Performance Assessment of Cycled Carbon at Gold Processing Plant: A Case Study Jopaf Goldfields Limited, Nkawkaw, Ghana

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Abstract

In this research, cycled carbon without regeneration performance has been assessed by means of batch cycled activated carbon adsorption test. The research work quantitatively established the adsorption strength of the plant carbon as activity values of 95.38% to 55.33% within the twelve month gold adsorption period, without regeneration. Also, the research pointed out that, the 146.2 to 307.9 ppm gold on barren carbon as call for reviewing the parameters of the elution process towards efficiency enhancement. The inverse functional relation dependency of solution losses on activity level carbon in process was revealed by the research. The approximately zero relationship between the activity of barren carbon and solid losses shown by this study authenticates fact that carbon adsorbs only gold in solution. For effective implementation, the study recommends further research works of tradeoff and financial appraisal assessment to be done on the use of regeneration Kiln in the Jopaf Mine Ghana limited, Processing Plant circuit. Statistically, at 95 % confidence limit, the error limit was 0.034(i.e. 3.4%) with the standard deviation was 12.80.

Keywords: Cycled carbon, activity, inverse, function and adsorption

1 Introduction

Performance assessment involves evaluating the level of demonstration and application of knowledge, services and work practices through execution of task. It answers the question of how well a skill or an ability can be utilized to achieve a results (ASCD, 2011). Carbon is believed to be composed of tiny graphite-like platelets which form walls of open cavities of molecular dimensions. That is the walls of open cavities form pore system. Notably, the hexagonal (tiny graphite-like platelets) carbon rings, many of which have undergone cleavage, are randomly orientated, and lack the directional relationship with one another that is present in single graphite crystals. The overall structure is therefore very disordered and is often referred to as turbostratic. Furthermore, the separation between the layers is greater than that found in graphite, which is 60 A. X-ray-diffraction studies have shown that the structure of thermally activated carbon is similar to that of graphite. (Van Winkle, 2000; McDougal, 1991)

The volume of the pores in activated carbons is generally evaluated as being greater than 0.2 mVg and the internal surface area is generally larger than $400m^2/g$ as measured by the nitrogen BET method. The width of the pores varies from 3 A to several thousand angstroms, and the pores are generally classified for convenience in terms of their diameters. (Mcdougal, 1991).

The adsorptive characteristics of activated carbons is the outcome of the great degree of surface reactivity. The high surface area comparative to the actual particle size of activated carbon creates the needed condition for easy removal solute elements from liquid solutions (Dash *et al*., 2009; Nowicki and Nowicki, 2016; Aneke and Echegi, 2015). This makes it very useful in most gold processing industries. This place importance on level at which gold ions are removed from a given solution for effective result gold processing industries. Hence, performance assessment of cycled activated carbon at gold Processing Plant at Jopaf Goldfields Limited, implies estimating the adsorption capability of cycled activated carbon.

Activated carbons are commercially available in numerous forms: powders, granular chips in various size ranges and shaped products. These are extruded into rod-like shapes of 0.8 o 6 mm in diameter by 3 to 10 mm in length. Other important characteristics of activated carbon that have effect on usage of a given form are the percentage contents of moisture, ash, attrition and acid soluble. In addition, iodine number in milligram per gram of carbon, surface area, specific gravity, activity and pH are pointers to the level of effectiveness and efficiency in the usage of a given product of activated carbon (Sundari and Meenambal, 2015; Mopoung *et al.* 2015). In gold processing granular carbon is used to adsorb gold from solution after which is striped and solution sent electrowining cell for electrolysis. The carbon which has been stripped of the gold is sent to the tank for another adsorption of gold. This cycle repeats itself until the carbon reduces in particle size, mass and adsorption capacity or strength. Reduction in these components carbon have adverse effect on recovery of gold as mineral of interest. Hence the current reduction in recovery from 94% to 85% experience at Jopaf Processing Plant is a call for evaluation of all related parameters to restore recovery.

