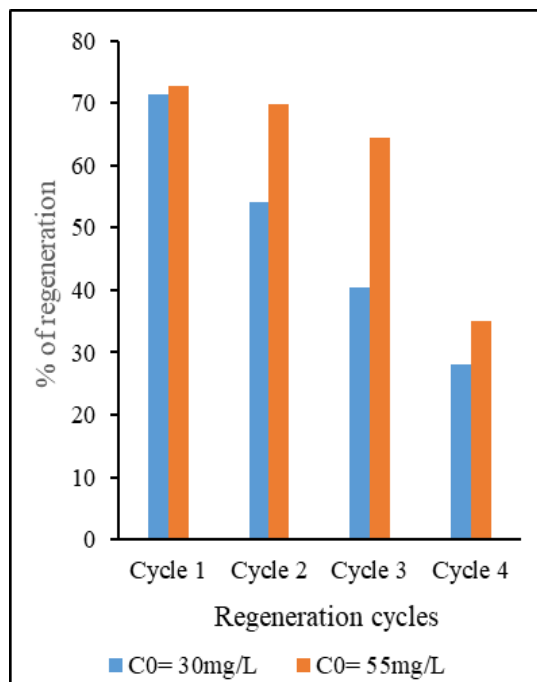


Fig. 12B: Variation of regeneration efficient as a function of regeneration cycles

Table. 5: Characteristics of regeneration times and regeneration cycles (dry season)

$C_0 = 30 \pm 1.2 \text{ mg/L}$			
T(h)	BA-AC Q(mg/g)	Q (mg/g) R	%R
1		8.56	31.87
2		15.6	58.10
3	26.86	19.15	71.29
4		14.83	55.21
5		10.53	39.20
Regeneration cycles			
1		24.04	71.29
2	26.87	19.93	54.05
3		14.9	40.40
4		10.35	28.06

Table. 6: Characteristics of regeneration times and regeneration cycles (rainy season)

$C_0 = 55 \pm 1.6 \text{ mg/L}$				Loss
BA-AC Q(mg/g)	Q (mg/g) R	%R	AER (g/L)	%P
	20.43	41.81	20	9.54
	32.05	65.61	12	13.02
48.86	35.47	72.6	8.5	15
	27.06	55.39	12	22
	23.95	63.81	15	23.58
Regeneration cycles				
	35.47	72.6	8.5	8
48.86	34.12	69.84	10	10.44
	31.43	64.33	12	13.55
	17.09	34.98	20	17.02

### 3. 5 Breakthrough characteristics of the logistic model

Continuous adsorption of nitrate after regeneration gave the characteristics shown in the table5 and breakthrough curve for two different concentrations. For an initial concentration of  $30 \pm 1.2 \text{ mg/L}$ , breakthrough times of 76.11, 67.103, 58.66 and 42.68 min were obtained for cycles 1, 2, 3 and the fourth regeneration cycle, respectively. When initial concentration was  $55 \pm 1.6 \text{ mg/L}$ , breakthrough times 61.51, 56.421, 48.717 and 37.724 min are obtained for regeneration cycles 1, 2, 3 and 4 respectively. This decrease in breakthrough times

over the regeneration cycles reflects a decrease in the adsorbent capacity of the activated carbon. This loss of adsorption power over the regeneration cycles was evoked by [13] through the decrease in the regeneration percentages. In addition, the observation relating to the influence of concentration has attracted the attention of several researchers. [16] obtained breakthrough times of 920 and 484.1 min respectively for concentrations of 10 mg/L and 20 mg/L. Also, [34] obtained breakthrough times of 2479 and 1774 min respectively for initial concentrations of 16000 CFU/mL and 65000 CFU/mL. Similarly, [36] and [37] found that concentration has a negative impact on breakthrough times. Indeed, the breakthrough times 6395.3 min and 2252.7 min are obtained respectively for concentrations of 30 and 50mg/L by [36] during their study relating to the adsorption on fixed column of polycyclic aromatic hydrocarbons contained in wastewater. As for [37], breakthrough times

of 140 and 115 min corresponding respectively to concentrations of 20 and 30 mg/L of hexavalent chromium contained in wastewater.

Table. 7: Logistic parameters

[NO <sub>3</sub> <sup>-</sup> ] ]	Q (mL/min)	Cycles	K	t <sub>50</sub>	V(ml)	R <sup>2</sup>
30± 1.2 mg/L	20	1	0.071	76.11	1400	0.87
		2	0.072	67.10	1200	0.97
		3	0.062	58.66	1000	0.99
		4	0.070	42.68	600	0.99
55± 1.6 mg/L	20	1	0.07	61.51	1200	0.99
		2	0.061	56.42	1000	0.97
		3	0.071	48.72	800	0.99
		4	0.083	37.72	600	0.96

## 2.6 Application of regenerated activated carbon for removing turbidity in lake water

The series of filters used to test the coals after each regeneration (R1, R2, R3, R4) yielded the breakthrough curves in fig. 13, fig. 14 and fig. 15 for the series of 3, 6 and 9 filters respectively. Indeed, during the test, the filter is considered to be pierced if the  $C/C_0=0.1$  which is the ratio of the turbidity at the outlet of the filter to the initial turbidity. Considering the series of 3 filters and the volume of water treated at the point of breakthrough, volumes of 18, 10, 6, 4 and 2 m<sup>3</sup> of water are freed from their turbid state by passing respectively for the raw activated carbon, the first regeneration, the second, third and fourth regeneration. Similarly, with the series of 6 filters, the volumes obtained are 32 m<sup>3</sup> for the raw activated carbon, 28 m<sup>3</sup> for the first regeneration, 16m<sup>3</sup> for the second, 12 m<sup>3</sup> for the third and 6 cm<sup>3</sup> for the fourth regeneration. As for the series of 9 filters, volumes of 72, 42, 36, 30 and 22 m<sup>3</sup> with a turbidity in the filter water of less than 1 NTU starting from the raw activated carbon at the fourth regeneration. In view of these volumes, which decrease with the regeneration of the carbon, this confirms the comments of [21] who believes that the number of regenerations, especially thermal regeneration, should be less than 5. Also, with percentages of 100 % removal of the turbidity obtained, filters with three materials (coarse sand - granular activated carbon - fine sand) are more efficient than filters with a single activated carbon and those made up of two materials (sand and carbon). Indeed, [38] could only obtain 65 % reduction in turbidity with an activated carbon filter alone. As for [39], they were

obtained percentages ranging from 75 to 78 % by associating a layer of sand with carbon.

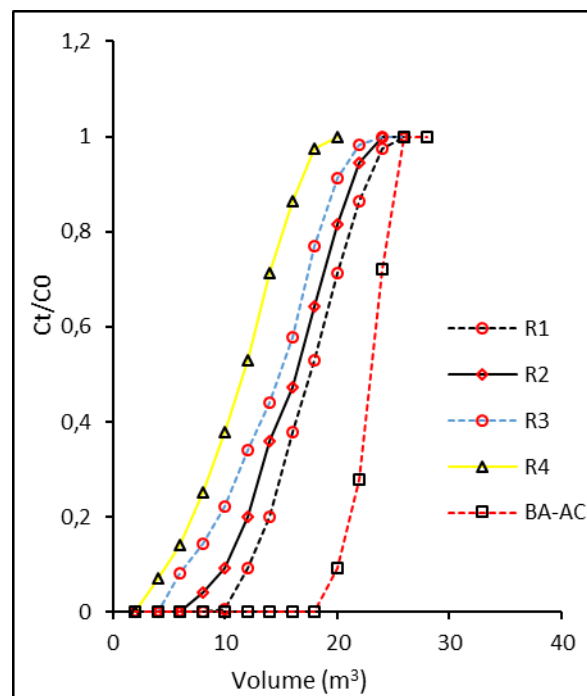


Fig. 13: Breakthrough curves of 9 columns at turbidity removal (turbidity=7,83 NTU ± 0,4; pH 6,49 ± 0,2)

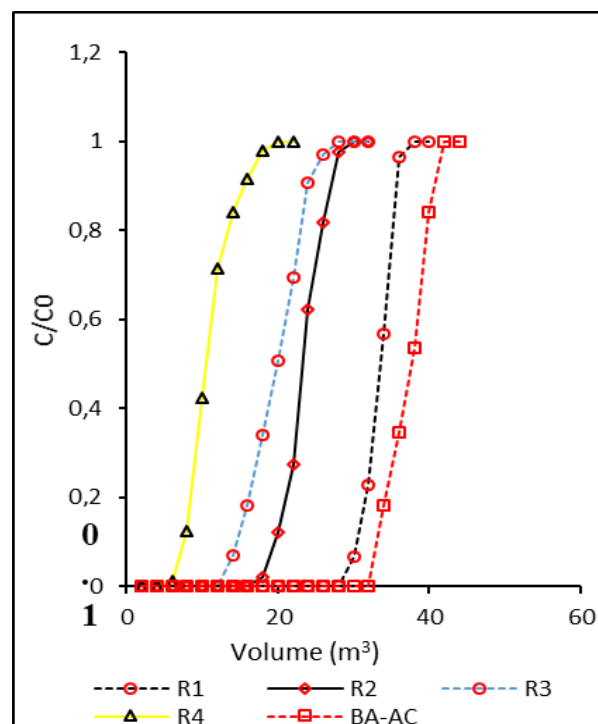


Fig. 14: Breakthrough curves of 6 columns at turbidity removal (7,83 NTU ± 0,4 ; pH 6,49 ± 0,2)



