



# Removal of Pesticide Residues in Aqueous Solution by Adsorption Using Pineapple Peel Activated Carbon



## ABSTRACT

The use of synthetic pesticides in crop protection generates dilute pesticide solution resulting from the cleaning of pesticide application equipment, also known as pesticide rinsate. If not disposed or treated properly, this may result to the contamination of surface water or groundwater. One of the possible management practices for pesticide rinsate is the use of activated carbon as an adsorbent. Activated carbon was prepared from pineapple peel using phosphoric acid through chemical activation. Characterization of the surface morphology through Scanning Electron Microscopy (SEM) confirmed the successful activation of the carbon. The resulting Pineapple Peel Activated Carbon (PPAC) was utilized as adsorbent in the removal of the carbamate methomyl in the pesticide rinsate. Analysis of the cleaned rinsate using a High-Performance Liquid Chromatograph confirmed the removal of 96.0-98.4% of methomyl residues in a 7.5 mg L<sup>-1</sup> methomyl pesticide rinsate using a 0.5-1.0% w/v PPAC:rinsate ratio. This study showed that activated carbon could be successfully prepared from pineapple peel and used as an effective adsorbent for the remediation of pesticide rinsate to prevent the pollution of surface water or groundwater.

**Keywords:** activated carbon, pesticide, pesticide rinsate, pineapple, remediation

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## INTRODUCTION

The growing population and the increasing demand for food lead to the intensive use of pesticides in agriculture to obtain maximum crop yields. Farmers use various pesticides to reduce crop losses mainly due to pests, diseases, and weeds. In the Philippines, the total importation of pesticides-technical materials in 2021 were 7.84 M kg l<sup>-1</sup> valued at US\$ 31.16 M, while importation of formulated products reached 68.45 million kg l<sup>-1</sup> valued at US\$ 337.21 M (FPA 2021). The use of pesticides to protect crops from pests and diseases to attain food security is an essential part of the integrated pest management. It is always accompanied by benefits and risks and generally considered acceptable if used judiciously. However, the lack of proper guidance, support, and education in the management of pesticides resulted to misuse and the improper disposal of leftover pesticides and their containers (Ibitayo 2006). Such indiscriminate activities were confirmed as major problems across many situations (Recena et al. 2006).

Pesticide wastes are any substance or material that contains pesticide which will not be utilized and should be disposed. These include leftover pesticide solutions, washings from equipment used in spraying, empty pesticide containers, pesticide-contaminated materials

used for cleaning spillage, and expired pesticide products (Nesheim and Fishel 2005).

In a survey conducted by Damalas et al. (2008), farmer's practices on the disposal of pesticide waste after use were identified. Among those surveyed, 4.3% dispose leftover spray solutions near or into water networks such as irrigation canals and streams. In the case of the dilute pesticide solution from cleaning the pesticide application equipment, known as pesticide rinsate, the majority of the farmers dispose it on non-cropped areas (45.7%) or near or into canals and streams (40.7%). Empty pesticide containers were either left in the field (30.2%) or thrown into canals and streams (33.3%).

In the study conducted by Perez et al. (2015), it was identified that most of the farmers in Mindanao, Philippines washed their spray equipment either directly in the field (29.16%), along the canals (57.01%), in nearby well (7.01%), and in the faucet/pump-well of their homes (6.82%). Moreover, Ngidlo (2013) reported that farmers from the Cordillera Region in the Philippines do not follow proper disposal of leftover pesticides, rinsate, and empty pesticide containers. It was found out that 64% of the farmers surveyed in Ifugao, Mt. Province,

and Benguet (n=75) leave their empty pesticide bottles in the farm and only 17.3% leave their bottles in waste bins. Furthermore, 74.6% of the surveyed farmers wash their sprayers in rivers, creeks, or spring and 25.4% wash their sprayers in irrigation canals or rice fields. These practices could contaminate groundwater or surface water and as such, could pose environmental risks and water quality concerns.