Therefore, this study seeks to analyze the performance of granular activated carbons as it goes through several cycles of adsorption and desorption without regeneration at a gold processing plant. The effects of adsorbent dosage, time and loading of gold on absorbent, and initial concentration of gold were observed. Major significance for the proposal of an adsorption process, equilibrium, kinetics and thermodynamic parameters for gold adsorption were also determined. There is lack of information on the limit to which activated carbon can be used for adsorption before regeneration in the Ghanaian mining arena. Consequently, this research is to close this lack of information gap by providing the quantitative evaluation of the decline in the carbon adsorption strength as a result of its reuse without regeneration at Jopaf Processing Plant. The paramount aim of this study is to overcome any factor that may be a recipe for production and revenue deficits.

1.1. Background information

Invariably, lack of information on the limit to which activated carbon can be used for adsorption before regeneration in the Ghanaian mining arena is recipe for the recovery decline. Evidently, Steyn (2010) pointed out that, cycled carbon contains a builds up organic (i.e. diesel fuel, lubrication oils, grease and fine vegetation) and inorganic (i.e. magnesium hydroxide-Mg $(OH)_2$, calcium carbonate-$CaCO_3$ and silica) foulants on carbon which reduce the activity, and hence gold adsorbing efficiency and capacity of carbon. Notably, at the Jopaf Processing Plant, acid treatment is used as measure to overcome the said adverse effect of the carbon foulance. On the contrary, Steyn (2004), pointed out that, acid washing partly reactivate carbon by removing only inorganic foulants (i.e. magnesium hydroxide ($Mg(OH)_2$), calcium carbonate ($CaCO_3$), and silica) in carbon cycling without regeneration.

Usually, during the CIL process, gold slurry is leached from the ore in an alkaline cyanide solution the resulting gold cyanide complex ions are then concentrated and separated from the slurry by adsorbing onto activated carbon (Marsden and House, 2006). Basically, at Pajof CIL Plant, gold slurry is leached from the ore with yearly average grade of 3.22g/t in an alkaline cyanide solution at pH of about 10.9. Specifically, there are 10 tanks at PAJOF CIL circuit each with a capacity of $135m^3$ purposefully to provide the required residence time 24 hours for the process. Cyanide solution at a concentration of 250ppm is dosed into the first tank whereas carbon into the last tank. Carbon concentration of 16g/t in the eight (8) absorption tanks are kept to ensure that the dissolved gold ions in the slurry are adsorbed onto carbon.

Additionally, each tank is fitted with one intertank screen to retain carbon in the tanks. Carbon advanced pump situated from tank 3 to 10 are used to move the carbon to the next upstream tank. To check the carbon profile, sample is taken every two hours. This is done to know the amount of carbon in each tank. 8L dipper is used to fetch a sample from the tank and poured onto a 106 micron screen. The liquid drains out leaving the carbon. The carbon is washed clean with the help of a funnel into a measuring cylinder. The carbon settles at the bottom of the cylinder with the water on top. After pouring out water from the cylinder, the volume of the granular carbon is noted. The value obtained is divided by sixteen to determine the mass of the carbon since the density of carbon is $0.5g/cm^3$. Loaded carbon is selectively pumped from tank 3 onto the recovery screen when the grade of gold on carbon ranges from 1500ppm to 2000ppm.

Moreover, the slurry is pumped onto the loaded carbon screen where the carbon is screened from the slurry. Spray bars fitted to the screen wash residual slurry from the carbon. The carbon discharges off the end of the screen into the desorption column. This is done in a batch process with 1.5 tonnes of carbon being treated in each strip. When the desorption column is full of carbon, potable water is flushed through the column to remove any remaining slurry. The desorption process is in a closed circuit with the electrowinning process. The prepared desorption solution containing 4% NaCN and 2% NaOH goes through heat exchangers to raise the temperature of the solution before entering the elution (desorption) column from the bottom. The pregnant solution is sent to the electrolyte tank for electrowinning. Barren carbon after desorption is washed with acid, water and alkali respectively and then finally transferred into the CIL tanks (Haigen and Longzong, 1997; Steyn, 2010). Clearly, in the design of Jopaf, barren carbon does not undergo thermal regeneration process before reuse which results in an accumulation of organic foulants on carbon. These organic foulants precipitate or adsorb onto the carbon, taking up active sites which would otherwise be available for gold adsorption and also may block the carbon pores, restricting the contact of solution through the active carbon in the adsorption process (Steyn, 2010). The purpose of carbon regeneration is to ensure that the barren carbon that is sent back to the adsorption circuit has restored its activity to the optimum possible degree by taking off these organic foulants.

