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A STUDY ON BEHAVIOUR OF BAMBOO CHARCOAL IN HUMAN URINE TREATMENT AND CORROSION INHIBITION

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Abstract: This research is to study the behaviour of bamboo charcoal in urine treatment and corrosion inhibition. The analysis of Scanning Electron Microscopy was utilised to analyse the microstructure and macrostructure pores within bamboo charcoal. The images obtained from the analysis showed that bamboo charcoal had a large amount of pores and hence had high adsorption capacity. Besides that, analysis of X-ray Fluorescence (XRF) showed that bamboo charcoal consisted of several minerals. Potassium, calcium, manganese, iron, copper and zinc were found in bamboo charcoal. In order to carry out the urine treatment process, a simple filtration apparatus was set up in which bamboo charcoal was the main adsorbent. Human urine samples which were filtrated or infiltrated were then analysed by spread-plate method. The result of the spread-plate method showed that the amount of bacteria colonies in untreated urine sample decreased after treatment. Bamboo charcoal had efficiently adsorbed and prevented the growth of bacteria in the urine samples. Steel nails and bamboo charcoal were prepared for corrosion process. The Electrochemical Impedance Spectroscopy (EIS) was used to analyse the steel nails. The percentage inhibition efficiency of bamboo charcoal was also calculated. The result from EIS showed that the more bamboo charcoal used in the water, the lower the corrosion rate of steel nails while the result of calculation for percentage inhibition efficiency showed that the more bamboo charcoal used, the higher the percentage of inhibition efficiency. As a summary, this study showed that bamboo charcoal was a good adsorbent in urine treatment and an efficient corrosion inhibitor.

KEYWORDS: *Bamboo charcoal; urine treatment; corrosion inhibition*

Introduction

Bamboo charcoal is becoming increasingly popular, especially in countries such as Singapore, China and Japan, as a healthy product. It is made from bamboo by burning bamboo at high temperature with little air in a furnace (Estill *et al.*, 2005). Compared with other charcoals, bamboo charcoal has better adsorption capacity. This is because bamboo charcoal has a larger amount of pores. It is widely used in removing odour from smelly places such as footwear, bathrooms and kitchens. It is also placed in the fridge to maintain the freshness of fruits and vegetables by adsorbing ethylene gas (Estill *et al.*, 2005). Many previous studies have proven that bamboo charcoal is a good adsorbent. Bamboo charcoal can adsorb 2, 4-dichloro-hydroxybenzene which is a pollutant in drinking water (Jiang, 2004). Bamboo charcoal has also proven its adsorption ability in adsorbing sulfur in fuels (Zhao *et al.*, 2008a, Zhao *et al.*,2008b, Zhao *et al.*,2008c), is an excellent adsorbent for the pre-concentration of atrazine and simazine at trace level from environmental water samples and is an efficient solid-phase adsorbent for the enrichment and determination of perfluorooctanoic acid in water samples. Bamboo charcoal has better adsorption capacity of nitrate-nitrogen from drinking water than commercial activated carbon. Mizuta and his colleagues have also shown that bamboo charcoal is less dependent on temperature compared to activated carbon (Mizuta *et al.*, 2004). Bamboo charcoal is very useful for soil improvement as it contains antibacterial ingredients like benzoquinne and acetic. Therefore, it can prevent growth of bacteria in soil according to a study of Takehiko (1999). Bamboo charcoal can be used for promoting crop growth, accelerating its sprouting, improving its quality and production. The source of minerals which are contained in bamboo charcoal can also be dissolved into the soil and hence enrich the soil with minerals. Because of the good adsorption capacity and antibacterial properties of bamboo charcoal, it was tested on its ability to treat urine in this study. Bamboo charcoal can also emit negative ions according to Lou and his friends in their research (Lou *et al.*, 2007). Hence, it was tested on its behaviour in corrosion inhibition of steel nails because it was believed that the negative ions which are emitted by the bamboo charcoal could prevent the oxidation process of corrosion. Corrosion-inhibition efficiency of bamboo charcoal was calculated. It is the efficiency of a corrosion-inhibitor to prevent corrosion or delay the corrosion process to occur. The corrosion-inhibition efficiency could be calculated using Equation 1 (Rosliza *et al.*, 2008) in percentage. The i'_{corr} was the corrosion current density with inhibitor whereas i_{corr} was the corrosion current density without inhibitor.