One of the well-established and effective means of removing or reducing pesticide residues in the rinsate is the use of activated carbon (*Ioannidou et al. 2010, Khan et al. 2022, Marsolla et al. 2022, Oba and Pasaogululari Aydinlik 2022*). Activated carbon is one of the most used materials for adsorption, due to its large surface area and high adsorption capacity (*Marton et al. 2020*). The structure and properties of activated carbon are influenced by the kind of raw material used, composition of activating agent, durations and temperatures of carbonization and activation processes (*Xia and Shi 2016*).

Agricultural wastes are carbon-based and can serve as starting materials in the production of activated carbon as an adsorbent for the removal of pesticide residues in water, making it safer for the environment upon disposal. Numerous studies worldwide had described the preparation of activated carbon from various agricultural wastes.

Activated carbon from banana peel was produced using HCl activation and used as adsorbent for the removal of cyanide, lead, chromium, and cadmium in wastewater. The degree of removal was proportional to contact time and dosage. Maximum removal percentages of 96.5 - 98% were recorded for cyanide, lead, and cadmium. Chromium was almost completely removed as traces are no longer detected in the treated wastewater (*Olaoye et al. 2018*).

The removal of methylene blue from aqueous solution was investigated by using pineapple peel waste activated carbon (PPWAC). This was prepared via chemical activation using sulfuric acid to enhance sorption capacity. Higher amounts of adsorbent lead to a more significant removal of methylene blue in 30 minutes. Percent removal of 86.6%-100% were recorded as the dose of the adsorbent was increased from 25 to 200 mg/50 mL of adsorbate (*Yamuna and Kamaraj 2016*). In a similar study (*Magoling 2019*), it was determined that activated carbon produced from mahogany fruit husk is suitable for the removal of methylene blue in simulated wastewater, resulting to a 92.6% removal from a 50 mg/L methylene blue solution.

## Removal of Pesticide Residues in Aqueous Solution

The Philippines is considered as one of the top pineapple-producing countries (*FAOSTAT 2021*) and as such, plenty of pineapple wastes such as peels, leaves, crown, and pulp are generated. The utilization of these agricultural wastes could potentially contribute to the development of technologies geared towards environmental protection. As such, this study aims to develop activated carbon from pineapple peel waste for the removal of pesticide residues in water. The main goal is to evaluate the utilization of pineapple peels as a sustainable material for the preparation of activated carbon adsorbent to develop an efficient remediation technology for pesticide residues in pesticide rinsate.

## MATERIALS AND METHODS

In this study, pineapple peels from pineapples stores in Calauan, Laguna, Philippines were used as starting material for the preparation of activated carbon. This study was conducted from November 2019 to July 2020 at the Pesticide Toxicology Chemistry Laboratory of the National Crop Protection Center – University of the Philippines Los Baños.

### Evaluation of Pesticides

Pesticides belonging to the organophosphates and carbamates class were identified from the list of registered pesticides indicated at the website of the Fertilizer and Pesticide Authority (FPA 2019). For each pesticide, literature search at Pesticides Properties Database (PPDB 2019) on physicochemical parameters such as water solubility, half-life, and KOC (organic carbon-water coefficient) were conducted. The risk of contaminating groundwater via leaching was identified through the calculation of the Groundwater Ubiquity Score (GUS).

### Sample Preparation

Pineapple peels were washed multiple times with tap water to remove adhering foreign materials (if any), and were cut manually using a kitchen knife into small pieces of approximately 1 x 1 cm. These were transferred to aluminum pans, and oven-dried at 105°C for a total duration of at least 8 hrs.

### Carbonization of the dried pineapple peels

The dried peels were transferred to porcelain crucibles (50 mL capacity) and placed in an electric muffle furnace (SNOL8.2/1100) pre-heated at 100°C and set at 300°C. The samples were carbonized for 1 hour at 300°C. The resulting pineapple peel carbon (PPC) was

cooled to room temperature using a desiccator followed by grinding multiple times using a high-speed blender to obtain the powdered pineapple peel carbon (PPPC).

