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The Kinetics Of The Adsorption Of Zinc In Sanitary Leachate Using Mango Seeds (Mangifera Indica) As Synthetic Activated Carbon For Treatment

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Abstract— *Mangoes are one of the most popular products in Cebu City. They are used in food, cosmetics, and occasionally in the furniture-making industry, which increases their demand each year. This study aims to find an alternative solution to its rising waste problems by turning its seed part into another product to treat Zinc, one of the prevailing minerals in sanitary leachate, because of its electronic waste composition. These mango seed wastes were processed into activated carbon through physical activation, placing it in the furnace at a temperature of 800°C with a controlled oxygen environment. They were tested for adsorption by placing the produced synthetic activated carbon on top of the filter paper in the funnel. Then, a liquid containing the synthetic Zinc with a concentration of 0.13 ppm was poured into the funnel. It showed that after 24 hours in the rotary shaker, the zinc concentration was significantly reduced to an average of 92.83%, revealing that the mango seed is an outstanding material for activated carbon. Mango seed wastes from industries have great potential as a source of activated carbon that influences the treatment of sanitary leachates with a higher concentration of Zinc.*
Keywords— *Activated Carbon, Adsorption, Mango Seeds, Sanitary Leachate, Zinc.*

1. INTRODUCTION

Cebu Province, Philippines, is known to be the country's mango food processing exporter and producer, with millions of tons of mango waste per year comprising commercial establishments, public markets, and industries (Ancog, R. et al. 2012). Mango raw fruits and mango food processing are the main export businesses in the province of Cebu. According to the Philippine Department of Agriculture data 2018, the country produces one million (1,000,000.00) tons of mangoes yearly, half processed into assorted products: dried, pureed, and others. Cebu province alone produces an average of 250 metric tons to 500 metric tons of mango waste, which is composed of seeds and skin. Various studies of mango waste, particularly on the peels, skin, and kennel part of the mango waste, have already been discovered by using it as a substitute in making flour, banana chips, etc.

1.1 History, Laws, and Regulations of Sanitary Landfills in the Philippines

Today, sanitary landfill area increases parallel to its demographic increase in population growth rate per year, producing more sanitary landfill leachates that need to be treated by the Department of Natural Resources, Department Administrative Order 16 (DENR DAO 16) guidelines on water quality of effluents. When precipitation emerges in the sanitary landfill during the storm, it produces sanitary landfill leachates that are composed of many different kinds of mixed pollutants, and one of its major pollutants is Zinc, which has a content in the range of 0.03-1000 mg/L (Kjeldsen et al., 2002). In response to the increasing problems in treating sanitary leachate, much previous research about low-cost sorbents came up for water treatment. The increased awareness of the importance of providing impacts due to the environmental strategies has pushed the research community towards developing robust, economically feasible, and environmentally friendly processes capable of removing pollutants from water and, at the same time, safeguarding the health of affected populations. (De Gisi, S. et al. 2016). One of the agencies, the Department of Environmental and Natural Resources - Department Administrative Order -16 (DENR-DAO 16) water quality guidelines main requirement is to reduce Zinc according to the discharge point category.

1.2 Effects of Zinc

1.2.1 Human Effects

Zinc is a significant element of the human body, mainly found in the skeletal, muscle, kidney, gastrointestinal, skin, heart, pancreas, and brain. The human body contains an average of 2-3 grams of Zinc and can sustain an amount of zinc intake, ingest, or inhale with 11mg for males and 8mg for females (National Institute of Health, 2022). Excess zinc exposure or intake can cause severe effects on the human body. The following are the effects of excessive intake of Zinc (Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine, 2005)

Brain

1. Lethargy
2. Local Neuronal Deficits

Respiratory Tract

1. Respiratory Disorder After Inhalation of Zinc Smoke
2. Metal Fume Fever

Gastrointestinal Tract

1. Nausea/Vomiting
2. Epigastric Pain
3. Diarrhea

Prostrate

1. Elevated Risk of Prostate Cancer

1.2.2 Marine Aquatic Effects

The high dosage of Zinc significantly affects marine aquatic sources in oceans and seas. Different studies have also shown that high dosages of Zinc in freshwater environments also critically affect the ecosystem's ecological cycle. When the dose of Zinc exceeds a certain amount, it may cause adverse effects on the organisms (Lindholmer, 1974; Smirnova & MelNichenko, 1997; Wadige et al., 2017) and continuously affects the whole ecological cycle of the aquatic resources affected by the food chain. Based on the US EPA (United States Environmental Protection Agency) water quality guidelines to protect freshwater aquatic organisms, 0.12 mg/L is acceptable for short-term hazardous concentrations, and 0.12 mg/L is acceptable for long-term hazardous concentrations.