$$IE\ (\%) = 100\ (1 - \frac{i'_{corr}}{i_{corr}}) \qquad (1)$$

The objectives of this study was to investigate and identify the morphology and minerals within bamboo charcoal, to count the bacteria colony in human urine before and after treatment by spread-plate method and to evaluate the corrosion-resistance behaviour of bamboo charcoal. Scanning Electron Microscopy (SEM) and X-ray Fluorescence (XRF) were used to determine the morphology and minerals in bamboo charcoal. Simple filtration method was used to carry out experimental method for urine treatment while spread-plate method was used to analyse urine samples before and after treatment. Steel nails were used as samples in corrosion process. Electrochemical Impedance Spectroscopy (EIS) was then used to analyse the steel nails and their corrosion rates were observed. The percentage inhibition efficiency was also calculated to determine the efficiency of bamboo charcoal as an inhibitor.

Experimental Method

There were a few experiments carried out in this study in order to investigate the morphology of bamboo charcoal, the minerals in bamboo charcoal, the behaviour of bamboo charcoal in urine treatment and the behaviour of bamboo charcoal as an inhibitor in the corrosion of steel nails.

Preparation of Bamboo Charcoal

Bamboo used for the research was taken from Kuala Terengganu areas at Kampung Tanjung Gelam, Mengabang Telipot. The bamboo is also known as *Bambusa Vulgaris* for its scientific name. The bamboo was cut into smaller sizes and carbonised in a nitrogen atmosphere at 700°C for 18 minutes.

Analysis of Morphology within Bamboo Charcoal

Morphology of bamboo charcoal was analysed using Scanning Electron Microscope (SEM) model JSM-6390LA. For the materials and samples preparation, bamboo charcoal was made into powdered form and put onto double-sided sellotape which was stacked on the surface of a stud. The stud was then put in a Petri dish and brought for gold-coating. After coating, the stud was put into a stud-holder and then placed into SEM. The sample was scanned with different magnifications of 250X, 500X, 2000X and 5000X. The images of the sample's structure were examined and saved.

Analysis of Minerals in Bamboo Charcoal

X50 mobile XRF Innox X System spectrometer was used in order to analyse the minerals in bamboo charcoal. Bamboo charcoal was made into powdered form and put in a sample-holder. Thin films were used to cover the top and bottom sides of the holder. The sample was then put into XRF spectrometer for analysis.

Urine Treatment

Urine treatment process was carried out by using filtration method. Bamboo charcoal was used as the main adsorbent in the filtration method. Soda bottle, gravels, sand, cheesecloth, powdered bamboo charcoal and human urine were prepared for the treatment process. For the analysis of bacteria counts, agar and saline were prepared in order to carry out the spread-plate method.

Filtration Method

The soda bottle was washed with Dettol in order to kill bacteria and then gripped upside down with a retort stand. Bamboo charcoal which was prepared earlier was put into the soda bottle. On top of the charcoal was the sand followed by stones. A set of the experimental set-up for urine treatment was prepared as shown in Figure 1 (National Aeronautics and Space Administration, 1998). Two sets of the experimental set-up were prepared for another two samples of human urine.