### Preparation of 30% $H_3PO_4$

In a 100 mL volumetric flask, 50 mL distilled water was added, followed by 35.3 mL of concentrated  $H_3PO_4$  (85% w/w equivalent to approximately 14.8 M, density = 1.71 g mL<sup>-1</sup>), shaken well, and diluted up to the 100 mL mark using distilled water, and shaken well multiple times prior to storage and use.

### Impregnation and Activation

The powdered pineapple peel carbon (PPPC) was impregnated and chemically activated based on the method used by *Magoling (2019)*, with a few modifications. Impregnation and activation were conducted with 30%  $H_3PO_4$  using a 1.0 impregnation ratio, which is a ratio of the weight of the activating agent (calculated as pure  $H_3PO_4$  in this study) and the weight of the carbonized raw material (i.e., 4.2 g of 30%  $H_3PO_4$  for every 1 g of PPPC). The acid was added in a beaker containing the PPPC and stirred well until a homogenous slurry was obtained. The reaction was allowed to be completed overnight and the final slurry was filtered using ashless filter paper via suction filtration. The residue obtained plus the ashless filter paper was transferred to Petri dishes and oven-dried at 105°C for 4 hrs. The dried residue was scraped off from the ashless filter paper and transferred to porcelain crucibles and heated in the electric muffle furnace at 400°C for 1 hr to produce the pineapple peel activated carbon (PPAC). The PPAC was washed multiple times with boiling distilled water until the washings are neutral in pH, oven-dried at 105°C, placed in sealed glass containers and stored in a desiccator.

### Remediation of methomyl using PPAC

A 400 mg L<sup>-1</sup> methomyl stock solution was prepared by dissolving 1 ± 0.0010 gram of Lannate® (400 g kg<sup>-1</sup> methomyl) in distilled water to a final volume of 1 L. A 6.25 mL aliquot of the 400 mg L<sup>-1</sup> methomyl stock solution was added to a 100 mL volumetric flask and diluted to volume with distilled water to produce a 25 mg L<sup>-1</sup> methomyl rinsate. For the adsorption experiments, a weighed amount of PPAC was added to the rinsate in a small beaker, mixed manually using a glass stirring rod, allowed to react for at least five minutes, and filtered using a Whatman® filter paper. A commercial activated carbon from JT Baker (termed as JT BAC in this study) served as the positive control. The level of methomyl residues in

the untreated and treated rinsate was evaluated using the Rapid Bioassay for Pesticide Residues (RBPR). A series of initial adsorption experiments using various adsorption ratios and mixing time were conducted to determine the optimum conditions for the removal of methomyl in water.

### Characterization using Scanning Electron Microscopy (SEM)

Samples of the PPPC, PPAC, and JT BAC were submitted to the National Institute of Molecular Biology and Biotechnology at the University of the Philippines Los Baños for surface characterization using scanning electron microscopy (SEM). The surface morphology of the carbon powder particles was examined using a Table-Top Scanning Electron Microscope (Phenom XL, Thermo Scientific). Powder particles were first fixed onto double-sided adhesive carbon tape mounted on an aluminum stub and then sputter coated with gold palladium at a current intensity of 5 mA for 4 min using a fine coat ion sputter (JFC-1100, JEOL, Japan). The sputter-coated particles were then examined with an accelerating voltage of 10 kV.

### Pesticide residue analysis

Using the results of the initial adsorption experiments, a final adsorption experiment was conducted using a 7.5 mg L<sup>-1</sup> methomyl rinsate prepared from 0.0038 ± 0.0001 gram analytical reagent grade (AR grade) methomyl (99.98% purity) dissolved with distilled water to a final volume of 500 mL. Samples of the untreated rinsate and filtrate of the treated rinsate were placed in amber bottles and stored in the freezer prior to submission to Jefcor Laboratories, Inc. for pesticide residue analysis. The method employed is as follows:

Dichloromethane was added to 60 mL of water samples and shaken vigorously for 3 minutes. The phases were allowed to separate for 10 minutes, and the organic layer was collected to round bottom distilling flask by passing through a heated and pre-washed anhydrous sodium sulfate. The extraction was repeated twice using 30 mL of dichloromethane. The organic phases were combined and concentrated to about 2 mL in a rotary evaporator at 65°C. The concentrated extract was added with 30 mL acetonitrile and concentrated to less than 2 mL. The concentrated extract was quantitatively transferred to a 10 mL graduated cylinder and diluted to the 2 mL mark with acetonitrile. The extract was filtered using a nylon syringe filter prior to residue analysis using a High-Performance Liquid Chromatograph equipped with a UV detector (HPLC-UV) (**Table 1**).

Table 1. High-Performance Liquid Chromatograph (HPLC) parameters for methomyl residue analysis in water.

Parameters	Details
Instrument	Shimadzu (HPLC-Prominence), LC-20AT, SPD-20A
Wavelength	233 nm
Column	Inertsil ODS-3 (5µm, 4.6 x 150 mm)
Oven Temperature	30 °C
Mobile Phase	80:20 (v/v) water:acetonitrile
Flow Rate	0.8 mL min <sup>-1</sup>
Injection Volume	20 µL

## RESULTS AND DISCUSSIONS

### Evaluation of Pesticides

From the Fertilizer and Pesticide Authority's list of registered pesticides, organophosphates (OP) and carbamates (CB) were identified (**Table 2**). Among the various classes of pesticides, OP and CB are considered the most toxic and hence may pose serious safety concerns when left untreated in the pesticide rinsate. In addition, these classes belong to the old generation category and serve as the active ingredients of numerous generic pesticides which are commercially available at a low cost. For these reasons, OP and CB are most widely used by the farmers. In the study of *Chowdhury et al. (2012)*, organophosphorus and carbamate insecticide residues were detected in water collected from rice paddies and vegetable field in Bangladesh. The pesticide residues found in vegetables exceeded the allowed maximum residue limits (MRLs). Moreover, the pesticide residues in water from the rice paddies were over the limit set by the European Economic Community (Directive 98/83/EC). The high pesticide residue content of the samples suggests the intense application and usage of pesticides in the area.

For each OP and CB pesticide, the half-life (DT50) and organic carbon-water coefficient (KOC) or the

Table 2. Organophosphates (OP) and carbamates (CB) registered in the Philippines.

Organophosphate	Carbamate
acephate	BPMC
chlorpyrifos	carbaryl
diazinon	carbofuran
dimethoate	carbosulfan
fenitrothion	formetanate HCl
malathion	methomyl
phenthoate	oxamyl
profenofos	
terbufos	

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organic carbon normalized Freundlich distribution coefficient (KFOC) values were identified to calculate the Groundwater Ubiquity Score (GUS). The DT50 is a measure of the pesticide's ease of degradation in soil and is usually measured in days. A lower DT50 indicates that the pesticide is relatively easily degraded in soil. On the other hand, the  $K_{FOC}$  or  $K_{OC}$  is the soil adsorption coefficient and is a measure of a pesticide's retention in soil, and thus, its degree of mobility. A lower value indicates that it is less retained in the soil. The Groundwater Ubiquity Score or GUS, is a simple method of assessing a pesticide's leachability (*Gustafson 1989*) and is calculated using the formula:

$$GUS = (\log DT50) (4 - (\log K_{FOC} \text{ or } K_{OC}))$$

A GUS below 1.8 indicates low risk of leaching, a GUS of 1.8-2.8 indicates a moderate risk and a GUS higher than 2.8 indicates high risk. From the calculated GUS for the identified pesticides, methomyl had the highest GUS (2.7) thus, was used as the test pesticide for this study (**Table 3**). Methomyl is a carbamate insecticide being used to control various insect pests across different crops. The GUS of 2.7 for methomyl indicates a moderate risk of leaching. The risk of leaching could be high depending on other factors, such as high amount of rainfall, type of soil (e.g., sandy), and low organic matter content (*Pérez-Lucas et al. 2018*).