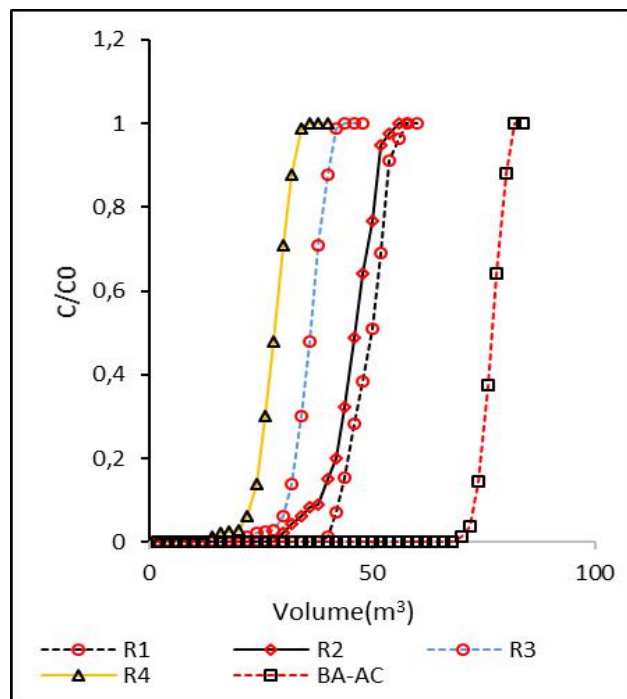


Fig. 15: Breakthrough curves of 9 columns at turbidity removal (turbidity = 7,83 NTU  $\pm$  0,4; pH 6,49  $\pm$  0,2)

#### IV. CONCLUSION

The adsorbent exhaustion rate (AER) 20, 12, 8.5, 12 and 15 g/L of the activated carbon at the respective times of 1h, 2h, 3h, 4h and 5h as well as the adsorption capacities of 8.56, 15.6, 19.15, 14.83 and 10.53 mg/g for  $C_0=30\text{mg/L}$  then 20.43, 32.05, 35.47, 27.06 and 23.95 mg/g for  $C_0=55\text{ mg/L}$  made it possible to fix the time of 3h as the necessary regeneration time. 4 regeneration cycles are obtained after evaluation of AERs 8.5, 10, 12, 20 and adsorption capacities 24.04, 19.93, 14.9 and 10.35 mg/L for dry season (30 mg/L) and 35.7, 34.12, 31.43 and 17.09 mg/L for rainy season (55mg/L). The four columns tested during the regeneration cycles gave breakthrough times 76.11, 67.103, 58.66 and 42.679min for  $C=30\text{mg/L}$  and 61.51, 56.421, 48.717 and 37.724 min for  $C=55\text{mg/L}$  according to the logistic model. In view of the regeneration percentages during the regeneration cycles, which are 71.29, 54.05, 40.40, 28.06 % and 72.6, 69.84, 64.33, 34.98 % respectively for dry season (30 mg/L) and rainy season (55 mg/L), the regeneration cycles deteriorate the quality of the activated carbon if they are prolonged. It can therefore be said that the artisanal furnace is a means of prolonging the use of activated carbon. However, for activated carbon that have adsorbed pollutants requiring high calcination temperatures above 500 °C, the traditional kiln will be inefficient because of its temperature limit of 500 °C.

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#### REFERENCES

- [1] Ferro-Garcia M, Utrera-Hidalgo E, Rivera-Utrilla J, Moreno-Castilla C and Joly J 1993 Regeneration of activated carbons exhausted with chlorophenols *Carbon* **31** 857–63
- [2] Madras G, Erkey C and Akgerman A 1993 Supercritical fluid regeneration of activated carbon loaded with heavy molecular weight organics *Industrial & engineering chemistry research* **32** 1163–8
- [3] Purkait M, Gusain D, DasGupta S and De S 2005 Adsorption behavior of chrysoidine dye on activated charcoal and its regeneration characteristics by using different surfactants *Separation science and technology* **39** 2419–40
- [4] Chihara K, Oomori K, Oono T and Mochizuki Y 1997 Supercritical CO<sub>2</sub> regeneration of activated carbon loaded with organic adsorbates *Water science and technology* **35** 261–8
- [5] Zanella O, Krummenauer Haro N, Cristina Tessaro I and Amaral Féris L 2015 Successive cycles of sorption/regeneration for granular activated carbon in the removal of nitrate ions *Desalination and Water Treatment* **55** 1908–14
- [6] le Cloirec P 2003 *Adsorption en Traitement de l'air* (Ed. Techniques Ingénieur)
- [7] Han X, Loggins V, Zeng Z, Favro L and Thomas R 2004 Mechanical model for the generation of acoustic chaos in sonic infrared imaging *Applied physics letters* **85** 1332–4
- [8] Durán-Jiménez G, Stevens L A, Hodgins G R, Uguna J, Ryan J, Binner E R and Robinson J P 2019 Fast regeneration of activated carbons saturated with textile dyes: Textural, thermal and dielectric characterization *Chemical Engineering Journal* **378** 121774
- [9] Han X, Wishart E and Zheng Y 2014 A comparison of three methods to regenerate activated carbon saturated by diesel fuels *The Canadian Journal of Chemical Engineering* **92** 884–91
- [10] Xiaojian Z, Zhansheng W and Xiasheng G 1991 Simple combination of biodegradation and carbon adsorption—the mechanism of the biological activated carbon process *Water Research* **25** 165–72
- [11] Zhang T, Walawender W P, Fan L, Fan M, Daugaard D and Brown R 2004 Preparation of activated carbon from forest and agricultural residues through CO<sub>2</sub> activation *Chemical Engineering Journal* **105** 53–9
- [12] Narbaitz R M and Cen J 1994 Electrochemical regeneration of granular activated carbon *Water Research* **28** 1771–8
- [13] Solano-Rivera V, Geris J, Granados-Bolaños S, Brenes-Cambronero L, Artavia-Rodríguez G, Sánchez-Murillo R