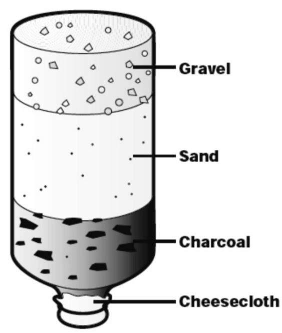

Figure 1. Experimental set-up for urine treatment

A sample of fresh human urine was collected and poured into the soda bottle for the filtration process. The filtrated urine was then collected with a sterile urine container which was put underneath of the mouth of the soda bottle. The collected urine was then poured back again to the soda bottle and filtrated again.

Bacteria Counting Analysis

Bacteria counting analysis was carried out by the spread-plate method. This method was used to analyse the bacteria colonies of treated and untreated urine. The amount of bacteria colonies was then compared.

Materials and Samples Preparation

In order to undergo the extraction and analysis of bacteria in urine, saline and agar were prepared. Saline was prepared by dissolving 1.02 g of Sodium Chloride (NaCl) into 120 ml of distilled water. The NaCl was then mixed thoroughly with the distilled water in a 1000 ml conical flask. The saline was then poured into twelve testing tubes with 9 ml of saline in each testing tube. The mouths of the testing tubes were covered with cotton and wrapped with aluminum foil. The testing tubes were labelled and brought for autoclaving in order to kill bacteria. Agar was prepared by dissolving 4.2 g of nutrient agar into 150 ml of distilled water in a conical flask. After mixing the mixture thoroughly, the mouth of the conical flask was covered with cotton and wrapped with aluminum foil. The conical flask was then put into an autoclave machine to sterilize it. After becoming sterile, the agar was poured evenly into twelve Petri dishes and left to dry. When the agar had dried thoroughly, samples for spread-plated method were prepared from the filtration method as discussed earlier.

Corrosion Inhibition

The mineral bottles were divided into four groups which consisted of 24 steel nails and 24 bottles. A group consisted of 12 bottles in which six bottles were used for analysis within the six weeks duration while another six bottles were used as backup in case any problem occurred during the analysis. Preparation of backup samples was important because steel nails should not be reused after one analysis. All the bottles were filled with 300 ml of tap water and steel nails were hung into the bottles dipping inside the water. It was important to make sure that the steel nails had no contact with the bottom of the bottles in order to ensure the steel nails were able to corrode evenly at every surface. 5 g, 10 g and 15 g of bamboo charcoal were weighed and placed into some bottles. The bottles were then placed on a flat surface at room temperature.

Electrochemical Impedance Spectroscopy (EIS)

Analysis of steel nails in water with 0 g, 5 g, 10 g and 15 g of bamboo charcoal was carried out once a week for the duration of six weeks. The analysis was carried out by using EIS. Electrochemical parameters and corrosion rates of steel nails were obtained and a graph of corrosion rate versus immersion time for steel nails in water with and without bamboo charcoal was drawn. The percentages inhibition efficiency of bamboo charcoal was also calculated.

Results and Discussion

In this section, all the results of SEM, XRF, spread plate method, EIS and percentage inhibition efficiency were displayed. Discussions were made for each of the results.

Analysis of SEM

The morphology of bamboo charcoal with different magnifications is shown in Figure 2, 3, 4 and 5.

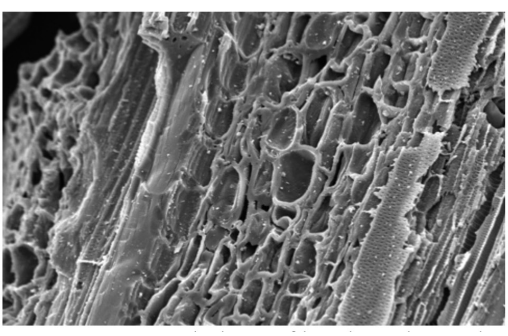

Figure 2. Morphology of bamboo charcoal with 250X.