### Carbonization of the dried peels

To produce the activated carbon, pineapple peels were dried using an oven and carbonized using an electric muffle furnace. A suitable temperature for the carbonization of the dried peels was determined at 200°C, 250°C, and 300°C. Visual inspection of the carbonized peels showed that 300°C is the optimum temperature among the temperatures tested. At 300°C, a satisfactory degree of carbonization was attained. Thus, this temperature was used for the carbonization step in the production of activated carbon.

Acidic/alkaline modification of the carbonized materials is a necessary step to alter its physico-chemical properties. Alkaline treatment of the carbonized material produces a material with a large surface area, higher ratio of aromaticity (H/C), higher N/C ratio, and lower O/C ratio (*Ahmed et al. 2016*). With increasing ratio of aromaticity (H/C), the lower the hydrophilic ratio will be signified by lower O/C. The increased N/C ratio indicates that more nitrogen-containing groups are present on the surface of the modified biochar. This improves the sorption of organic contaminants and negatively charged

Table 3. Physicochemical properties of organophosphates (OP) and carbamates (CB) pesticides.

Pesticide	DT50 , days	K <sub>FOC</sub> or K <sub>OC</sub> , mL g <sup>-1</sup>	Calculated GUS, average	Risk of Leaching
acephate	3	1.9 - 188	1.3	low
BPMC	7 - 23	1068	1.1	low
carbaryl	2.3 - 98.7	134 - 320	1.8	moderate (lower bound)
carbofuran	5.7 - 60	9.7 - 433	2.4	moderate
carbosulfan	0.35 - 71.9	1644 - 2652	0.4	low
chlorpyrifos	0.32 - 1000	1520 - 5442	0.2	low
diazinon	7.5 - 40	259 - 4175	1.0	low
dimethoate	2.1 - 7.2	16.3 - 51.9	1.4	low
fenitrothion	0.04 - 2.7	252 - 1966	-1.0	extremely low
formetanate HCl	5.93 - 19	140 - 1146	1.3	low
malathion	0.1 - 1	151 - 308	-1.0	extremely low
methomyl	4.6 - 30	13.3 - 42.8	2.7	moderate (upper bound)
oxamyl	0.6 - 19.4	4.1 - 37	1.2	low
phenthoate	35	1000	1.5	low
profenofos	7	2016	0.6	low
terbufos	8 - 12	700	1.1	low

Source: Pesticides Properties Database (PPDB 2019)

GUS- Groundwater Ubiquity Score

ions from wastewater (Ma et al. 2014).

Modification using sulfuric acid increases the percentage of oxygen which results to increased O/C and H/C molar ratios (Vithanage et al. 2015). According to Hadjittofi et al. (2014), chemical modification using nitric acid resulted to breaks in the pore wall of the material which made the biochar to have more acidic functional groups such as carboxylic, ketonic, and hydroxyl moieties. This can lead to more chemisorption of pollutants from wastewater.

### Impregnation and Activation

The carbonized pineapple peel was ground multiple times using a high-speed blender to obtain the powdered pineapple peel carbon (PPPC), which was then impregnated and chemically activated with 30% H<sub>3</sub>PO<sub>4</sub>. Chemical activation could be performed using a variety of activating agents such as H<sub>3</sub>PO<sub>4</sub> and KOH. Phosphoric acid is the most commonly used chemical activating agent for the synthesis of activated carbon from lignocellulosic biomass because of its ease of recovery, low environmental impact, and higher carbon yield. Its use results to excellent synthesis of mesopores, resulting in higher total pore volume and diameters (Neme et al. 2022).