- and Birkel C 2019 Exploring extreme rainfall impacts on flow and turbidity dynamics in a steep, pristine and tropical volcanic catchment *Catena* **182** 104118
- [14] GUEYE M 2015 *Développement de charbon actif à partir de biomasses lignocellulosiques pour des applications dans le traitement de l'eau* (Institut International de l'Ingénierie de l'Eau et de l'Environnement (2))
- [15] Shafeeyan M S, Daud W M A W, Houshmand A and Shamiri A 2010 A review on surface modification of activated carbon for carbon dioxide adsorption *Journal of Analytical and Applied Pyrolysis* **89** 143–51
- [16] Onyango M S, Leswif T Y, Ochieng A, Kuchar D, Otieno F O and Matsuda H 2009 Breakthrough analysis for water defluoridation using surface-tailored zeolite in a fixed bed column *Industrial & Engineering Chemistry Research* **48** 931–7
- [17] Zhou Y, Davidson T A, Yao X, Zhang Y, Jeppesen E, de Souza J G, Wu H, Shi K and Qin B 2018 How autochthonous dissolved organic matter responds to eutrophication and climate warming: evidence from a cross-continental data analysis and experiments *Earth-Science Reviews* **185** 928–37
- [18] Adinata D, Daud W M A W and Aroua M K 2007 Production of carbon molecular sieves from palm shell based activated carbon by pore sizes modification with benzene for methane selective separation *Fuel processing technology* **88** 599–605
- [19] Daza L, Mendioroz S and Pajares J 1986 Preparation of Rh/active carbon catalysts by adsorption in organic media *Carbon* **24** 33–41
- [20] Danish M and Ahmad T 2018 A review on utilization of wood biomass as a sustainable precursor for activated carbon production and application *Renewable and Sustainable Energy Reviews* **87** 1–21
- [21] LU J 2005 Etude comparative sur les charbons actifs
- [22] Yorgun S and Yildiz D 2015 Slow pyrolysis of paulownia wood: Effects of pyrolysis parameters on product yields and bio-oil characterization *Journal of analytical and applied pyrolysis* **114** 68–78
- [23] Mamaní A, Sardella M F, Giménez M and Deiana C 2019 Highly microporous carbons from olive tree pruning: Optimization of chemical activation conditions *Journal of Environmental Chemical Engineering* **7** 102830
- [24] Sricharoenchaikul V, Pechyen C, Aht-ong D and Atong D 2008 Preparation and characterization of activated carbon from the pyrolysis of physic nut (*Jatropha curcas* L.) waste *Energy & Fuels* **22** 31–7
- [25] Meldrum B J and Rochester C H 1990 In situ infrared study of the surface oxidation of activated carbon dispersed in potassium bromide *Journal of the Chemical Society, Faraday Transactions* **86** 2997–3002
- [26] Sreńscek-Nazzal J and Kielbasa K 2019 Advances in modification of commercial activated carbon for enhancement of CO<sub>2</sub> capture *Applied Surface Science* **494** 137–51
- [27] Wang L, Tian C, Wang B, Wang R, Zhou W and Fu H 2008 Controllable synthesis of graphitic carbon nanostructures from ion-exchange resin-iron complex via solid-state pyrolysis process *Chemical communications* 5411–3
- [28] Cao F, Lian C, Yu J, Yang H and Lin S 2019 Study on the adsorption performance and competitive mechanism for heavy metal contaminants removal using novel multi-pore activated carbons derived from recyclable long-root *Eichhornia crassipes* *Bioresource technology* **276** 211–8
- [29] Ouyang T, Ye Y, Wu C, Xiao K and Liu Z 2019 Heterostructures Composed of N-Doped Carbon Nanotubes Encapsulating Cobalt and  $\beta$ -Mo<sub>2</sub>C Nanoparticles as Bifunctional Electrodes for Water Splitting *Angewandte Chemie International Edition* **58** 4923–8
- [30] Sun H, Liu S, Zhou G, Ang H M, Tadó M O and Wang S 2012 Reduced graphene oxide for catalytic oxidation of aqueous organic pollutants *ACS Applied Materials & Interfaces* **4** 5466–71
- [31] Liu L, Black R E, Cousens S, Mathers C, Lawn J E and Hogan D R 2015 Causes of child death: comparison of MCEE and GBD 2013 estimates *The Lancet* **385** 2461–2
- [32] Li L Y, Gong X and Abida O 2019 Waste-to-resources: Exploratory surface modification of sludge-based activated carbon by nitric acid for heavy metal adsorption *Waste Management* **87** 375–86
- [33] Altaweel A 2014 *Synthèse de nanostructures d'oxyde de cuivre par micro-post-décharge micro-ondes à pression atmosphérique* (France: Université de Lorraine)
- [34] Mthombeni N H, Mpenyana-Monyatsi L, Onyango M S and Momba M N 2012 Breakthrough analysis for water disinfection using silver nanoparticles coated resin beads in fixed-bed column *Journal of hazardous materials* **217** 133–40
- [35] Albayati T M and Kalash K R 2020 Polycyclic aromatic hydrocarbons adsorption from wastewater using different types of prepared mesoporous materials MCM-41 in batch and fixed bed column *Process Safety and Environmental Protection* **133** 124–36
- [36] Singha S and Sarkar U 2015 Analysis of the dynamics of a packed column using semi-empirical models: Case studies with the removal of hexavalent chromium from effluent wastewater *Korean Journal of Chemical Engineering* **32** 20–9
- [37] Sountharajah D P, Loganathan P, Kandasamy J and Vigneswaran S 2016 Column studies on the removal of dissolved organic carbon, turbidity and heavy metals from stormwater using granular activated carbon *Desalination and Water Treatment* **57** 5045–55
- [38] Torres-Lozada P, Amezcua-Marroquín C P, Agudelo-Martínez K D, Ortiz-Benítez N and Martínez-Ducua D S 2018 Evaluation of turbidity and dissolved organic matter removal through double filtration technology with activated carbon *Dyna* **85** 234–9

# Pedagogical Approaches and Techniques of Non-Education Graduates Teaching General Mathematics in the Senior High School

Cherry Rose T. Malgapo<sup>1</sup>, Cristo Mark D. Ancheta<sup>2</sup>

<sup>1</sup>Mathematics Teacher, Aliaga National High School, Nueva Ecija, Philippines

<sup>2</sup>Mathematics Professor, Nueva Ecija University of Science and Technology, Nueva Ecija, Philippines

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**Abstract**— Pedagogical approaches and techniques are common among teachers, but some are more effective and appropriate than others. The study is focused on identifying the basic pedagogical approaches and techniques of Senior High School non-education graduate teachers (SHSNEGT) teaching General Mathematics using the purposive sampling method, the main respondents of the study are 12 SHSNEGT and two experts per school in Aliaga District, Municipality of Aliaga in Nueva Ecija. With the use of concurrent mixed-method research design and data statistical analysis, the results show that teacher-respondents whose age ranges from 25 to 38 are categorized as "young adults and professionals" and 83.33% are female with two years teaching experience in SHS, having BS Degree and specialization related in business courses as well as in their previous work. Using logical/matrix and inductive analysis and weighted mean, the subject matter-centered approach has weighted mean 3.92 and the teacher-centered approach has 3.31 mean and considered dominant and "significantly evident" in teaching General Mathematics. With regards to pedagogical techniques applied by the teachers using weighted mean, "setting of objectives" has the highest weighted mean of 3.44, lesson development has 3.39, application 3.36, evaluation 3.35 and materials being used have 3.28. All items with a verbal description of "outstanding". They set their objectives based on learning competencies with three domains of learning, using board, with motivational activity on lesson development and board-work, group activity, problem sets, and quiz as a means of evaluation. Using ANOVA test analysis, previous work has significant differences in the pedagogical approaches ( $F=10.667$ ,  $sig = .004$ ) but there are no significant differences in terms of techniques ( $F=.510$ ,  $sig=.65$ ). The majority of the teachers are challenged about the attitude and behavior of the students towards learning. To develop productive notions of teaching, teachers must think of appropriate pedagogical approaches and techniques for every topic/lesson.

**Keywords**— General Mathematics, Non-Education Graduate Teachers, Outstanding, Pedagogical Approach, and Techniques, Senior High School.

## I. INTRODUCTION

Pedagogical approaches are common among teachers, but some are more effective and appropriate than others. Effective approaches often depend on particular subject matter to be taught and on understanding the diverse needs of different learners.[1] Teachers' approaches differ in

the level of the student's participation and teachers' teaching techniques are a series of related and progressive acts performed to achieve the objectives of the lesson. An approach gives rise to methods, the way teachers teach by utilizing classroom activities or techniques that educationally help learners.

The pedagogical approach is like a description of how educators ponder about teaching the students. It is a set of principles, beliefs, or ideas about the nature of learning which is applied in the classroom.[2] Teachers always sustain the interest of learners through the use of encouraging questions, set formative assessments, and providing constructive feedback to notice and measure students' improvement. In other words, the teaching approach is the teacher's own personal philosophy of teaching. (Principle of Teaching: Different Methods and Approaches) [3].

There are different approaches that teachers integrate with their teaching and learning process like - teacher-centered, learner-centered, subject-matter centered, teacher dominated, interactive, constructivist, collaborative, direct, indirect, individualistic, research base approach and integrated approach, meta-cognitive approach, and problem-based approach. Some teachers usually use only one teaching approach, but some use a combination of two or more approaches. [4]All these teaching approaches need to have appropriate teaching techniques that the teachers can use to achieve learning goals and objectives.

Effective teaching strategies and approaches, classroom management, and mastery of the subjects are the main focus for the holistic development of the learners. [5]Teachers must recognize individual differences among students and adjust instruction appropriate for them. Educators play varied and vital roles in the classroom and considered as light by the students. As teachers, they are entrusted with so many responsibilities that range from the very simple to most complex and very challenging jobs. They need to understand that they should be motivated in doing their work, so as to have motivated learners in the classroom.

Teachers must recognize the diversity and complexity of the situation in the classroom including the ethnicity, gender, culture, language abilities, and interests of students. Getting students to work and learn in class is largely influenced by all these factors. [6]Classroom diversity exists not only among students but may also be exacerbated by language and cultural differences between teachers and students.

According to Beausaert (2013), the teachers, being the focal figure in education, must be competent and knowledgeable to impart the knowledge they could give to their students. Good teaching is not only a professional matter but also a personal one. [7]

Based on the preceding arguments, it showed that a class would not be a class if the teacher had failed to motivate the learners; there opens the gate of the approaches and techniques the teacher uses to encourage the class to not just learn, but also to absorb every information and ideas then consider those as additional knowledge.

According to the article "Understanding differences in teaching approaches in Higher Education: An Evidence-Based Perspective", published in 2014, the teaching approach refers to the set of principles, beliefs, or ideas about the nature of learning which is applied to the classroom. Teaching technique is a long-term plan of action designed to achieve a particular goal – that is to impart knowledge to the learners that will not only stay at the moment but will be nurtured and instilled in their minds; to create critical thinking individuals and to produce life-long learning skills.[8]

[9]The pedagogical approach has a lot of divisions that suit the needs of both the learners and the teachers. Teaching techniques depend upon the discretion of the teachers themselves on how they are going to apply those approaches and techniques in terms of objective settings, materials to be used, lesson development, application, and evaluation in the sets of lessons. [10]

The Philippine educational system is now in the 7<sup>th</sup> year of implementation of K-12 curriculum however Senior High School is only in its 3<sup>rd</sup> year of implementation, for the advancement in Basic Education legalized by the Republic Act 10533 or the Enhance Basic Education Act of 2013. This law implements the K-12 Program which covers one (1) year in kindergarten, six (6) years in elementary, and six (6) years in secondary education which has four (4) years of junior high school and two (2) years of senior high school education.