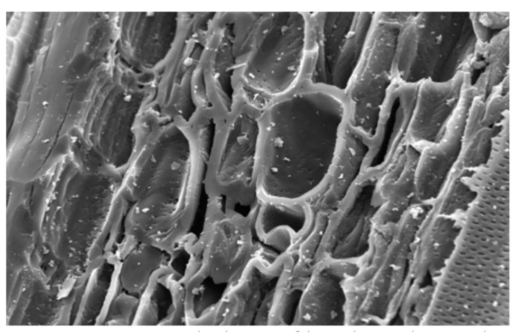

Figure 3. Morphology of bamboo charcoal with 500X.

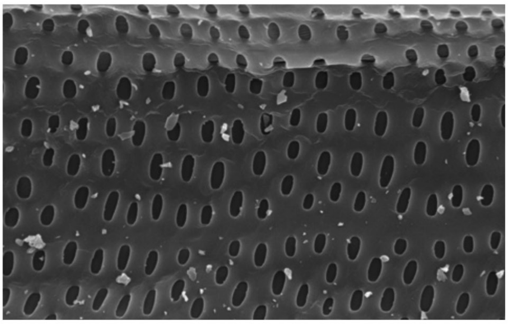

Figure 4. Morphology of bamboo charcoal with 2000X.

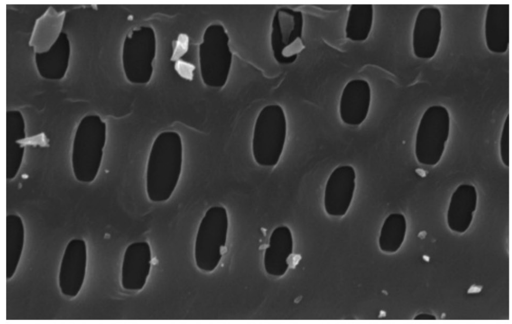

Figure 5. Morphology of bamboo charcoal with 5000X.

From the morphology of bamboo charcoal, it could be observed that there were a lot of pores within its structure. The images obtained in this study were similar to the images obtained from previous study (Wiriyaumpaiwong *et al.*, 2004). Large amount of pores enhanced the bamboo charcoal to have a high adsorption capacity.

Analysis of XRF Spectrometer

Results from XRF spectrometer showed that there were several minerals that existed in bamboo charcoal. The types of minerals with the unit of parts per million (ppm) are listed in Table 1.

Table 1. Mineral in Bamboo Charcoal

Mineral in Bamboo Charcoal	Parts per million (ppm)
Potassium (K)	6683
Calcium (Ca)	271
Manganese (Mn)	560
Iron (Fe)	47
Copper (Cu)	590
Zinc (Zn)	289

From Table 1, minerals such as potassium, calcium, manganese, iron, copper and zinc existed in bamboo charcoal. Those minerals which existed in the bamboo charcoal are essential elements, especially to the human body (Hayes, 2001). Potassium is needed by humans to maintain normal body stores and plasma levels, calcium is essential for strong bones, manganese can activate a wide variety of enzymes, iron is important for the formation of blood, copper is needed for formation of hemoglobin and zinc is a required component of many enzymes which is stored in bone and muscle.

Bacteria Counts

In the urine treatment section, spread-plate method was used to analyse the bacteria counts and the results are as shown in Table 2. Based on the results in Table 2, histograms were drawn for each sample and are as shown in Figure 6, 7 and 8.

Table 2. Number of Bacteria Colonies in Urine Samples before and after Treatment

Testing Tube	Urine Sample 1		Urine Sample 2		Urine Sample 3	
	Untreated	*Treated*	*Untreated*	*Treated*	*Untreated*	*Treated*
1	0	0	0	0	1	0
2	8	0	0	0	1	0
3	10	0	0	0	1	0
4	54	1	0	0	2	1
5	91	21	2	0	201	1
6	141	22	4	0	202	0

From Table 2, it could be observed that, when the number of times of diluents increased, the bacteria colonies increased. This showed that the more diluted the sample was, the more bacteria colonies could appear. However, urine sample two showed the least number of bacteria colonies at the last diluents when compared to urine sample one and three. This might be due to the fact that urine sample two was a healthy urine sample which consisted of less bacteria.