Chemical modification using H<sub>3</sub>PO<sub>4</sub> was found to have several advantages over other chemical treatments, such as fairly low pyrolysis temperature, low corrosivity, minimal pollution, and low cost (Girgis and El-Hendawy 2002, Li et al. 2010). Previous studies have investigated the effect of H<sub>3</sub>PO<sub>4</sub> treatment on the characteristics of the carbonized material for adsorbent application for

contaminants. Fernandez et al. (2015) studied activated hydrochars (char substrates produced by hydrothermal carbonization from orange peels) using H<sub>3</sub>PO<sub>4</sub> treatment. After modification, improved porosity was observed and the sorption of newly emerging organic pollutants on hydrochars was investigated. Wu et al. (2017) investigated the sorption of Cr (VI) on modified pomelo peel biochar and noted that after being treated with H<sub>3</sub>PO<sub>4</sub> at 450°C, the modified biochar had established a porous structure. According to Chu et al. (2018), H<sub>3</sub>PO<sub>4</sub> pretreatment produced a carbonized material with a large surface area and plenty of porous structures resulting to increased sorption capacity.

In the study of Sugumaran et al. (2012), the activated carbon produced using H<sub>3</sub>PO<sub>4</sub> resulted to a higher yield and a higher surface area and pore volume as compared to activated carbon produced using KOH. According to Tana et al. (2018), activated carbon impregnated with H<sub>3</sub>PO<sub>4</sub> possessed a more extensive exfoliated and multilayer structure as compared to activated carbon impregnated with KOH, resulting to a better adsorption performance.

### Remediation of methomyl using PPAC

To determine if the carbonized peels were successfully activated, both the unactivated and activated carbon were used as adsorbent (1% w/v) in the remediation of a 25 mg L<sup>-1</sup> (nominal concentration) methomyl rinsate prepared from a pesticide formulation. Among the pesticides, methomyl has the highest risk of leaching as shown by the calculated average GUS of 2.7 (Table 3). At 25 mg L<sup>-1</sup>, methomyl is expected to result to ~50%

inhibition when analyzed using the Rapid Bioassay for Pesticide Residues (RBPR). This degree of inhibition is considered suitable to assess the successful activation of the carbon as the decrease in % inhibition without reaching negative values is attainable using this concentration. The samples were shaken twice for one minute each at 30-minute intervals prior to filtration. The filtrate of the treated rinsate was analyzed for the remaining methomyl residues using RBPR. The untreated rinsate served as the control (**Table 4**).

Table 4. Rapid Bioassay for Pesticide Residues results of treated rinsate using unactivated powdered pineapple peel carbon (PPPC) and pineapple peel activated carbon (PPAC).

Adsorbent	RBPR Result, % Inhibition
None (untreated)	47.1
Unactivated Carbon (PPPC)	36.4
Activated Carbon (PPAC)	3.4

The RBPR is a rapid detection tool based on Ellman's method for cholinesterase activity measurement. It is an enzymatic method that employs a spectrophotometer in the detection of pesticides that inhibits the enzyme acetylcholinesterase (AChE) and is thus specific for pesticides belonging to the organophosphates and carbamates class. The result of RBPR analysis is expressed in terms of % inhibition of the AChE. For the same pesticide, higher % inhibition means higher concentration of the pesticide. This rapid detection tool was developed in Taiwan and was used for fruits and vegetables market inspection and farm education (*Kao et al. 2010*). It can be inferred that the activation was successful due to the very low % inhibition of the PPAC-treated rinsate, indicating a more effective adsorbent than the unactivated carbon.

After confirming the successful production and utilization of activated carbon (AC) as an adsorbent, the effect of activated carbon:rinsate ratios in the treatment of the rinsate was determined to investigate the cost-effective amount of AC to be used (**Table 5**).

The lowest amount of adsorbent used (0.5 % w/v) led to a significant reduction in % inhibition, indicating

Table 5. The effect of adsorption ratio on the removal of methomyl.

Treatment	RBPR Result, % Inhibition
Untreated	36.4
0.5 % w/v	5.1
0.8% w/v	1.9
1.0% w/v	< 0

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that methomyl residues were removed from the treated sample (**Table 5**). Increasing the amount of adsorbent to 0.8-1.0% w/v led to highly significant removal of the pesticide as shown by the reduction of % inhibition from 36.4% to <0 - 1.9%.