2. Materials and Methods Used

Fundamentally, the deficiency of current circulation of carbon in the leaching circuit without regeneration, call for the evaluation of the carbon in the system at Jopaf Mine Ghana limited to overcome any factor that may be a recipe for production and revenue deficits. According to Chang-Mao (2009), test work results revealed that the conversion of ammonia by wet oxidation in the presence of cupper activated carbon catalysts was a function of the metal loading weight ratio of the catalyst. Specifically, in this test work, fresh carbon and monthly representative sampled carbon were dried and 2g each was weighed into separate beakers to assess the functional relationship of the adsorption factors. These monthly representative sampled carbon of 2gm was taken from a composite sample of four different striped batches in a month by the use of cone and quarterly method of sampling. A 200ml of prepared 12.17 ppm stock solution was poured into the carbon containing beakers. Each was agitated for thirty (30) minutes. Afterwards, each solution was analyzed to determine the concentration gold left after adsorption. Technically, Nowicki and Sherman (2006), suggest the use characteristic curve data that fit to a polynomial equation of two or more terms as a qualitative analysis process that provides pragmatic conclusions for activated carbon. Hence, quantitative evaluations of the gold left after adsorption and their corresponding activity were obtained to enhance practical conclusions. Logically, Saunder, lewis and Thornhill, (2009), affirmed the use of linear regression trendline and equation to predict values of a dependent variable from given values of one or more independent variable. Authentically, Clements (2002) used linear regression to assess a decline relationship in percentage colour removal and days of regeneration operational frequency. Again, Anisuzzaman *et al.* (2014) pointed out that, the adsorption kinetic in first and second order have high coefficient of determination (R^2) of 0.9626 and 0.9999 respectively. That is the two adsorption kinetic models show high dependency between their respective adsorption dependent and independent variables. Therefore, the application of regression trendline of the activity data generated in this study will go a long way to enhance pragmatic conclusion for monitoring the adsorption capability of cycled carbon at Jopaf Mine Gold Processing Plant.

3. Results and Discussion

Profoundly, the lack of carbon regeneration before circulation in the leaching circuit, call for the evaluation of the carbon in the system at Jopaf Mine Ghana limited to eradicate any factor that may be a cause for production and revenue shortfalls. Meng *et al.* (2012), confirmed the used of adsorption experiment to evaluate the efficiency of activated carbon fiber cloth. Therefore, one gram of Barren Carbon and fresh carbon samples were separately subjected to adsorption activity test in 200ml of a known gold standard solution for an hour contact time. Table 1 shows the Carbon activity analysis on the twelve month available barren carbon samples as at August, 2019. Fresh carbon was used as reference carbon. The loadings or gold on each barren carbon was tested before activity test was done. The barren carbon samples were found to have gold loading levels of between 146.2ppm as the lowest to the highest of 307.9ppm. Similarly, the barren carbons recorded average adsorption of gold between 5.87 to 10.12 ppm whiles the average adsorption of gold for the fresh carbon was 10.61ppm. Fresh carbon adsorption activity level was take as the reference level with 100 % activity value. The barren carbon activity levels deduced were from 55.33% to 95.38%. The characteristic parameter specifications of Jopaf Mine Ghana limited activated carbons are given as: Particle size, Surface area, Bulk density, Ash Content, pH, Attrition, Conductivity and Iodine number with values of 0.6mm, 1126 m^2/g, 0.44 g/cm^3, 8.3%, 7.9, 10.8%, 4.7 uS and 500–1200 mg/g respectively.