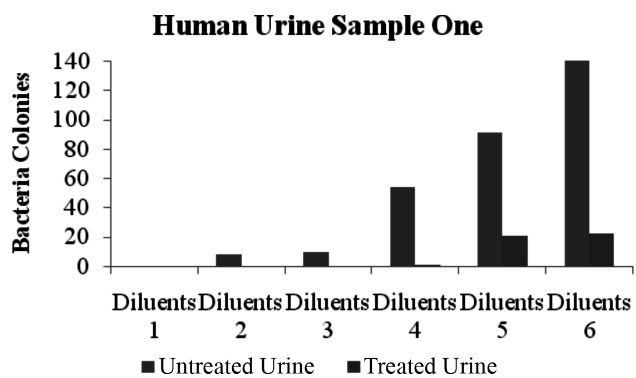

Figure 6. Bacteria colonies between treated and untreated urine sample 1

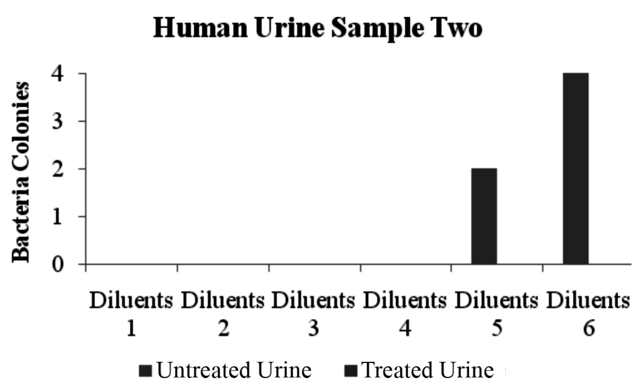

Figure 7. Bacteria colonies between treated and untreated urine sample 2

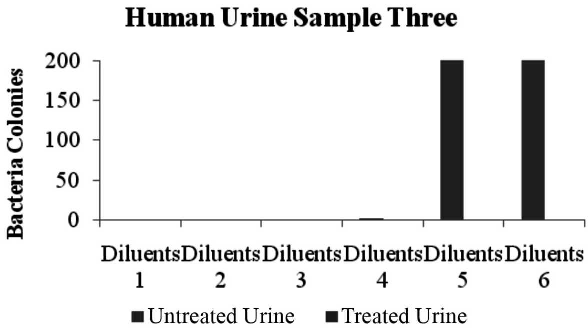

Figure 8. Bacteria colonies between treated and untreated human urine sample 3

Figure 6, 7 and 8 showed that the bacteria colonies in untreated urine samples had decreased after the samples went through treatment. This showed that bamboo charcoal had efficiently adsorbed the bacteria in the urine samples after treatment. For the diluents which consisted of no bacteria, they would remain with nil bacteria colony. This showed that the growth of bacteria had been prevented. Urine sample 3 consisted of the most bacteria colonies in the sixth diluents among all the samples. However, the bacteria colonies were fully adsorbed by bamboo charcoal after going through the filtration process. This showed the efficiency of bamboo charcoal in adsorbing a large amount of bacteria colonies in a urine sample.

Corrosion Inhibition

The electrochemical parameters which were obtained from the EIS analysis are listed in Table 3. The i_{corr} and i'_{corr} were then used to calculate the percentage inhibition efficiency of bamboo charcoal which are listed in Table 4.