1.3 Adsorption Capacity and Efficiency of Activated Carbons

The treatment of Zinc found in liquid or gaseous effluents by using adsorption in activated carbon or other adsorbent materials has been studied by several researchers, including Bernal and Lopez-Real (1993), Turner et al. 1994, Saiki et al. 1994 and El-Nabarawy et al. 1997. Activated carbons are the most versatile and commonly used adsorbents because of their extremely high surface areas and micropore volumes, large adsorption capacities, fast adsorption kinetics, and relative ease of generation (Prahas D. et al., 2008). In developing a synthetic AC, it goes through a physical process in a regulated heat and oxygen called Carbonization. Carbonization is a heat treatment at 400-800 degrees C which converts raw materials to carbon by minimizing the content of volatile matter and increasing the carbon content of the material. This increases the material's strength and creates an initial porous structure, which is necessary if the carbon is to be activated (Kibami D. et al., 2017). This mango seed waste is placed in a furnace to heat at a specific temperature until there is a constant pH level. Adsorption is a mass transfer process that involves the accumulation of substances at the interface of two phases, such as liquid-liquid, gas-liquid, gas-solid, or liquid-solid interface (De Gisi S. et al., 2016). AC is extensively used as an adsorbent due to its prominent level of effectiveness, but it is more expensive and has high usage costs; this led many researchers to search for inexpensive and locally available adsorbents so that the process can become economically feasible (G. Vijayakumar et al., 2012). In solution to the expensive imported AC and tons of mango seed waste from mango manufacturers, instead of burying and waiting for them to decompose in sanitary landfills, these wastes are turned into synthetic ACs to help resolve the increasing problem of sanitary leachate treatment of sanitary landfills. The adsorption equilibrium capacity can quantify the affinity of an adsorbent on the adsorbate.

1.4 Other Materials Used to Make Activated Carbons

There is much further research in finding alternative raw material sources for activated carbon to push through its low-cost but efficient and effective AC. Bioproducts such as rattan sawdust, jackfruit peel, coconut husk, rubber wood sawdust, oil palm fiber, waste apricot, sugar beet bagasse, etc., have already been studied by other researchers and showed significant porous structures that are capable of more monolayer surface coverage for adsorption capacities and its rate. The chemical activation process of coconut husk, sawdust, and jackfruit peels has already been studied by previous researchers to treat other heavy metallic elements aside from Zinc, like lead, copper, and nickel, which showed that it requires an impregnation process to increase its adsorption kinetics. The increase in activation temperature will make several functional groups decompose to form CO and CO2. Carbonization is a heat treatment at 400-800 °C that converts raw materials to carbon by minimizing the content of volatile matter and increasing the carbon content of the material (D. Kibami et al. 2017). Some of the carbonization processes are through the chemical process, which this phenomenon is due to the instability of acidic groups at high temperatures (D. Prahas et al. 2008).

1.5 Langmuir Adsorption Model

The Langmuir adsorption isotherm describes the equilibrium between the adsorbate and adsorbent system, where the adsorbate adsorption is limited to one molecular layer at or before a relative unity pressure is reached. Although the isotherm initially proposed by Langmuir in 1918 is generally suitable for describing the chemisorption process when ionic or covalent chemical bonds are formed between the adsorbent and the adsorbate, the equation is obeyed in many systems with moderately low coverage. It can be easily extended to describe the behavior of the binary adsorption system. Adsorption isotherms are performed by weighing a known amount of adsorbate in a fixed volume of liquid with different adsorbent doses. In addition, amber glass bottles (250–1000 L) with Teflon screw caps are used for aqueous-phase isotherms to prevent the loss of adsorbate because of volatility, light sensitivity, or adsorption onto the container. Moreover, if the adsorbent is granular, it needs to be a powder (Liu L., Lou, X. et al. 2019)