The impregnation process enhances the property of the produced activated carbon offering a synergism between the substances and the carbon (*Henning and Schafer 1993*). This enables the cost-efficient elimination of the contamination which would not be feasible otherwise. In terms of the impregnation ratio (IR), or the ratio between the weight of the pure activating agent and the weight of the unactivated carbon used, satisfactory results were observed using an impregnation ratio of 1.

## Pesticide residue analysis

Considering the effect of the adsorption ratio at an impregnation ratio of 1, and 0.5 - 1.0% w/v adsorption ratio were utilized in designing the final and confirmatory adsorption experiment. The degree of pesticide removal was validated by High Performance Liquid Chromatography (HPLC) analysis of the untreated and treated rinsate (**Table 6**).

The use of activated carbon in the remediation of methomyl rinsate was highly effective (**Table 6**). Significant reductions by 96.0 – 98.4 % were observed from the use of PPAC in the remediation of 7.5 ppm methomyl rinsate. This level of methomyl was determined to be the lowest concentration of methomyl that will result to a % inhibition that is significantly above the background level of 15%. The use of lower concentration may lead to inaccurate results and the use of higher concentrations will require the use of more amounts of activated carbon. This is difficult to obtain noting that this study used a lab scale method only. The results obtained are comparable with the effect of using a laboratory grade activated carbon (JTAC). In terms of cost effectiveness, the 0.5% w/v is inferred to be the optimum as further increase in the amount of adsorbent will increase percent removal by only 1.2 – 2.7%.

In the study of *El-Kady et al. (2013)*, activated carbon from dates stones, considered as an agricultural waste, effectively removed 97% of malathion and profenofos in aqueous media within 5 hr. This was comparable to the use of a commercial activated carbon in removing 98% of malathion and profenofos residues. In addition, activated carbon from tangerine peels (TPAC) successfully removed acetamiprid in aqueous solutions (*Mohammad et al. 2020*).

Table 6. Results of pesticide residue analysis using High Performance Liquid Chromatograph (HPLC)..

Methomyl Rinsate	Methomyl, ug mL <sup>-1</sup>			% Removal
	Trial 1	Trial 2	Mean	
Untreated	7.458	7.603	7.5305	
PPAC-treated (0.5% w/v)	0.281	0.319	0.3	96.0
PPAC-treated (0.8% w/v)	0.241	0.230	0.2355	96.9
PPAC-treated (1.0% w/v)	0.136	0.136	0.136	98.2
PPAC-treated (1.0% w/v)	0.129	0.110	0.1195	98.4
JTBAC-treated (1.0% w/v)	0.042	0.042	0.042	99.4

### Characterization using Scanning Electron Microscopy (SEM)

The unactivated carbon and the final activated carbon (PPAC) used were analyzed using Scanning Electron Microscopy to validate that the activation was successful. Comparison of the surface morphology of the carbon before activation (**Figure 1**) and after activation (**Figure 2**) confirmed the successful production of activated carbon from pineapple peel. The activation using 30% H<sub>3</sub>PO<sub>4</sub> resulted in obvious cracks and cavities on the external surface. The process of impregnation and activation resulted to the collapse of the microstructure.

A prototype packaging material was developed and the trade name “PestiSorb” was coined, a combination of the words “pesticide” and “adsorb” (**Figure 3**).