Clearly, Figure 1 shows the relationship between the various percentage activities and their corresponding months. Comparatively, the polynomial trendline shows the highest R^2 as against linear, exponential, logarithmic and power trendline options. The estimated R^2 values were 0.7635, 0.5126 and 0.495 for polynomial, linear and exponential trendline options respectively. The logarithmic and power trendline options shows no relation between the variables of activity and month. Considering Figure 1 under the company's activity level budget of not less than 75%, the graph of activity versus month shows an inverse function relation between the activity levels and monthly changes. This implies that, activated carbon should not be used continuously (i.e. within a period of one month) for adsorption without regeneration. Again, figure 2 shows a strong linear relationship (i.e. R^2 value of 0.8401) between activity of carbon and gold that may be left on carbon (i.e. barren carbon gold) before regenerations. The inference from Figure 2 graph, is that, activity of the activated carbon can be adversely affected by barren carbon gold. This implies that, there is the need adjust the elution factors towards the achievement of lower barren carbon gold.

Table 2 shows recorded monthly average solution and solid losses that were recorded at the plant within the period of respective activated carbon usage activities. The plant average head grade for the period under consideration was 1.31g/t. During period under consideration, the solution losses range between 0.001 to 0.08 g/t as against the budget of 0.005g/t whiles the solid losses were between 0.10 to 0.17g/t. Figures 3 and 4 portray the relationship between the activity of the barren carbon and residual gold losses (solution and solid respectively). Whiles figure 3 shows comparatively stronger inverse relation (R^2 = 0.77) between activity of carbon and solution losses, figure 4 point out the very weak relation (approximately zero relation under one decimal place evaluation – i.e. 0.006 ≈ 0.0) between activity of carbon and solid losses. The trends of figures 3 and 4 imply that, all things being equal, achievement of lower solution losses are link to higher activity of carbon in process and solid losses cannot be solved by the use of activity variations of carbon in process. Statistically, at 95 % confidence limit, the error limit was 0.034(i.e. 3.4%) with the standard deviation was 12.80.

Table 1 Activity test results

Month	Sample Name	Carbon Gold before Test, ppm	Carbon Mass, g	Solution Volume, ml	standard solution Gold, ppm	Time, h	Residue solution Gold, ppm	Adsorbed gold onto Carbon, ppm	Activity, %

0	Fresh Carbon	0	2	200	12.17	1	1.56	10.61	100.00
1	Barren Carbon	146.2	2	200	12.17	1	2.05	10.12	95.38
2	Barren Carbon	233.6	2	200	12.17	1	4.34	7.83	73.80
3	Barren Carbon	206.6	2	200	12.17	1	3.41	8.76	82.56
4	Barren Carbon	244	2	200	12.17	1	4.89	7.28	68.61
5	Barren Carbon	256.6	2	200	12.17	1	5.09	7.08	66.73
6	Barren Carbon	266.5	2	200	12.17	1	4.73	7.44	70.12
7	Barren Carbon	397.4	2	200	12.17	1	6.3	5.87	55.33
8	Barren Carbon	297.4	2	200	12.17	1	5.4	6.77	63.81
9	Barren Carbon	300.9	2	200	12.17	1	4.03	8.14	76.72
10	Barren Carbon	307.9	2	200	12.17	1	5.63	6.54	61.64
11	Barren Carbon	307.5	2	200	12.17	1	4.92	7.25	68.33
12	Barren Carbon	298.5	2	200	12.17	1	5.3	6.87	64.75

Table 2 Activity test and Residual gold loss results

Month No.	solution loss, ppm	Activity %	Solid loss, ppm
1	0.001	95.38	0.12
2	0.04	73.80	0.17
3	0.001	82.56	0.07
4	0.04	68.61	0.08
5	0.04	66.73	0.14
6	0.03	70.12	0.10
7	0.08	55.33	0.10
8	0.07	63.81	0.10
9	0.05	76.72	0.10
10	0.06	61.64	0.10
11	0.06	68.33	0.10
12	0.05	64.75	0.10