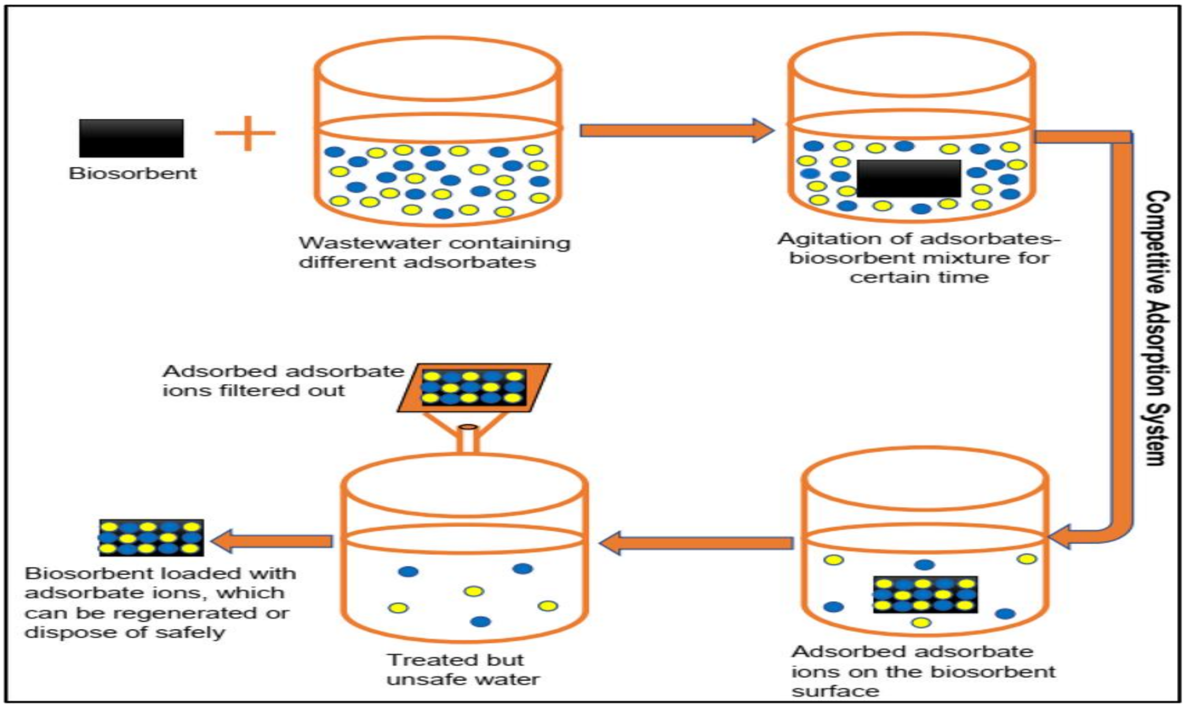

Fig 1. Schematic diagram showing competitive adsorption of adsorbate molecules from aqueous systems onto a sorbent material.

Source: Bayuo J. et al., 2023. Removal of heavy metals from binary and multicomponent adsorption systems using various adsorbents – a systematic review. Jpeg. Research Gate. https://www.researchgate.net/figure/Schematic-diagram-showing-competitive-adsorption-of-adsorbate-molecules-from-aqueous_fig7_370389936

2. MATERIALS AND METHODS

2.1 Source of Mango Seeds for Activated Carbon and Raw Sanitary Landfill Leachate Source

The experimental activity was conducted at the University of San Carlos and Cebu Technological University – Danao Campus (CTU-Danao), with guidance and help from my previous university under the Department of Chemical Engineering, Physics, and Chemistry and some of my colleagues at the Mechanical Engineering of Cebu Technological University, Danao Campus.

2.1.1 Mango Seeds

The mango seed waste samples were taken from the by-products directly in the factory and were packed in a tightly closed bag, which was composed of 30 seeds and sun-dried before being sent to the laboratory for work.

2.1.2 Raw Sanitary Leachate

Sanitary leachate samples were gathered at the source point of the sanitary landfill by immersing the pale of a trimmed water container and pouring into the tip of the water container for sampling in the leachate drainage before it reached its stagnant lagoon, waiting for the treatment process through the assistance of Prime Integrated Waste Solutions Incorporated (PIWSI) in Binaliw, Cebu City, Province of Cebu in their response to my case study for my master's degree. In determining the amount of concentration to be used as the basis for the synthetic Zinc in the laboratory experiment, it was submitted in a tightly packaged box to the USC Waterlab within 4 hours of the time of leachate extraction to prevent any technicalities and alterations of the results in the laboratory.

2.2 Preparation of Synthesis of Mango Seeds as Activated Carbon

2.2.1 Laboratory Preparation

There were at least three trial waste mango seed samples for each temperature to be synthesized as activated carbon, which is abundant in the City of Cebu. Before it was activated, the mango seed wastes were washed with distilled water to remove impurities and dried for 2 days in the sun. After being sun-dried, it was oven-dried for 6 hours to check its final moisture content. It was crushed in a pulverized machine to make it into a particle size based on the range of sieve no. 16 up to sieve no. 30 granular, then placed in the furnace at 800℃ heat temperature without oxygen for 6 hours. The procedure was repeated until three trials were achieved for each temperature. The finished activated synthetic AC was placed in a tightly concealed zip lock to prevent degradation and infection from the outside environment before transferring to the USC Chemical Engineering Laboratory. The AC was then placed inside the Erlenmeyer Flask in preparation for mixing with the synthetic Zinc through the rotary shaker.

2.2.2 Experimental Treatment of Synthetic Zinc in Laboratory Scale)

The ready-prepared synthetic Zinc was then poured into the Erlenmeyer Flask, where the activated carbon was placed. Each flask had a 50 mL solution containing the synthetic Zinc with 150 mL of synthetic AC. After the synthetic activated carbon and Zinc were placed inside the Erlenmeyer flask, it was set up inside the rotary shaker to begin mixing for the adsorption test, starting at six (6) hours. After six (6) hours of mixture, the solution was extracted, and the zinc concentration was determined and measured. The process is repeated for 6 hours and 12 hours with three (3) trials to check the precision and accuracy of the results.