Table 3. Electrochemical Parameters and Corrosion Rate of Steel Nail

Sample	Bamboo Charcoal (g)	Week	Electrochemical Parameters				Corrosion Rate (mm/yr)
			i_{corr} (μA/cm^2)	I_{corr} (μA)	R_p (kΩ)	E_{corr} (V)	
Steel nail	0	1	5.574	1.394	23.56	-0.549	$3.66x10^{-2}$
		2	3.192	0.7980	40.40	-1.079	$2.10x10^{-2}$
		3	2.248	0.5621	47.08	-1.100	$1.48x10^{-2}$
		4	1.538	0.3845	65.71	-1.089	$1.01x10^{-2}$
		5	1.729	0.4322	42.05	-0.758	$1.14x10^{-2}$
		6	2.588	0.6470	7.601	-0.525	$1.70x10^{-2}$
	5	1	2.143	0.5358	14.50	-0.670	$1.41x10^{-2}$
		2	1.069	0.2672	5.048	-1.052	$7.02x10^{-3}$
		3	0.6585	0.1646	48.03	-1.071	$4.33x10^{-3}$
		4	0.3386	0.08466	50.91	-1.084	$2.23x10^{-3}$
		5	0.2506	0.06266	43.20	-0.818	$1.65x10^{-3}$
		6	0.5068	0.1267	21.10	-0.520	$3.33x10^{-3}$
	10	1	0.8168	0.2042	15.79	-0.766	$5.37x10^{-3}$
		2	0.3531	0.08828	59.48	-1.045	$2.32x10^{-3}$
		3	0.1471	0.03677	95.04	-1.033	$9.66x10^{-4}$
		4	0.09667	0.02417	63.04	-1.078	$6.35x10^{-4}$
		5	0.07659	0.01915	34.33	-0.835	$5.03x10^{-4}$
		6	0.09514	0.02379	24.13	-0.769	$6.25x10^{-4}$
	15	1	0.1836	0.04590	25.42	-0.863	$1.19x10^{-3}$
		2	0.1012	0.02531	72.32	-1.026	$6.65x10^{-4}$
		3	0.05307	0.01990	58.78	-1.055	$3.43x10^{-4}$
		4	0.02781	0.006951	215.90	-1.052	$1.83x10^{-4}$
		5	0.01659	0.004148	41.47	-0.930	$1.09x10^{-4}$
		6	0.04311	0.01078	29.10	-0.526	$2.83x10^{-4}$

Table 3 showed the electrochemical parameters which were the corrosion current density (i_{corr}), corrosion current (I_{corr}), polarisation resistance (R_p) and corrosion potential (E_{corr}). It was observed that in the water with 0 g, 5 g, 10 g and 15 g of bamboo charcoal, i_{corr} generally decreased against immersion time. Same trend went to $I_{corr.}$ This was due to the increase of protectiveness of oxide on the surface of steel nail as a function of time (Kim & Cho, 1996). Increment in immersion time caused I_{corr} to decrease due to the protectiveness of the oxide. Since i_{corr} is defined as I_{corr} over the specific area of a sample, i_{corr} is directly proportional to I_{corr}. Hence, a reduction in I_{corr} caused a reduction of i_{corr}. From the corrosion rates obtained from EIS analysis, a graph of corrosion rate of steel nail versus immersion time in tap water was then drawn and is shown in Figure 9. Based on a proof from a previous study, corrosion rate changed proportional to i_{corr} (Kruger, 2001).