Senior High School Teacher refers to a person who meets the minimum requirements whether on a full-time or part-time basis and qualified to practice teaching profession under RA 7836 and/or those performing functions in support of education such as standard-setting, policy, and programs formulation, research, and sector monitoring and evaluation.

Despite the number of years of implementation of the K-12 curriculum the Department of Education continuously hires professionals that most of them non-education graduates because of the demand needs of teachers and their expertise in line with the Senior High



School curriculum that needs to cater to the different tracks/strands offerings. They believe that non-education graduates who previously worked from other industries and business establishments can satisfy the needs in a teaching position.[11]Non-education graduates are accepted to teach in senior high school as long as they meet all the necessary requirements, have successfully undergone the application process for a SHS teaching position, and as long as they come from industries and have fields of specialization like business managers, engineers, nurses, architects, etc. Most of them are given mathematics as teaching loads particularly General Mathematics.

General Mathematics is one of the core subjects in the senior high school curriculum wherein most of the teachers handling this subject are non-education graduates. They are hired because schools are in dire need of teachers.[12]

The researcher decided to conduct this study to determine and identify the basic pedagogical approaches and techniques applied by Senior High School Non-Education Graduate Teachers in teaching General Mathematics with techniques and approaches like teacher-centered, student-center, subject matter-centered, interactive, integrated meta-cognitive, constructivist, problem-based approach.[13] Teachers set their lesson objectives, materials to be used, lesson development, application, and evaluation in selected lessons or topics in general mathematics like simple and compound interest; annuities, propositions and its operations, truth values, and tautology.

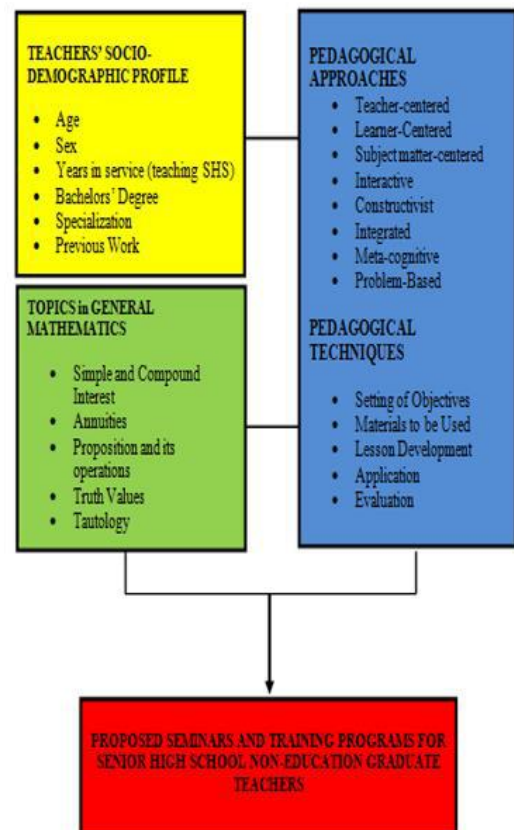
It is with huge hope that this research study can generate significant results.

## II. THEORETICAL/CONCEPTUAL FRAMEWORK

The research study was based on several theories and references that exhibit the vital effects of teaching approaches and techniques toward the learning process of the students in General Mathematics.

This study was anchored on pedagogical theory. Pedagogy is the study of the theory and practice of education. This theory was based on the learning theory of Watson in the early 20<sup>th</sup> century. It is concerned with the underlying values and principles that influence our approaches to learning, teaching, and assessment. It is thus important to think about how we teach, how we deliver the

information to our students that must be delivered. The National College for Teaching and Leadership's paper (2012), nine characteristics of highly successful pedagogies based on their review of the literature. They conclude that effective pedagogies: (1.) give serious consideration to pupil's voice; (2.) depend on behavior (what teachers do), knowledge and understanding (what teachers know) and beliefs (why teachers act as they do); (3.) involve clear thinking about longer-term learning outcomes as well as short-term goals; (4.) build on pupils' prior learning and experience; (5.) involve scaffolding pupil learning; (6.) involve a range of techniques, including whole-class and structured group work, guided learning and individual activity; (7.) focus on developing higher-order thinking and meta-cognition, and make good use of dialogue and questioning in order to do so ; (8.) embed assessment for learning; and (9.) are inclusive and take the diverse needs of a range of learners, as well as matters of student equity, into account.



*Fig.1: The research Paradigm*

And with regards to the concepts of this study, it was based on autonomy concepts of Michael Moore, all teaching-learning process has three components: first, preparation activities, in which objectives and strategies are set; second, application activities, in which information, datum, and ideas are actualized and lastly, evaluation activities, in which a judgment is made on the efficiency of reaching the objectives of teaching processes.

The researcher also modified three to five components anchored on the DepEd Nueva Ecija components in the daily lesson log (DLL) wherein the five components were shown and integrated as teaching approaches and techniques. These are setting of objectives wherein all the objectives are set in three domains of learning, materials to be used lesson development in which pedagogical techniques are applied for the particular topic and application in which pedagogical approaches applied on are known and evaluated.

The preceding statements are products of the various theories where the study was anchored and the researcher's view of the problem being studied.

The above-cited concept guided this study in the teaching approaches and techniques of Senior High School Non-Education Graduate Teachers (SHSNEGT) in teaching general mathematics based on selected lessons/topics listed as least learned in item analysis in previous years. These are simple interest, compound interest, annuities, truth values, and tautology.

The researcher used the IV-DV model or independent variable and dependent variable. The independent variables are teachers' socio-demographic profile in terms of age, sex, years in teaching services, bachelors' degree, specialization, and previous work, and the selected least learned topics in Gen. Mathematics would also be included.

The dependent variables are the pedagogical approaches (teacher-centered, learner-centered, subject-matter centered, interactive, integrated, meta-cognitive, constructivist, and problem-based) and techniques in terms of objectives settings, materials being used, lesson development, application and evaluation of teachers in teaching General Mathematics.

The output of the study was the proposed seminars and training programs for Senior High School Non-Education Graduates teachers.

### III. OBJECTIVES OF THE STUDY

This paper sought to answer the following:

1. What is the socio-demographic profile of teacher-respondents teaching General Mathematics in terms of age, sex, years in service (teaching SHS), bachelor's degree, specialization, and previous work?
2. What are the pedagogical approaches applied by the teacher-respondents in general mathematics lessons: simple interest, compound interest, annuities, truth values, and tautology?
3. How do the pedagogical techniques of teacher-respondents be described in terms of setting of objectives, materials to be used, lesson development, application, and evaluation?
4. How may the pedagogical approaches and techniques applied by the teacher-respondents in teaching selected topics in General Mathematics be compared?
5. Are there significant differences in pedagogical approaches and techniques applied in General Mathematics based on teachers' profiles?

### IV. METHODOLOGY

This study utilized a mixed-method research design, a combination of the qualitative and quantitative design in order to secure a relevant answer to the problem of the study. And in selecting the sample respondents, the researcher used a purposive sampling technique, a total of 12 SHS teachers, 6 school heads, and 6 master teachers were selected as respondents coming from public secondary schools in Congressional District 1, Division of Nueva Ecija. A survey questionnaire, observation tool, and interview questions served as the instrument to gather the needed data and were personally designed, developed, and validated by the researchers. The questionnaire was accompanied by a letter stating the purpose of the survey and personally administered by the researchers. The respondents were briefed on the significance of the survey questions so that the researcher would elicit honest responses from them. And finally, the data gathered will be tabulated and analyzed thru data and statistical tools analysis.

## V. RESULTS AND DISCUSSION

### 1. Socio-Demographic Profile of Teachers

In terms of age, there are two teacher-respondents from each of these ages: 28, 34, 36, 38, and there is only one teacher for each of the following age range 25, 29, 31, and 32. They are all categorized as "young professionals" or "young adults". As to sex, 10 (83.33%) of the teachers are female and 2 (16.67%) are male. With regards to years in service (teaching SHS), five of the teachers have two years with the verbal description "experienced", four of the teachers have three years with verbal description "highly experienced" and three of the teachers have one-year teaching experience considered as "least experienced". On a bachelor's degree, five teachers have a BS Degree related to business degree courses like management, entrepreneurship, marketing, and accounting. Two of the teachers have a BS Degree in the field of Engineering, Computer courses, and in other fields of studies (BS Nursing and AB MassCom). As to specialization, six of the teachers are specialized in business-related industries, two in Mathematics, another two in computer-related works and the remaining two specialized in other fields (computer-related, auditor, none, etc.). Six teachers have previous work in sales/clerical work-related, two teachers are engineers, another two are teachers, and the remaining two previously worked as journalists.