2.3 Adsorption Rate Calculation

The adsorption rate at the time will be calculated using the following formula:

$$q_t = \frac{(C_0 - C_t)V}{W}$$

(Bernard, P., Chahine, R. 2008)

qt = Adsorption Rate at a Given Time
Co = Initial Concentration
Ce = Concentration at Equilibrium
W = Mass of the Activated Carbon
V = Volume of the Activated Carbon

Where Ct (mgL-1) is the liquid phase concentration of synthetic Zinc at any given time, C0 (mgL-1) is the initial concentration of the synthetic Zinc ion in the solution. V is the volume of the solution (L), and W is the mass of the dry synthetic AC mango seed kernel (g).

$$q_t = \frac{(C_0 - C_t)V}{W}$$

(Bernard, P., Chahine, R. 2008)
qe = Maximum Adsorption Rate
Co = Initial Concentration
Ce = Concentration at Equilibrium
W = Mass of the Activated Carbon
V = Volume of the Activated Carbon
The amount of adsorption will be calculated using the formula.

$$\%\text{ of synthetic zinc removal} = \frac{(C_0 - C_e)}{C_0} x100$$

(Bernard, P., Chahine, R. 2008)

Where C0 and Ce (mgL-1) are the liquid-phase concentrations of the synthetic Zinc initially and at equilibrium, and the percentage can be calculated using the formula

2.3.1 Evaluation and Testing on the Langmuir Adsorption Isotherm Model

The application of the Langmuir model to the adsorption of Zinc from leachate using synthetic activated carbon from Kernel seeds will be made using the following steps:

2.3.2 Experimental Data Collection

Data was collected from adsorption experiments using concentrations of synthetic Zinc in the leachate solution and specific adsorbent material. Measuring the equilibrium concentration of Zinc in the solution after adsorption at each initial concentration.

2.3.3 Calculation of the Fractional Surface Coverage (θ)

Determining the fractional surface coverage of Zinc (θ) on the adsorbent surface using the following equation:
θ = (Ce / Ceq)
(Bernard, P., Chahine, R. 2008)
where Ce is the equilibrium concentration of Zinc in the solution and Ceq is the equilibrium concentration at maximum adsorption capacity.

2.4 Langmuir Isotherm Model

Plotting the concentration of adsorbate at equilibrium (Ce) over the amount of adsorbed per amount of adsorbent (qe) versus the concentration at equilibrium (Ce)

$$\frac{1}{q_e} \text{ vs } \frac{1}{C_e}$$

2.4.1 Linearization of the Langmuir Equation

The Langmuir isotherm equation can be linearized using the equation:
Langmuir Equation Form 1

$$\frac{C_e}{q_e} = \frac{1}{Q_{max}(kL)} + \frac{C_e}{Q_{max}}$$

(Bernard, P., Chahine, R. 2008)

Langmuir Equation Form 2

$$\frac{1}{q_e} = \frac{1}{Q_{max}} + \frac{1}{(kL)C_e Q_{max}}$$

(Bernard, P., Chahine, R. 2008)

Qmax = Maximum Adsorption Capacity
kL = Langmuir Constant
Ce = Concentration at Equilibrium

where Qmax is the maximum adsorption capacity of the adsorbent. Plotting Ce / θ on the y-axis against Ce on the x-axis.

2.4.2 Determination of the Langmuir Constants

To determine the Langmuir constants, such as Qmax and the Langmuir equilibrium constant (K), the slope and intercept of the graph are compared to the equation mentioned in the previous step.

2.4.3 Validation of the Model

Using the Langmuir constants obtained to calculate the fractional surface coverage (θ) at different concentrations and then compare the calculated values with the experimental data to validate the Langmuir model's accuracy in describing the adsorption behavior of Zinc from leachate.

2.4.4 Assumptions

It is essential to note that the Langmuir model assumes ideal monolayer adsorption, and its applicability depends on the system and adsorbent properties. Further modifications or the consideration of other isotherm models may be required if the adsorption behavior deviates significantly from the assumptions of the Langmuir model.

3. RESULTS AND DISCUSSIONS

3.1 Weighted Sieve Analysis Results

The table below shows that the moisture content of the 30 pieces of raw mango seed waste from the industrial factories is at an average of 35.49%. Thus, it requires a drying process to reach at least 10% moisture content to be able to get the yield that is the best for the preparation of the activated carbon, given that, based on other researchers' studies, the mango kennel seeds' carbon content ranges from 49.8% to 96%. Moreover, in Table 1, the average weight of one mango seed is about 14.81 g, which is one of the parameters to determine the ratio of the number of seeds versus its efficiency in the adsorption process of the synthetic Zinc, whose concentration was based on the raw sanitary leachate.