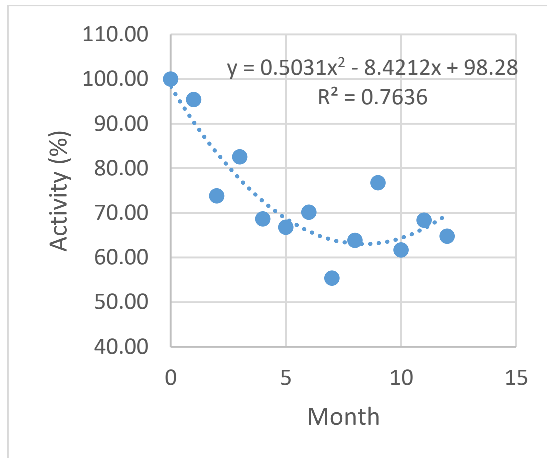

Figure 1 Polynomial Graph of Activity of Carbon versus month

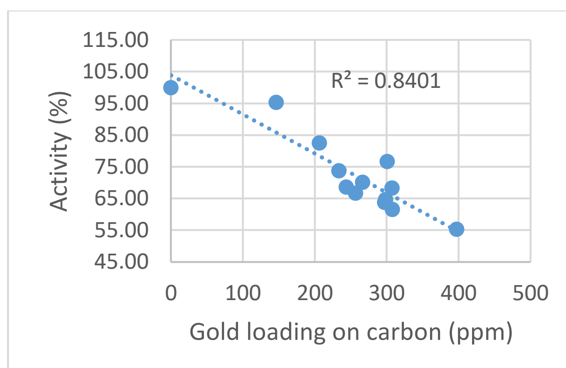

Figure 2 Linear Graph of Activity of Carbon versus monthly gold loadings

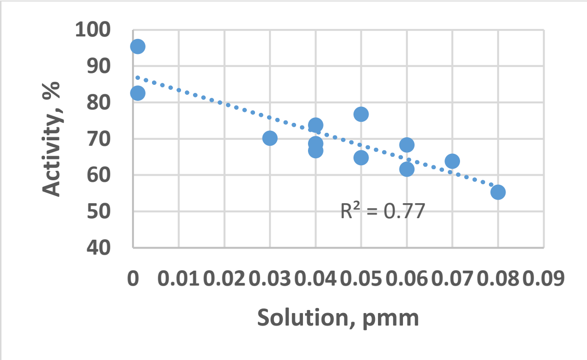

Figure 3 Graph of Activity of Carbon versus monthly Average Solution loss

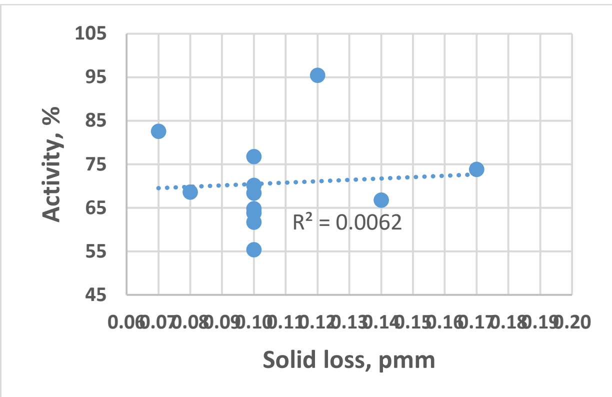

Figure 4 Linear Graph of Activity of Carbon versus monthly Average Solid loss

4. Conclusion and Recommendation

Obviously, the nonexistence of carbon regeneration before reuse is indeed a recipe for decline in production and revenue. This call for the evaluation of the activity carbon levels in the system from the adsorption of gold from the leaching system at Processing Plant of Jopaf Mine Ghana limited to eradicate any adverse causative factor. From the table 1, activity of plant barren carbon ranges from 95.38 % to 64.95% with reference to the fresh carbon at the Plant. This implies that, the barren carbon is still active for effective adsorption. However, the barren carbon shows a reduction in strength of 30.48 % adsorption affinity within the twelve month period. The reduction in adsorption strength is due to presence of organic foulness and the high value of gold on the barren carbon. This because of the fact that, the operating process procedure only take care of inorganic components by the acid wash step. Hence, the need for regeneration Kiln to eradicate the organic compounds is very paramount. Consequently, the critical position of the carbon in gold recovery process, point to the need of continuous monitoring, the activity of the barren carbon to avoid future reduction in gold adsorption and the overall effect on gold recovery. The 146.2 to 307.9 ppm gold on barren carbon, point to the need to review the parameters of the elution process towards efficiency enhancement. Further research works to assess the tradeoff and financial appraisal of using a kiln in the circuit of the Jopaf Mine Ghana limited, Processing Plant are highly recommendable.

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