Table 1. Summary of Assessment by Experts (Department Head/Master Teacher/Principal) on the Pedagogical Approaches of Teachers in Teaching General Mathematics

PEDAGOGICAL APPROACHES AND TECHNIQUES	WM	VD
Teacher-Centered Approach	3.31	Significantly Evident
Learner-Centered Approach	1.17	Not Evident
Subject Matter Centered Approach	3.92	Significantly Evident
Interactive Approach	1.19	Not Evident
Constructivist	1.19	Not Evident
Integrated Approach	2.00	Insignificantly Evident
Metacognitive Approach	3.00	Evident
Problem-Based Approach	2.04	Insignificantly Evident

### 2. Pedagogical Approaches and Techniques

Table 1, shows the summary of assessments by experts (Department Head/Master Teacher/ Principal) and from the series of observations on pedagogical approaches of the teachers teaching General Mathematics, the subject matter-centered approach has a weighted mean of 3.92 with a verbal description of "significantly evident". This is

followed by a teacher-centered approach with a weighted mean of 3.31 and with a verbal interpretation of "significantly evident", meta-cognitive approach 3.00 with the verbal description "evident" and problem-based approach 2.04 interpreted as "evident".

Table 2. Summary of Pedagogical Techniques Applied by SHSNEGT in Teaching General Mathematics

Pedagogical Approaches and Techniques	WM	Verbal Description
Setting of Objectives	3.44	Outstanding
Materials being used	3.28	Outstanding
Lesson Development	3.39	Outstanding
Application	3.36	Outstanding
Evaluation	3.35	Outstanding

On validation of data gathered through series of actual observations, the teachers use varied pedagogical approaches and techniques in different topics/lessons like simple interest, compound interest, and annuities, subject matter-centered approach, problem-based approach, teacher-centered approach are evident. The techniques used are motivational activities, board-work, and group activities. And in topics truth values and tautology, teacher-centered and subject matter-centered with lecture/discussion is evident.

And the results of the interview, the majority of them are preparing their lesson objectives ahead of time using various references and they consider the individual differences of the students in selecting their resources. They say that the problem-based approach, collaboration, and group learning techniques are the most helpful and effective to apply in General Mathematics.

### 3. Pedagogical approaches and techniques applied by SHSNEGT teaching General Mathematics

Table 2 presented the pedagogical approaches and techniques applied by teachers teaching General Mathematics, "setting of objectives" has the highest weighted mean, 3.44 with the verbal interpretation of "outstanding". This is followed by lesson development with a mean of 3.39, application with 3.36, evaluation with 3.35, and materials being used with 3.28 and all having a verbal interpretation of "outstanding".

### 4. Comparison in pedagogical approaches and techniques applied by SHSNEGT teaching General Mathematics

The teachers execute and evidently show different approaches and techniques like subject matter-center, teacher-centered, and problem-based approaches in simple interest, compound interest, and annuities, while in truth values and tautology are lecture/discussion techniques, therefore there are no differences in the pedagogical approaches and techniques applied by the teachers in topics/lessons in General Mathematics. They execute different approaches in the first three topics maybe because the topics are more on formulas while the two topics about truth values and tautology are requiring logical analysis of statement and the teachers had no enough knowledge of them since the expertise of the majority of teachers are not aligned in that field of specialization.

### 5. Differences in pedagogical approaches and techniques applied in teaching and based on teachers' profile

Table 3, shows the differences in pedagogical approaches previous work has an F-value of 10.667 and sig. of .004, reveals that there is a significant difference in pedagogical approaches but has no difference in techniques (F-value of 0.571 and sig. .650). Pedagogical approaches and techniques applied in General Mathematics have no significant differences in terms of teachers' age, sex, years in service, bachelor's degree, and specialization.

**Table 3. Differences in Pedagogical Approaches and Techniques Applied in General Mathematics based on Teachers' Profile**

PROFILE	PEDAGOGICAL APPROACHES			TECHNIQUES		
	F	sig	Verbal Interpretation	F	Sig	Verbal Interpretation
AGE	2.857	.164	NS	2.984	.154	NS
SEX	0.465	.511	NS	1.053	.329	NS
YEARS IN SERVICE	1.215	.341	NS	0.115	.892	NS
BACHELOR'S DEGREE	3.435	.072	NS	.261	.851	NS
SPECIALIZATION	0.333	.802	NS	0.615	.624	NS
PREVIOUS WORK	10.667	0.004	S	0.571	.650	NS

## VI. CONCLUSION

Based on the findings the following conclusions are attained.

1. The SHSNEGTS are considered as young professionals and the majority of them are female with entry-level in Senior High School, having BS degree and specialization with previous work related to business courses and industry, therefore, SHSNEGTS are eager to learn. They can easily adopt different environment settings especially in

teaching General Mathematics as they can apply their expertise and skills gained from their previous experiences and prior knowledge related to the topics.

2. There can be no doubt that teacher-centered, subject-matter centered and problem-based pedagogical approaches are dominant in teachers and collaborative, group work activity and board-work in techniques are also evident in teaching General Mathematics. The teachers use two to three pedagogical approaches among several approaches in teaching.
3. On pedagogical techniques applied in General Mathematics, the setting of objectives has the highest weighted mean 3.44 interpreted as "outstanding", it is concluded that teachers planned well with the integration of three domains of learning – cognitive, psychomotor, and affective to satisfy the learning competencies and objectives of the topic/lesson.
4. There are no differences in the pedagogical approaches and techniques applied by teachers, therefore the teachers have the same pedagogical approaches and techniques applied in teaching General Mathematics. Because the topic is new to them, they can only rely on what they know and the easiest way to deliver the subject matter.
5. The teachers' previous has there is a significant difference in pedagogical approaches but had no significant difference in pedagogical technique, therefore teachers' capability, knowledge, and skills gained from their previous work have a great impact to pedagogical approaches that can be applied in teaching with diverse learners and different situations. On the other hand, previous has no significant difference in pedagogical techniques because teaching is different from their previous environment, so all teachers used the basic techniques in teaching General Mathematics.

## VII. RECOMMENDATIONS

Based on the conclusions the following are recommended.

1. Since the teachers are young professionals regardless of the sex they are eager to learn, they can share their ideas, knowledge, and skills with



others and easily adjust in a different environment it is recommended for them to pursue graduate studies that are aligned to their field of specialization in teaching. They should attend more seminars and trainings on pedagogical approaches and techniques that can be applied for the current work as Senior High School teaching position.

2. The teachers may try to use and integrate other pedagogical approaches and techniques that will make teaching and learning [14] more interesting, fun, and enjoyable like interactive approach, inquiry-based approach, constructivist approach, integrated approach, and many more. They may integrate virtual simulation that most of the students confirmed to be more helpful and effective.
3. Since pedagogical techniques applied by teachers have been found outstanding, teachers may continue to look into the other side of other techniques especially in planning and selecting appropriate approaches that best suited to individual differences and needs of the students to satisfy their learning objectives and competencies.
4. Given that no differences in the pedagogical approaches and techniques applied in teaching General Mathematics [15] and the topic is new for the teachers, it is recommended for school heads or department heads to form a group for mentoring and coaching teachers in different teaching and learning tasks to improve teachers' pedagogical approaches and techniques that will maximize learning time and activities.
5. Previous work is found out with significant differences in pedagogical approaches. It is recommended that the good side of it may serve as their springboard for continuous professional growth and development in the selection, preparation, and utilization of instructional materials in General Mathematics.
6. Teachers may consider students' individual differences, implementing classroom rules and regulations and they should integrate more patience in teaching whereas school heads showed to provide the budget for instructional materials needed in teaching General Mathematics.

7. Based on the conclusion of this study, it is recommended to have continuous development, organization, and implementation seminars and training programs for improvement and enhancement of teachers' pedagogical approaches and techniques in teaching different learning areas.