Table 1 Raw mango seeds' weight and weight during sun dry and oven dry.

Weight of Pan, W_p (kg)		0.210	Sun Dry	2	Days	Temp.	32-37	Celcius
No. of Seeds per Bag, n		30	Oven Dry	6	Hours	Temp.	100	Celcius
	Raw Data			Sun Dry		Oven Dry		Final
Bag No.	Weighted Value, W_g (kg)	Initial Weight, W_i (W_g - W_p) (kg)	Average Weight per seed (kg)	Weight w/ Pan	Weight Sun Dry, Ws (kg)	Weight Oven Dry, W_{od} (kg)	Weight of Water Content, W_f (W_i - W_s - W_{od}) (kg)	Average Weight per seed (kg)
1	0.890	0.680	0.022666667	0.830	0.620	0.434	0.246	0.01447
2	0.900	0.690	0.023	0.880	0.670	0.443	0.247	0.01477
3	0.890	0.680	0.022666667	0.840	0.630	0.412	0.268	0.01373
4	0.900	0.690	0.023	0.880	0.670	0.419	0.271	0.01397
5	0.910	0.700	0.023333333	0.790	0.580	0.398	0.302	0.01327
6	0.870	0.660	0.022	0.810	0.600	0.404	0.256	0.01347
7	0.920	0.710	0.023666667	0.900	0.690	0.457	0.253	0.01523
8	0.910	0.700	0.023333333	0.910	0.700	0.473	0.227	0.01577
9	0.880	0.670	0.022333333	0.790	0.580	0.428	0.242	0.01427
10	0.890	0.680	0.022666667	0.890	0.680	0.505	0.175	0.01683
11	0.910	0.700	0.023333333	0.900	0.690	0.422	0.278	0.01407
12	0.890	0.680	0.022666667	0.830	0.620	0.389	0.291	0.01297
13	0.910	0.700	0.023333333	0.900	0.690	0.466	0.234	0.01553
14	0.900	0.690	0.023	0.860	0.650	0.452	0.238	0.01507
15	0.890	0.680	0.022666667	0.810	0.600	0.413	0.267	0.01377
16	0.930	0.720	0.024	0.860	0.650	0.449	0.271	0.01497
17	0.880	0.670	0.022333333	0.840	0.630	0.473	0.197	0.01577
18	0.910	0.700	0.023333333	0.880	0.670	0.496	0.204	0.01653
19	0.980	0.770	0.025666667	0.890	0.680	0.421	0.349	0.01403
20	0.920	0.710	0.023666667	0.860	0.650	0.401	0.309	0.01337
21	0.920	0.710	0.023666667	0.870	0.660	0.451	0.259	0.01503
22	0.980	0.770	0.025666667	0.970	0.760	0.531	0.239	0.01770
23	0.970	0.760	0.025333333	0.910	0.700	0.451	0.309	0.01503
24	0.960	0.750	0.025	0.930	0.720	0.441	0.309	0.01470
25	0.950	0.740	0.024666667	0.890	0.680	0.481	0.259	0.01603

Drying the seeds directly in the sun for 2 days lessens their moisture content to an average of 46 g, diminishes their stickiness, and stenches before it is laid in the oven to dry. When heated at a temperature of 100°C for over 6 hours in the oven dry, the average weight of the mango seed significantly dropped from 6.47% to 36.91%, as shown in Fig. 1. The determined final average weight of the mango seed is crucial to know its weight loss and changes during the physical activation process of the product.

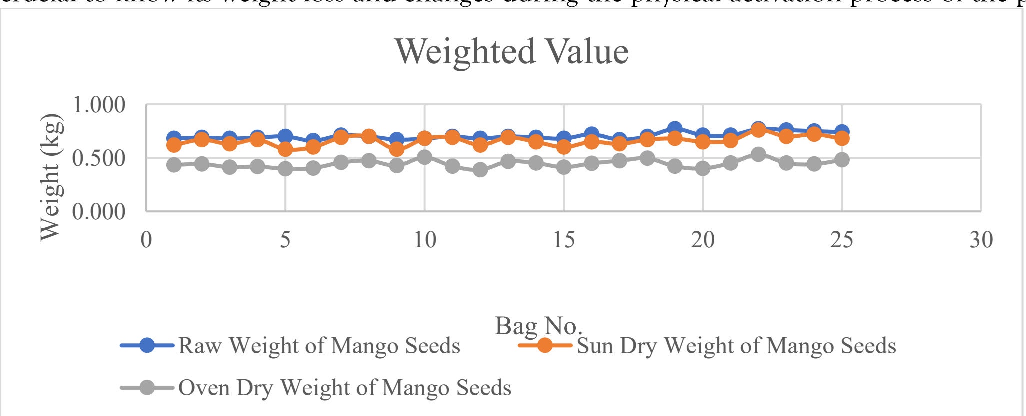

Fig. 2 Graphical presentation of the raw weight of the mango seed and its weight during the sun-drying and oven-drying process

Characterization results of mango seeds through proximate analysis from researchers showed that a single mango seed has a moisture content of 4.24±0.04%. At the same time, during the drying process, it was 1.98%, which has a difference of more or less 2.35% from the published results of other literature. According to Aaron Dzigbor and Annie Chimphango, characterization results of mango seeds regarding volatile matter are predominantly very high, exhibiting a greater porosity. Subsequently, the activated carbon's higher surface area is produced in chemisorption, which depends on the surface coverage.