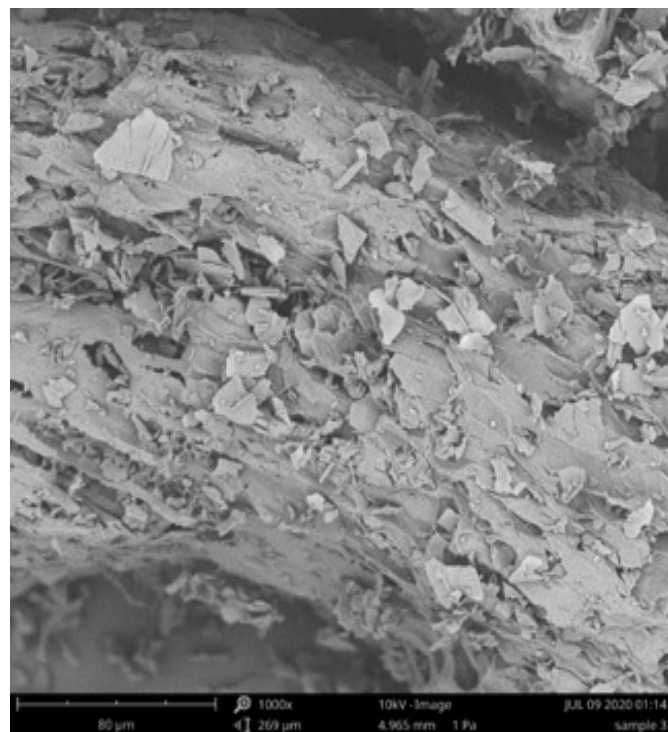


Figure 1. Surface morphology (1000X) before activation of Powdered Pineapple Peel Carbon (PPAC).

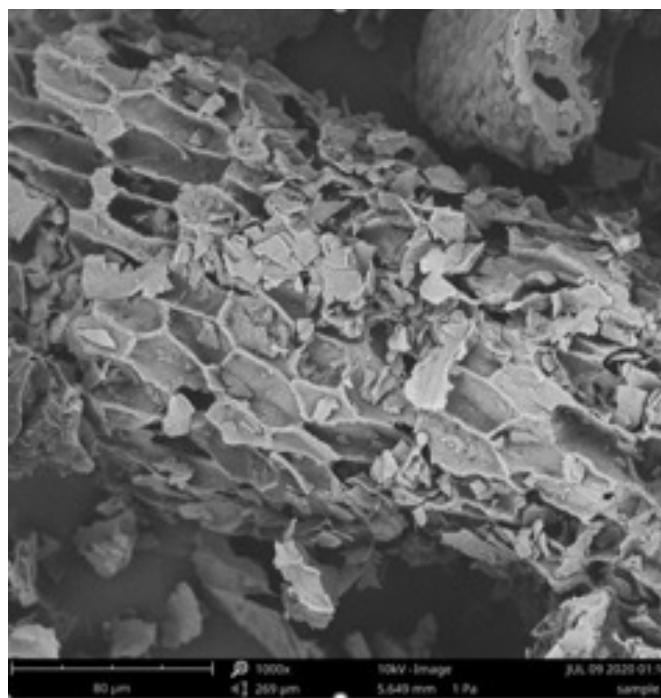


Figure 2. Surface morphology (1000X) of Pineapple Peel Activated Carbon (PPAC).



Figure 3. Prototype packaging for Pineapple Peel Activated Carbon.

## CONCLUSIONS AND RECOMMENDATIONS

Pesticides are one of the crop protection tools included in the Integrated Pest Management (IPM). The use of pesticides leads to the generation of dilute pesticide solution from the cleaning of pesticide application equipment, also known as pesticide rinsate. If not disposed properly, this may contribute to the contamination of surface water or groundwater through run-off, leaching, or direct disposal. This study investigated the utilization of an agricultural waste as starting material to produce activated carbon which could potentially remove pesticide residues in the rinsate, making it cleaner and more environmentally safe to dispose.

This study showed that activated carbon could be successfully prepared from pineapple peel and used as an effective adsorbent for the remediation of pesticide rinsate. It is recommended that the production of activated carbon from other types of agricultural wastes to remove different pesticides and other pollutants from water be studied. In addition, the use of pineapple peel activated carbon for the treatment of various contaminants in wastewater could be investigated. Lastly, the farmer's knowledge, attitude, and practices in the disposal of pesticide rinsate from various vegetable-producing areas in the Philippines could be assessed and the social acceptability of the use of activated carbon in farm operations be evaluated.

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