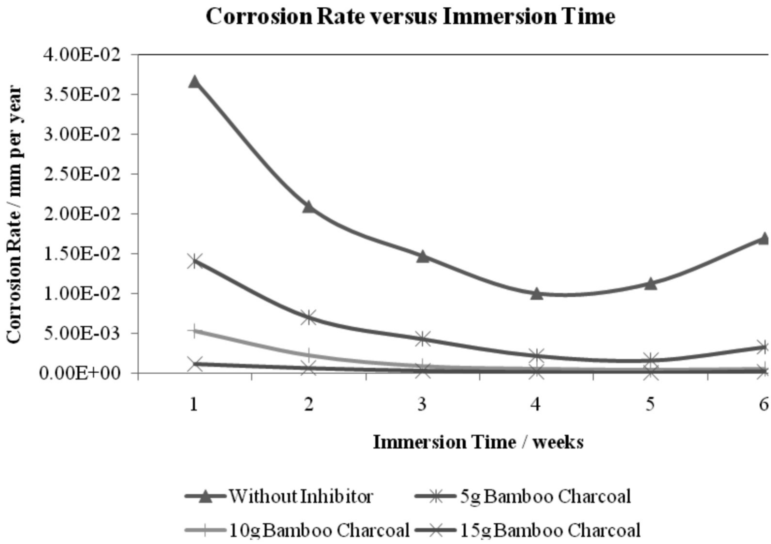

Figure 9. Graph of corrosion rate of steel nail versus time

From Figure 9, the corrosion rate of steel nails in water which contained no bamboo charcoal decreased for the first few weeks but increased again after that (Warren, 2006). For the steel nails in the water with 5 g, 10 g and 15 g of bamboo charcoal respectively, the corrosion rates had the same trend as the corrosion rate of steel nails in water without bamboo charcoal. These were due to the solubility of oxygen in the water. For the first week, large amount of solubility of oxygen in water caused the steel nails to corrode rapidly and hence the corrosion rates were high. In the following weeks, solubility of oxygen in water had decreased and hence the corrosion rates decreased. After week 4 and 5, the corrosion of steel nails had become severe and hence the corrosion rate increased. The corrosion rate in inhibited as well as uninhibited systems decreased with the increasing of the exposure time due to the contamination of the water environment by corrosion deposits that weakened the water and reduced the chemical reactivity. This tends to stifle further increases in the amount of corrosion relative to time (Abdallah, 2002). It was expected that, during extended study period, the corrosion rate continue to decrease until the entire corrosion mechanisms stop (Rosliza & Nik 2009). From the graph, it could also be observed that the corrosion rate of steel nail in water with more bamboo charcoal was lower than the corrosion rate of steel nail in water with less or without bamboo charcoal. This was due to the effectiveness of bamboo charcoal in inhibiting the corrosion of steel nail and hence delayed the corrosion rate.

Table 4. Percentage Inhibition Efficiency of Bamboo Charcoal

Sample	Week	Without inhibitor	With inhibitor (Bamboo Charcoal)					
			5g		10g		15g	
		i_{corr}	i'_{corr}	*IE (%)*	i'_{corr}	*IE (%)*	i'_{corr}	*IE (%)*
Steel Nail	1	5.574	2.143	61.55	0.8168	85.35	0.1836	96.71
	2	3.192	1.069	66.51	0.3531	88.94	0.1012	96.83
	3	2.248	0.6585	70.71	0.1471	93.46	0.05307	97.64
	4	1.538	0.3386	77.98	0.09667	93.71	0.02781	98.19
	5	1.729	0.2506	85.51	0.07659	95.57	0.01659	99.04
	6	2.588	0.5068	80.36	0.09514	96.32	0.04311	98.33

Table 4 showed that the more bamboo charcoal put in the water, the higher the percentage inhibition efficiency of the bamboo charcoal was. This could prove that bamboo charcoal performs efficiently in inhibiting corrosion of steel nails which were immersed in the water.

Conclusion

From the morphological images and analysis of XRF studies, bamboo charcoal was identified to have large amount of pores within its structure and contained several minerals. The urine treatment process showed that bamboo charcoal had efficiently adsorbed the bacteria and prevented the growth of bacteria in the urine samples after treatment. The corrosion study proved that, with more bamboo charcoal in the water, the corrosion rates of steel nails decreased. The inhibitor efficiency which was calculated also showed that bamboo charcoal was efficient in inhibiting the corrosion of steel nails, especially when large amount of bamboo charcoal was used. As a conclusion, bamboo charcoal was found to be an efficient material in treating urine and inhibiting corrosion.

Acknowledgements

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