3.2 Experimental Study of Zinc in Sanitary Leachate

Table 2 Raw sanitary leachate results of zinc concentration

<table>
<tr><td>No. of Trials per Sample = 2</td><td colspan="2">Sample 1</td><td colspan="2">Sample 2</td><td colspan="2">Sample 3</td></tr>
<tr><td>Zinc (mg/L)</td><td colspan="2">0.09</td><td colspan="2">0.13</td><td colspan="2">0.07</td></tr>
<tr><td>Average Zinc Concentration (mg/L)</td><td colspan="6">0.09667</td></tr>
<tr><td rowspan="3">Allowed Zinc Concentration According to Water Classification for Marine Waters (DAO2016-08)</td><td>SA</td><td colspan="2">SB</td><td colspan="2">SC</td><td>SD</td></tr>
<tr><td>0.04</td><td colspan="2">0.05</td><td colspan="2">0.8</td><td>1.5</td></tr>
<tr><td>FAIL</td><td colspan="2">FAIL</td><td colspan="2">PASS</td><td>PASS</td></tr>
</table>

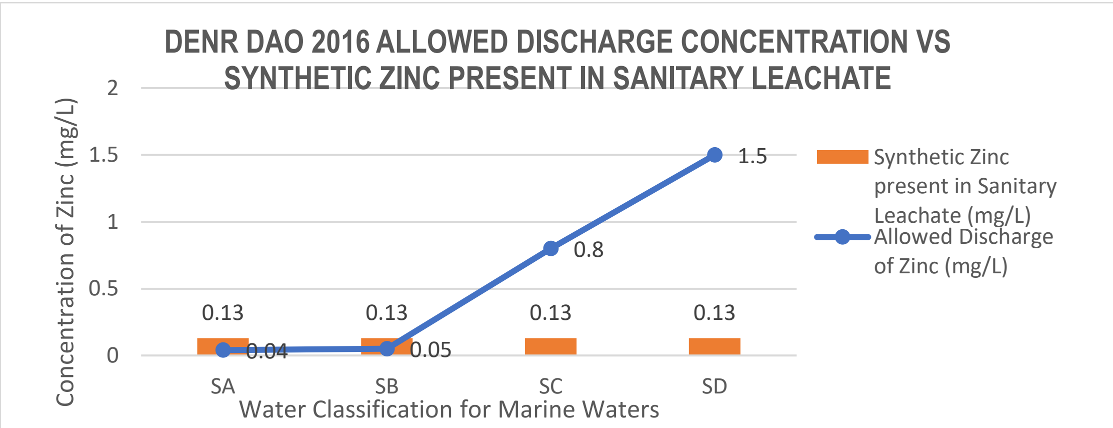

Fig. 3 Graphical representation of DENR DAO 2016 vs zinc concentration in sanitary leachate

The raw sanitary leachate resulted in high zinc concentrations that are not allowed, particularly in the SA and SB, which have intended beneficial use for fishery water class I and protected waters, while SB is for fishery water class II, and tourist zones for skimming, swimming, bathing, skin diving, etc. The highest concentration of Zinc in the test results of the raw sanitary leachate samples, which is 0.13 mg/L, is used in the modelling of the synthetic zinc concentration for laboratory procedures to test the zinc adsorption efficiency of the synthetic activated carbon made from waste mango seeds. The benchmark was used to have substantial results.

Table 3 Physical activation results and efficiency results of synthetic mango seeds adsorption to zinc

PHYSICAL AC ACTIVATION						EXPERIMENTAL VALUES							
TEMPERATURE			ZINC	PARTICLE SIZE		Wt. of Flask (g	117.882	Wt. of 200 mL soln of Zn (g)	179.908		Final Concentration of Zinc, C_e (mg/L)		
AC Activation Temperature (°C)	No. of Hours	Trial	Initial Concentration, C_i (mg/L)	Sieve No.	Average Size of Particle (mm)	Volume of Synthetic Zinc, V_{Zn} (mL)	Volume of Activated Carbon, V_{AC} (mL)	Weight of Flask + Activated Carbon, Wt (g)	Weight of Activated Carbon, W_{AC} (g)	Rotary Shaker (Hours)	C_e (mg/L)	Percentage Removal (%)	Adsorption Rate
800°	6	1	0.13	#16 - #30	0.5	200	50	131.636	13.754	24	0.009	93.076923	0.00175949
	6	2	0.13	#16 - #30	0.5	200	50	134.442	16.56	24	0.009	93.076923	0.00146135
	6	3	0.13	#16 - #30	0.5	200	50	135.12	17.238	24	0.01	92.307692	0.00139227