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## REFERENCES

- [1] Adunola, O. (2011), "*The Impact of Teachers' Teaching Methods on the Academic Performance of Primary School Pupils in Ijebu-Ode Local cut Area of Ogun State*," Ego Booster Books, Ogun State, Nigeria.
- [2] Beausaert, S. (2013). *Effects of using a personal development plan on learning and development*. Journal of Workplace Learning. ISSN 1366-5626
- [3] Cristillo, L. (2010). *Teacher-Centered Dominated Approaches*. Academic Journal of Educational Research. 2016
- [4] Das (2010). *The Internship of Teaching*. Handbook Department of Education. *General Mathematics*. Teachers' Guide and Learner's Materials
- [5] Educational Consultancy and Research Center, (2012), *Educational Sciences: Theory and Practice-12* (1). Winter. 497-505
- [6] Hill-Miller, P. (2011). *A different approach, different results: A study of mastery learning instruction in a developmental reading class at an urban community college*. The University of North Carolina at Charlotte). ProQuest Dissertations and Theses, 120. Retrieved from: <http://search.proquest.com/docview/897948393?accountid=28682>. (897948393).
- [7] Jadama L.M. (2014). *Impact of Subject Matter Knowledge of a Teacher in Teaching and Learning Process*. School of Education University of The Gambia, Middle Eastern & African Journal of Educational Research, Issue 7 the Year 2014 20E-mail: [ljadama@hotmail.com](mailto:ljadama@hotmail.com) Mobile: 00220 3650114
- [8] Jalbani, L.N. (2014). *The Impact of Effective Teaching Strategies on the Students' Academic Performance and Learning Outcomes*. ISBN 9783656963530

- [9] J Adv Med Educ Prof. (2016), *Effective Teaching Methods in Higher Education: Requirements and Barriers*, October 2016;4(4): 170-178. PMCID: PMC5065908, PMID: 27795967
- [10] National Research Council, (2013). *Improving the health, safety, and well-being of young adults*. Institute of Medicine; National Research Council. Washington DC.
- [11] Rothstein, J. (2010). *Teacher quality in educational production: Tracking, decay, and student achievement*. Quarterly Journal of Economics, 125(1), 175-214.
- [12] Rice J. K., (2010). *The impact of teacher experience, Examining The Evidence and Policy Implication*. National Center for Analysis of Longitudinal Data in Education Research.
- [13] Subia, G. S. (2020). Treasure Chess: Worthy Contributions of the Game in the Lives of Student Champions. The Normal Lights, 14(1),100-121.
- [14] Subia, G., Marcos, M., Valdez, A., Pascual, L. & Liangco, M. (2020). Cognitive Levels as Measure of Higher Order Thinking Skills in Senior High School Mathematics of Science,Technology, Engineering, and Mathematics (STEM)Graduates. Technology Reports of Kansai University. Volume62, Issue 3, pp 261-268.

# Influence of SDR on RMB Internationalization

Ran Wei

School of Economics, Central University of Finance and Economics, Beijing, China

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**Abstract**— In 2016, IMF officially announced that RMB was included in the currency basket of SDR, with the RMB accounting for 10.92% of the total currencies in SDR ranking the third place. The RMB's accession to the SDR has played a role in promoting the RMB's internationalization status, opening up the international market and making the RMB become an international currency. However, at the same time, it is also necessary to clearly realize that the RMB's accession to the SDR does not have the final word as expected by the international community, and will not really increase the international holdings of RMB, which is, on one hand, restricted by "Triffin Dilemma" and "Mundellian Trilemma", and on the other hand, is as a result of the issue volume of the SDR and the inherent fragility of the real economy, resulting in the actual challenge to the internationalization of RMB. China has a long way to go to promote the internationalization of RMB, and there is still more work to be done.

**Keywords**— SDR, RMB, internationalization, Triffin Dilemma, Mundellian Trilemma.

## I. INTRODUCTION

The full name of SDR is Special Drawing Right. It is known internationally as the "paper gold," which is an international currency reserve allocated by IMF (International Monetary Fund) according to the share of funds subscribed by the participating countries. In 1969, the IMF created a complementary reserve asset that could act as an international currency like gold and dollar, in order to address the defect in international liquidity and to make up for the shortfall in official reserves. By November 2015, the International Monetary Fund officially announced that RMB was included in the currency basket of SDR on October 1, 2016. Meanwhile, RMB became the third largest currency after it was included in the SDR. Among the currencies in SDR, dollar, euro, RMB, pound and yen account for 41.73%, 30.93%, 10.92%, 8.33% and 8.09% respectively. It is the first time since the euro was adopted that one currency has been added to the basket, and the first time that the currency of the emerging country

has been included.

During the Second World War, the political situation was in turmoil, so number of currency groups appeared, followed by the fierce competition, leading to the devaluation of currency and market turbulence. After the Second World War, the U.S. dollar-centric Bretton Woods system came into being, including the International Monetary Fund (IMF) and WB (World Bank), which created the relevance of US dollar to gold, and other currencies link up with the dollar. This system adopted the fixed exchange rate. Since the United States had stronger economy and higher international position, the international holdings of US dollar are much higher than other currencies, naturally, the US dollar became an international currency. However, it also put higher requirements on the United States. The United States needed to maintain a long-term trade deficit in foreign trade in order to maintain the internationalization of the dollar, which in turn led to a reduction in the intrinsic

value of the dollar, making it difficult for the dollar to maintain a fixed exchange rate against other currencies. At the same time, the core premise of the dollar as an international currency was that the currency value of dollar should be strong and stable, and it needed to maintain a long-term trade surplus. The surplus and deficit constituted a contradiction, which was known as the "Triffin Dilemma". Subsequently, the emergence of the dollar crisis caused the universal concern of international community to the international reserve status of the dollar and the reform of the international monetary system. At this point, the International Monetary Organization was in urgent need of an international reserve currency and new means of international circulation.

To solve this problem, in 1966, Pierre Schweitzer, CEO of IMF, published two plans of creating reserve assets. Plan one was to set up an affiliated agency--International Reserve Fund (IRF), issuing reserve unit and link it to gold. IRF was responsible for issuing the International Reserve Unit, and all Members shall consult with the IRF when they need to obtain the Reserve Unit that shall be loaned uniformly through IRF. The quota Reserve Unit borrowed shall be determined by the shares of the members in IRF. Plan two was to expand the automatic drawing rights of IRF. In the event of an international payment crisis, members can apply to the IMF for 25% shares of their original subscription when they joined the IMF, which is known as the "automatic drawing rights". This time, IMF wanted to expand the shares, which was called the "special reserve facility," predecessor to the "special drawing rights." In 1969, IMF Annual Meeting formally adopted the *First Amendment to the International Monetary Fund Agreement*, marking the official emergence of SDR, and SDR was formally introduced in August of the same year.

Robert Triffin, an American scholar, pointed out that as an international reserve and payment currency, it depended on the confidence of other countries in the economic strength and international liquidity of the currency issuer, regardless of whether the currency was linked to gold. The more frequently the country's currency is used internationally, the greater the amount of reserves in other countries, and the greater the country's external

liabilities. Thereby affect the confidence of other countries in the economic prospects and international liquidity of the country. Based on this theory, if RMB becomes an internationally recognized currency, it needs to constantly expand the international payment deficit to maintain the continuous circulation of RMB in the international market or to be used as a reserve currency by the central banks of other countries. In 2008, China and South Korea signed a currency swap agreement. Since then, China has signed a series of agreements with many countries. Based on the currency swap agreement, RMB is held and reserved by the central banks of numerous countries.

In 2009, China opened the pilot program of RMB settlement of cross-border trade transactions in Shanghai and Guangdong, followed by other places nationwide. At the same time, China lifted a series of regional restrictions and added a number of related projects, enriching the form of trade. By 2012, cross-border trading companies were allowed to use RMB directly for international trade in accordance with state regulations. According to statistics, the amount of RMB trade settlement in 2009 was 3.58 billion yuan, increasing to 33.74 billion yuan in 2013. Cross-border trade has been steadily promoted in size and achieved remarkable results.

In 2013, According to statistics of IMF, RMB ranked 13th in world currency usage rate, and by 2015, it ranked fifth in world currency usage rate. In terms of foreign exchange, in 2014, China's foreign exchange value accounted for 2.17% of global monetary expenditure, ranking second in the world. This is an important manifestation of China's currency going international and gradually gaining a foothold in the world.

China joining the SDR is another step toward internationalization. According to the statistics of *2016 RMB Internationalization Report*, by the end of 2015, RII—the quantitative indicator of the RMB's international use, reached 3.6, increasing more than ten times in five years. And RMB settlement accounted for nearly 30% of the trade with China. At the same time, data shows that after China joined the SDR, the RMB exchange rate flexibility has been greatly enhanced, the two-way fluctuation has become more obvious, the pricing mechanism has been constantly revised and improved, and

the combined use of the three foreign exchange policy tools: exchange rate, intervention and control has also been strengthened.

## II. POSITIVE ROLE OF JOINING SDR

Since China joined the SDR, RMB has been circulating around the world as an international reserve currency, which is a milestone for China's currency internationalization process. It fully demonstrates that the IMF has a full affirmation of China's economic strength, international status, trade globalization and its voice in the world. It also indirectly demonstrates that China's economic development has made leaps and bounds. China's growing strength has ensured the progress of the internationalization of RMB, and in turn, joining the SDR has promoted the development of China's economy, trade and financial system.

**Conducive to strengthening the international recognition of RMB.** Throughout the global development situation, the economic growth potential determines the future rise and fall of a country. Compared with developed countries, China's economic growth potential is more outstanding and remains stable in the medium and long term, which is also a major reason for China to attract foreign investment. RMB joining the SDR is more a declaration of the RMB's international status, which is equivalent to an affirmation of the currency's function and value, thereby attracting global investment, promoting international flows and increasing the international circulation of RMB. It has played a powerful role in promoting the internationalization of RMB, expanding the international influence of RMB, and promoting the circulation and use of RMB in the world. Of course, this is also a signal of external release, which shows that RMB, like other currencies such as the US dollar and euro, has a certain degree of international influence and has become an international reserve unit. It is of great significance for enhancing national self-confidence and international recognition. For sovereign wealth funds, in the preconditions of well-controlled risk, big holdings of RMB-denominated assets will be one of the main options in the future.