The physical activation process was used in producing the synthetic activated carbons, and bag samples no. 7, 8, and 9 were used for the activation process at a temperature of 800°C. After the process, the weight of the synthetic AC using mango seeds measured a difference of 31.946g, 30.74g, and 25.56g, which is 30.09%, 35.01%, and 40.28%, respectively. These show that the activation process reduced the weight of the raw material after the process, suggesting that the composition of the mango seed has a watery substance.

The result shows that upon mixing the synthetic activated carbon and Zinc and placing them in a rotary shaker for 6 hours, 12 hours, and until it reaches its equilibrium state at 24 hours with a constant speed of 50 rpm, an average percentage removal of 92.82% was observed from the liquid substance, where the initial concentration was 0.13 mg/L (ppm) after from the experimental procedure its final concentration was 0.009 mg/L (ppm), showing that the material mango seed as the raw material for activated carbon has sufficient porous structure when physically activated at a temperature of 800°C to effectively attract Zinc through physisorption, without altering any of its pore structures by impregnation. It also indicates that the AC can be reused for another batch process since physisorption is reversible, unlike the chemisorption process. The results also show that the average adsorption rate of the synthetic activated carbon is 0.0015377.

3.3 Langmuir Model

Table 4 Mass of adsorbate and adsorption rate of the adsorbent

Mass of Adsorbate (mg)	Ce Final Concentration	1/Ce	qe (mg/g)	1/qe	Ce/qe
0.0242	0.009	111.1111	0.001759	568.3471	5.115124
0.0242	0.009	111.1111	0.001461	684.2975	6.158678
0.024	0.01	100	0.001392	718.25	7.1825
Intercept	1545.6				
kL	0.005352937				
Slope	-8.2735	Dimension Index	0.999305		
Qmax (mg/g)	0.120867831				

The adsorbent shows a massive percentage drop in concentration at the equilibrium of the adsorption process, with an average drop of 0.1207 mg/L, a 92.82% difference from the initial concentration of Zinc. The mass of the adsorbate also appeared to have a constant weight of 24.2g, defining a ratio of every average of 15.85g of adsorbent; at least an average of 24.2g of adsorbate of Zinc is present. A graphical representation in Fig. 2 of the equilibrium of the concentration at 24 hours area versus the maximum adsorption.