**Conducive to deepening international cooperation and building an international platform.** As the currency

basket weighted by exchange rate, SDR has relative stability, and because SDR combines several exchange rates, it also reflects the development orientation of the global economy to a certain extent. If the currency basket can truly reflect the true value of variables such as imports and exports, international trade and economic scale, SDR can completely be the indicator of global economy. Therefore, multilateral talks and international cooperation around SDR and relevant weights will become the important contents among major economies. Although SDR does not have the ability to become the super-sovereign currency due to the constraints of systems and IMF, SDR has very good development prospect in the future. After it becomes the super-sovereign currency, SDR will also become an advanced form of cooperation for international community in the financial field, which will create a positive effect on the stability of exchange rate, international trade and financial capital investment.

For China joined the SDR, on one hand, since Chinese enterprises can trade directly in RMB, the risk due to the exchange rate will be greatly reduced, which will greatly promote China's foreign trade and investment. And on the other hand, RMB joining the SDR will reduce the fluctuation frequency of the exchange rate, improve the stability of the exchange rate, and reduce the cost of trading in foreign currencies such as US dollar and euro, which will reduce the transaction cost of Chinese foreign trade enterprises. At the same time, RMB joining the SDR will also be conducive to China's international development strategies, such as "the Belt and Road", which will greatly simplify the currency exchange procedure, reduce the waste of human resources and other expenses, facilitate the cross-border cooperation, attract more countries to join "the Belt and Road" strategy, and encourage countries to strengthen communication and join hands to build a platform for cross-border cooperation. In a word, the convenient transaction settlement method has reduced the transaction risk, improved the transaction efficiency and reduced the transaction cost, and played an excellent role in promoting the development of China's economy and trade.

**Conducive to the reform of China's financial system.** RMB being included in the currency basket, while



promoting the development of Chinese enterprises, will also inject a large number of funds for the domestic market, which will certainly promote the development of the Chinese market. With the improvement and perfection of the market, the domestic market will also be more open, which will help promote the reform of China's financial system. Taking the bond market as an example, when the currency of a country is held by other countries as the world's reserve unit, the main target of overseas asset allocation is fixed-income bonds. Driven by funds and under the international impact, China's bond market will be bound to become more mature. At the same time, it has helped to break down trade barriers, especially has had an important effect on the implementation of the strategy of "opening and action-forcing reform". Reform and development support each other forward. While improving the competitiveness of the financial sector, the efficiency of enterprises has been promoted, thus promoting the reform of the financial system.

### III. CONSTRAINTS AND CHALLENGES OF SDR TO RMB INTERNATIONALIZATION IN THEORY

#### Constraints of the "Triffin Dilemma" on RMB

Since RMB was included in the currency basket of SDR, expectations have been high in China, believing that RMB has become an international currency. However, it cannot be denied that if the RMB is to become an international currency and an international reserve unit, it will be required to meet the condition of requirement of "freely usable". Similar to the previous dollar, it needs to maintain a long-term trade deficit to make it widely used in the international community, which is closely related to the international status of the economy of a country, even will have a negative impact on the economy in order to maintain the trade deficit. The trade deficit, in turn, leads to fluctuations in the intrinsic value of the currency of a country. At the same time, in order to maintain the stability of the currency of a country and maintain the trade surplus, this inherent contradiction has not been fundamentally resolved, and "Triffin Dilemma" still exists. Theoretically, it restricts the development of RMB in the international community. On top of that, suppose that if China wants to

maintain a trade deficit, the first approach is to make net exports negative, such as purchasing foreign goods. As a developing country, China cannot support such a large trade deficit as the United States, which will limit China's development. The second approach is to liberalize the capital market and maintain the use of the RMB by selling domestic capital to foreign companies or individuals. However, China's capital market in the system is not perfect, and some measures to deal with the crisis for capital supervision are not perfect enough, so that China cannot timely deal with the uncertainties and risks brought by the liberalization of the capital market. The above contradictions have restricted the development of RMB internationalization.

#### Challenges of the "Impossible Trinity" to monetary policy

Impossible Trinity is a theory put forward by Paul Krugman, an American economist, on how to choose national policies in an open economy, which is also called the "trilemma". The main contents of this theory are: under the condition of an open economy, a country cannot realize the independence of monetary policy, the free entry and exit of capital and fixed exchange rate at the same time. At most, two of them can be satisfied, but the third one shall be abandoned, which is so called the perfect balance that we cannot achieve.

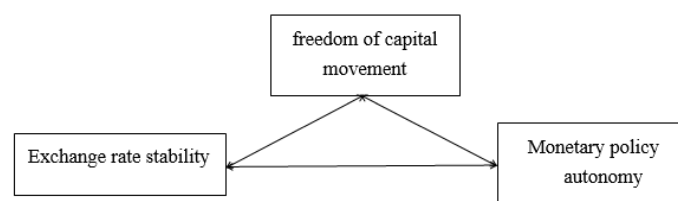


Fig.1: "Impossible Trinity"

From the domestic environment, if China wants to promote the internationalization of RMB, it shall open the market more vigorously, liberalize the capital control environment, fully invite the international floating capital, and maintain the liquidity of the capital. At the same time, as a large country in the reform and opening-up, China shall maintain the independence of the monetary policy while actively integrating into the world to advance the

process of internationalization and increase its international influence. However, we know that if it maintains the independence of its monetary policy, the capital cannot completely flow, or the exchange rate cannot be stable. Imagine, if we make the capital to achieve a complete flow, then the market will be full of floating capital, which will certainly make the balance of payments of the country cannot be stable, but at the same time, because we maintain the independence of the monetary policy, the government's ability to intervene will be weakened, which means that China's exchange rate will not be able to be effectively controlled, and then the stability of the exchange rate cannot be guaranteed. This constitutes the impossible trinity. With the participation of RMB in the SDR, the domestic exchange rate will be more market-oriented, which means that the domestic exchange rate control space will be greatly reduced. At the same time, as a large developing country, China will not sacrifice its own development to seek the complete stable equilibrium of exchange rate. In order to stimulate investment and maintain the high-speed growth of economy, the low-interest rate stimulus policy will remain active for a long period of time, which will lead to a great reduction in the control effect of domestic macro-policy, and the Impossible Trinity will become more obvious.

#### IV. CONSTRAINTS AND CHALLENGES OF SDR TO THE INTERNATIONALIZATION OF RMB IN THE REALITY

##### Small Issuance Volume of SDR

SDR is a monetary unit designed and established to maintain the Bretton Woods System. Up to now, SDR has played a certain role in stabilizing the foreign exchange market. However, when SDR was first established, it was used as an international reserve unit to stabilize the market and replace the US dollar as a single international currency. But, less than a few years after the SDR was issued, the Bretton Woods System was declared bankrupt. SDR ushered in an era of floating exchange rate, and its original purpose was difficult to achieve. At the same time, the allocation amount of SDR is relatively small. Up to now, its issuance volume is only 670.926 billion US dollars, which is only 20% of China's foreign exchange

reserves. Such a small issuance volume is difficult to deal with the huge exchange rate fluctuations caused by political risks in various countries. Moreover, SDR lacks a substantial economic foundation. Today, in such a complicated world political structure, SDR is difficult to detach itself from the interconnected world and to avoid being affected by changes in the international structure, so the stability of exchange rate is difficult to realize in a real sense. China joining the SDR has changed the international status of RMB more in a sense. However, judging from the actual influence on the monetary system, it is difficult to achieve the expected effect by relying solely on the issuance volume of SDR and its stability.

##### Limited international holdings of RMB

RMB joining the SDR is the result of the rapid growth of China's economic strength and the gradual improvement of its international status since China's reform and opening-up, which fully demonstrates China's determination and attitude to actively integrate into the international community and commit itself to becoming a major international power. However, joining in the currency basket does not mean that RMB has become the world currency since then. Whether a currency can truly become an international reserve unit and really have international influence depends on whether the holdings of such currency in the international community achieve a scale effect. Even the voice of a country in the IMF is closely related to the amount of capital holdings. We know that the weight of RMB joining the SDR is close to 11%, while that of the dollar reaches 42%, and the euro is 31%, so our international influence is limited in numerical terms. Moreover, the weight index of the SDR of a country does not fully represent the share of the currency in the foreign exchange reserves of various countries. According to the IMF data, by mid-2017, the world's official reserve of the RMB was 99.36 billion US dollars, accounting for just 1.07% of the world's total foreign exchange reserves, while the United States accounted for 41.73% in SDR and 64% of the foreign exchange reserves of other countries. Moreover, the current IMF system restricts the international influence of the SDR on the RMB. IMF relies on the share of member countries to determine voting rights and SDR shares, that is, the currency composition of

the SDR has nothing to do with the IMF's decision-making power. As of December 2017, the United States still had 831,407 votes, accounting for 16.52% of the total votes, still maintaining a 15% veto threshold for decisions on major issues. Although both the RMB's entry into the SDR and the 2010 share reform program helped China win 30,2694 votes and 6.09% voting rights in the IMF, it was still slightly lower than Japan's (6.15%).