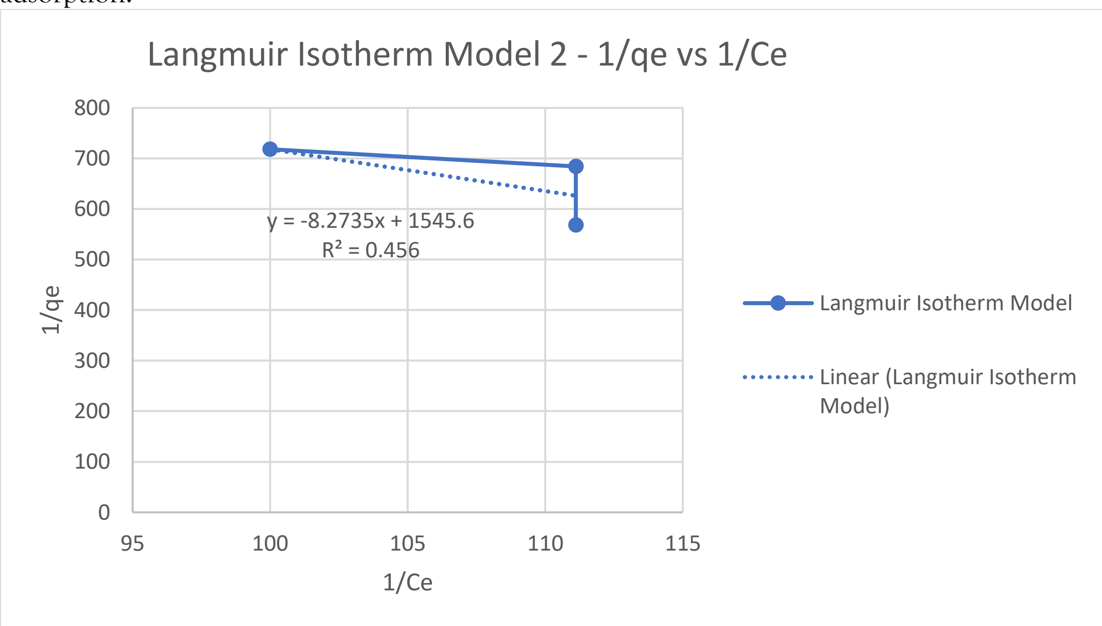

Fig. 4 Graphical representation of the Langmuir Isotherm Adsorption

The graphical demonstration in Fig. 2 also shows that the Langmuir isotherm model number is suitable for modeling its kinetics of adsorption of the AC mango seed. The values of maximum adsorption capacity, Qmax, and Langmuir constant, kL, were obtained from the intercept and slope, respectively (Mehr, M. et al., 2019) as shown in Figure 2, where the approximate value of Qmax by computation, the maximum adsorption capacity is 0.120867831 mg/g with a Langmuir constant of, kL of 0.005352937. The Dimension Index (R1) is used to test the usability of the Langmuir equation and is expressed as R_1=1/(1+kC_o). If the value is R1>1, the model is inappropriate; if R1=1, it is appropriate as the linear model; if 0<R1<1, the model is suitable; and if R1=0, the model is inefficient (Mehr, M. et al., 2019). Based on the data, the Dimension Index result is R1=0.999305, which signifies that the Langmuir Isotherm equation is appropriate for modeling the adsorption of the AC-MS. Furthermore, the R-squared value of the graph, as shown in Figure 2, presents a 0.456 moderate correlation between the linear model and the dependent variables.
Therefore, the modeling equation for the kinetics of zinc adsorption of the AC mango seed is in the form of Langmuir Isotherm equation number 2, shown in Figure No. 3 below.

$$\frac{1}{q_e} = \frac{1}{0.121} + \frac{1}{(0.00535)(0.121)C_e}$$

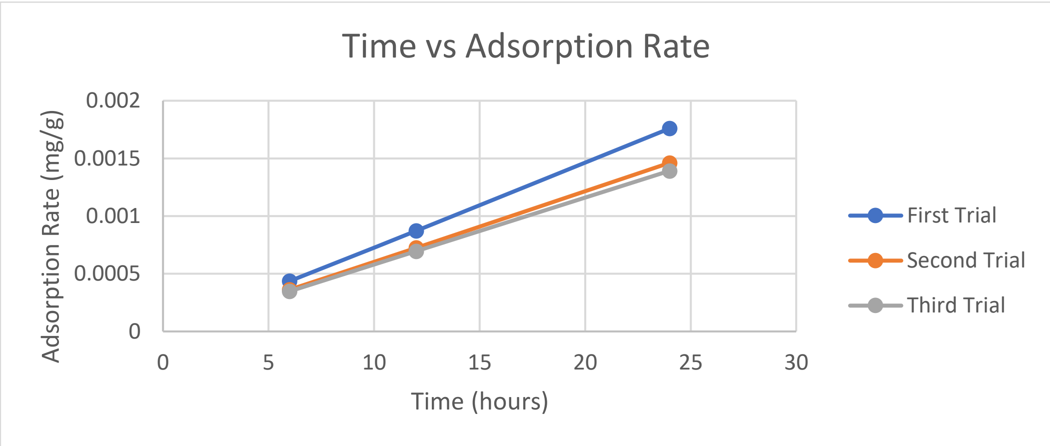

Fig. 5 Graphical representation of the time and its rate of adsorption
As time increases during the agitation of the synthetic AC and synthetic Zinc, the adsorption rate increases until it reaches its equilibrium stage at 24 hours, confirming the previous study's statement that adsorption reaches equilibrium at 24 hours.

4. CONCLUSIONS

The AC-MS that is physically activated at a temperature of 800°C and size mesh number between No. 16 and No. 30 shows a good interaction with Zinc as an adsorbent, effectively reducing the zinc concentration in a synthetic aqueous solution. Then, it was perfectly fitted in the Langmuir isotherm model, stating that the computed dimension index of the graph is relatively 1.
Its approximate adsorption rate of 0.000894776 mg/g*min, in fact, significantly reduced its initial concentration to an average of 92.82% of its initial concentration with an average mass of the adsorbate of 0.0242 grams in an AC-MS weight of 15.85 grams.
The adsorption capacity of the AC-MS is close to 0.00154 mg/g concerning the mass of adsorbate present in the adsorbent and the zinc concentration removal in the aqueous solution. The results of the adsorption capacity, percentage removal, and adsorption rate, the MS as a synthetic AC has proven a high-efficiency rate in the interaction of zinc removal from wastewater, given a 15.81:0.00089 average ratio between the weight of the AC-MS and the adsorption rate upon reaching the equilibrium. Further, the impregnation caused by adding chemicals to improve the surface area in making the AC-MS is already unnecessary due to its high-efficiency rate at a natural state of activation.
That waste mango seed can be used as a synthetic AC through a thorough drying process to treat Zinc. The adsorption rate of the waste mango seed AC shows excellent results. It has consistently shown good adsorption kinetic results based on its adsorption rate, percentage removal, and adsorption capacity.

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