### **Inherent fragility of the real economy**

While RMB was included the currency basket, China's "13<sup>th</sup> Five-year Plan" has also just begun. Five ideas of "innovation, coordination, green, opening up and sharing" and five tasks of "cutting overcapacity, cutting inventory, deleveraging, reducing cost and improving weakness" were set up. It is expected that in 2020, that is, through 10 years of time, GDP and per capita income of urban and rural residents can double, which means that the "middle income trap" can be successfully crossed. To achieve this goal, China's economic growth is required to be maintained at an average annual rate of more than 6.5%, and especially the components of scientific and technological progress shall make over 60% contributions to the economic growth. However, nowadays, China's real economy is still facing many problems, especially the rapid expansion of virtual economy in recent years, and the crowding-out effect on the real economy is even worth the attention of the whole society.

According to Figure 2, the author has analyzed the year-on-year growth rate of real GDP and the trend of fictitious economic factors, hoping to get a certain economic connotation. Since the reform and opening-up, China's rapid economic development has created one "China miracle" after another. After the financial crisis in 2008, China's economic development has entered a new stage, and the problems behind the long-term rapid economic growth are gradually exposed. The financial crisis has led to a sharp contraction in demand for Chinese exports in developed countries, which was a major blow to

China's export-oriented economy, directly leading to a drop in China's net exports from 9% of GDP to less than 3%, and causing a sharp slowdown in economic growth. After the GDP growth rate reached 12.1% in the first quarter of 2010, it fluctuated downward. It was below "7" for the first time in the third quarter of 2015 with a year-on-year growth rate of 6.9% of China's GDP, which still failed to reverse the downward trend. China's overall economic situation is grim, and there has been a gradual decline in the economic growth rate, causing problems such as overcapacity, real estate bubble and high leverage ratio of government and state-owned enterprises. In contrast to the trend of virtual economic factors, before the financial crisis in 2008, the change was relatively smooth. After the financial crisis, there was a sharp rise, and in a fixed time range, it was still showing an upward trend. From the single representation of representative index capital market of virtual economic factors, from 2006 to 2007, there was a big bull market in China's stock market. The main reason was that the banking system had sufficient funds, resulting in a large amount of money flowing into the stock market, and sufficient market liquidity resulted in market overheating, pushing up the market index with the Shanghai Composite Index reaching 6000 points; since China's securities companies rose from 2016, the market sentiment has been high. Investors increased the allocation of financial assets by the means of "adding leverage", and the money flowed from the real economy to the virtual economy. With the bursting of the bubble, "thousands of stocks fell" and other market collapse phenomenon emerged, and the economy was hit hard. In a word, it can be seen from the trend of virtual economy and real economy that there is obvious deviation between the two trends, which has typical characteristics of "deviation between the reality and virtuality". It also shows the inherent fragility of China's real economy.

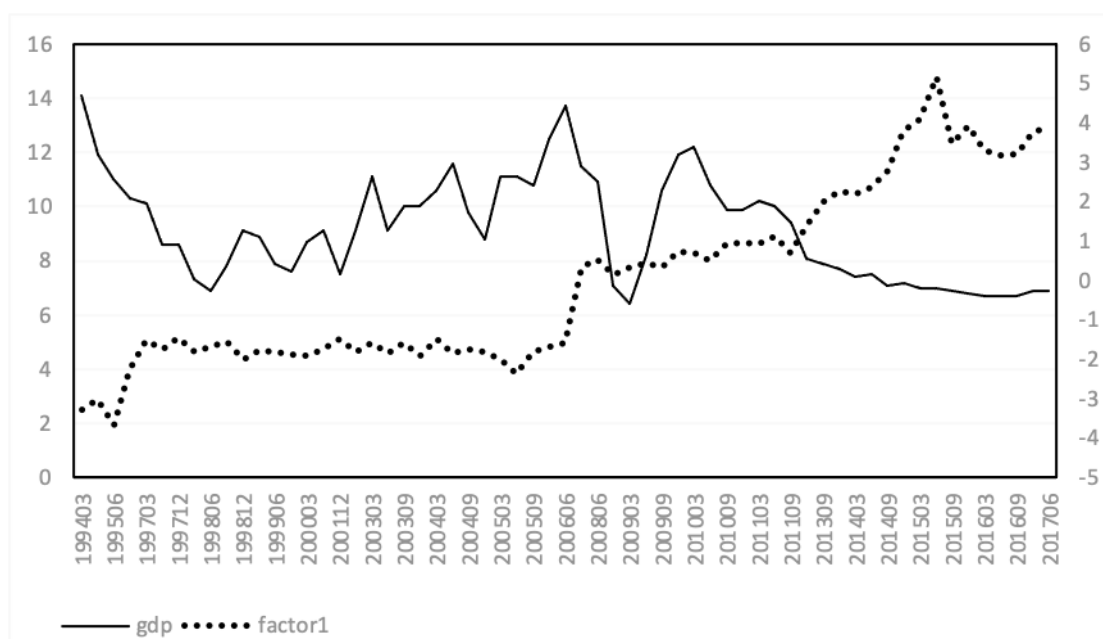


Fig.2: The trend of real economy and virtual economy

## V. SOME INSPIRATION TO THE INTERNATIONALIZATION OF RMB

First, establishment risk prevention mechanism. After the RMB's entry into the SDR, as the opening-up to the outside world deepens, the Chinese market also faces higher risks, which also puts forward higher requirements for China's risk control. The short-term profit-seeking international capital has the speculation behavior, and this part of capital will bring huge risks when entering China. Therefore, prudently and abstemiously control the capital inflow to guarantee the security of the capital market is particularly important. For our regulators, attention should be paid to the co-operation and co-management among financial departments, timely blocking the risks and avoiding regulatory blind spots and regulatory loopholes. Firewalls shall be set up to implement adjustment measures such as handling fees for foreign exchange transactions so as to enhance the ability to defend against risks.

Second, strengthen the development of the real economy. A strong real economy is the driving force and fundamental guarantee of the economic strength of a country, and it is the pillar of a country, playing the role of a mainstay. Facing the impact of globalization and

standing on the crossroads of rapid economic development, China shall make a good choice to reduce the excessive expansion of the virtual economy and prevent the impact of the virtual economy on the real economy. Strengthen the supervision measures, perfect the repair mechanism, strive to improve the virtual economy vitality, and at the same time, enhance the real economy power and promote the core competitiveness of the real economy. Improve the supporting role of science and technology in economic development, realize industrial transformation and upgrading, and accelerate the process of internationalization.

Finally, deepen the reform of the financial system. For example, in monetary policy regulation, China should speed up the reform of monetary policy regulation system. In the operation mechanism of monetary policy regulation, China uses the administrative mechanism to carry out the direct regulation and control, and the legal deposit reserve ratio mechanism, open market operation, control of the benchmark interest rate of deposit and loan, and new loan scale are commonly used means, but these means do not fully meet the requirements of the market mechanism; to a large extent, China's monetary policy regulation is still focused on financial institutions, and taking financial market as the focus of regulation is still under discussion;

so far, we have not effectively formed the exchange rate policy and interest rate policy transmission mechanism as a regulation tool of monetary policy under the market economy condition, and lack of relevant control experience. After RMB joined the SDR, the reform of these institutional mechanisms shall be accelerated, the financial self-regulation mechanism shall be improved, and the regulation ability of monetary policy shall be enhanced, so as to realize all-round and multi-angle regulation and control, and effectively curb the monetary problem.

### REFERENCES

- [1] Axel Dreher.(2006).Does globalization affect growth? Evidence from a new index of globalization.*Applied Economics* .
- [2] Barry,Rachita,Ugo Panizza.(2011).Capital account liberalization, financial development and industry growth: A synthetic view.*Journal of International Money and Finance*.
- [3] Ben S Bernanke.(2017).Federal Reserve Policy in an International Context.*IMF Economic Review* .
- [4] Lagoarde-Segot T.(2017).Financialization: Towards a new research agenda.*International Review of Financial Analysis* 51:113-123.
- [5] Lapavistas.C.(2009).Financialised Capitalism: Crisis and Financial Expropriation.*Historical Materialism* 17(17):114-148.
- [6] Lin J. Y. & Zhang P.(2007).Development Strategy, Optimal Industrial Structure and Economic Growth in Less Developed Countries.*General Information*.
- [7] Mark Illing,Ying Liu.(2006).Measuring financial stress in a developed country: An application to Canada. *Journal of Financial Stability* .
- [8] William R. White.(2008).Past financial crises, the current financial turmoil, and the need for a new macrofinancial stability framework. *Journal of Financial Stability* .