The Use of Beach Sand as Seed for Floc in Water Clarification

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Cudjoe, W., Andoh, B., Nyarko, D. N. Y. and Manu, C. (2022), "The Use of Beach Sand as Seed for Floc in Water Clarification", 7th UMaT Biennial International Mining and Mineral Conference, UMaT, Tarkwa, pp. 1-5

Abstract

Geochemical and anthropogenic activities have led to the solubilisation of heavy and toxic metals, which have to be removed to avoid contamination of water bodies. In the mining industry, wastewater is treated prior to discharge into the aquatic environment or recycled back to the processing plant for reuse. Technologies employed in achieving this include the use of Actiflo™ method. The Actiflo™ process is a proven, high performance, compact clarification system that utilises microsand to enhance flocculation and settling. The microsand also enhances system stability, enabling the process to produce a consistently high-quality effluent despite changing raw water conditions such as flow rate or solids content. Since Ghana hosts large volumes of beach sand similar to the sand from Australia (Actisand^{TM}), it was important to assess the possibility of employing the Ghanaian beach sand in the Actiflo™ process. This research was therefore conducted to ascertain the usefulness and compatibility of local beach sands in running the Actiflo^{TM} and the possibility of complementing Actisand^{TM} with local sand. Samples from the various beaches (Actisand^{TM}, Saltpond, Cape Coast, Takoradi, Elmina and Sekondi) were subjected to the various stages of oxidation, coagulation and flocculation to determine the percentage of Arsenic precipitated. From an initial concentration of 4.2 ppm, the results revealed that the sands from Saltpond, Sekondi and Takoradi accounted for 85.2%, 84.2% and 84.0% respectively of arsenic removal as against 84.0% for Actisand^{TM}.

Keywords: Actiflo^{TM}, Microsand, Water treatment, Beach sand, Arsenic removal

1 Introduction

The mining industry is one of the world's largest producers of industrial waste globally. Associated with all mining operations is the need to dispose of large volumes of waste in the form of tailings (slimes) and waste rock (Hudson *et al*., 2011). Both types of mine wastes often contain elements and compounds in elevated concentrations that can have severe effects on the ecosystem and humans (Lottermoser, 2011; Aznar-Sánchez *et al*., 2018). The nature of contamination is dependent on the geochemistry of the ore deposit and the method of mineral processing. The commonest among these are release of cyanide from gold processing; liberation of transition metals and arsenic from the breakdown of ore minerals; and Acid Mine Drainage (AMD) from the oxidation of sulphides, which could lead to the infiltration of a low pH solution with high concentrations of toxic metals such as Pb, Cu, Ni, Zn, As, and Cd into surface and ground water (Iatan 2021; Rodríguez-Galán *et al*., 2021).

Ground water interacting with mine waste poses a major health threat to consumers due to the adverse health effects of some metallic ions. Mine wastes, especially tailings are major repositories of arsenic due to its association with most sulphide containing mineral deposits (Cohen *et al*., 2014; Craw *et al*., 2014). Arsenic concentration above 10 μg/L in drinking water, could lead to cardiovascular diseases, developmental abnormalities, neurologic and neurobehavioral disorders, bronchitis, skin cancer and other skin related diseases (Mensah *et al*., 2020; Baffoe, 2019). Majority of people affected by arsenic contamination are the poor residing in rural areas (Shaji *et al*., 2021). Contamination resulting from mining also has global economic implications. Control and mitigation of AMD is considered as one of the major environmental challenges facing the mining industries worldwide (International Network for Acid Prevention, 2011). The total estimated costs for worldwide liability associated with the current and future remediation of acid drainage are approximately US$100 billion (Trembley *et al*., 2001; Hudson *et al*., 2011). The toxicity of both metals and cyanide pollution is long-lasting. This is because these pollutants are non-biodegradable (Acheampong *et al*., 2010).

In view of this, various technologies have been employed to treat mine waste water before discharge into the environment (Teh *et al*., 2016; Acheampong *et al*., 2010). One of these technologies employed is the Actiflo^{TM} method. Many mines in Ghana employ the Actiflo^{TM} Clarification Plant, developed by Veolia Water Solutions and Technologies, as an effective means to remove heavy metals from wastewater. Some mines employ the Actiflo^{TM} technology in the process water circuit as one of the three distinct water treatment steps. The overall objective of the Process Water Treatment Plant (PWTP) is to improve the quality of process water to allow reuse of the treated water in the metallurgical process.

The plant consists of a coagulation chamber followed by flocculation and lamella clarification chambers. The process consists of an aeration step, followed by chemical oxidation in which the heavy metals and arsenic are oxidized in order to co-precipitate. pH is raised to 9.5 at which point the bulk of the heavy metals precipitate from the solution. The Actiflo^{TM} process is a proven, high performance, compact clarification system that utilizes a patented micro sand, Actisand^{TM} to enhance flocculation and settling. Actisand^{TM} also enhances system stability, enabling the process to produce a consistent high-quality effluent despite changing raw water conditions such as flow rate or solids content (Plum *et al*., 1998; Chaitra *et al*., 2017).

The Actiflo^{TM} plants in Ghana import the micro sand from Australia for the operation, which makes the process expensive. In Ghana, there are large volumes of beach sands which have similar characteristics to the micro sand from Australia. Therefore, this research seeks to assess the possibility of using these beach sands to ensure accessibility, availability, and cost-effectiveness.

2 Materials and Methods

2.1 Materials and Equipment

Beach sands were collected from the various Ghanaian beaches namely Cape Coast, Elmina, Sekondi, Takoradi, and Saltpond. The sands were unconsolidated sediment of grains of weathered quartz (silica) rock. The finest of the sand were of the order Actisand^{TM}, Saltpond, Sekondi and Takoradi whiles Cape Coast and Elmina were the coarser upon physical observation.

These samples were taken at 20 m interval to accumulate about 5 kg beach sand from each location. The solution sample for the test work (15 m^3) was taken from the feed to the Actiflo plant at a Sulphide Treatment Plant in Ghana. Meanwhile, caustic soda, potassium permanganate ($KMnO_4$), anionic polymer and coagulant $FeSO_4$ were obtained from the Minerals laboratory of the University of Mines and Technology.

2.2 Methods Used

2.2.1 Medium Preparation, Floc Formation and Arsenic Precipitation

Six (6) 1000 ml samples of Actiflo™ feed were put into 1500 ml beakers and agitated at 50 rpm. NaOH (45% v/v) was added to modify the pH to 9.5, and the samples were aerated for 5 min prior to the oxidation step. The solution was dosed with 10 mg/l $KMnO_4$ (4% v/v) and agitated for 32 min to allow for oxidation to come to a completion. 80 mg/l dosage of $Fe_2(SO_4)_3$ was added and agitation increased to 200 rpm, after which coagulation was allowed to proceed for 2 min. 1.5 ml of flocculants (0.1% v/v) and 5 g of the various beach sands as well as Actisand^{TM} were introduced into each of the six samples. Flocculation was allowed to proceed for 2 min. Agitation speed was reduced to 50 rpm and 6 min maturation period was allowed followed by 8 min settling time. The settled water was decanted and the clear solution was sent for AAS analysis to determine the concentration of arsenic after the jar test simulation.

2.2.2 Size Distribution and Sieve Analysis of Samples

Each of the sands weighing 600 g was placed on a set of screens ranging from 600 µm to 106 µm. The screens set was placed on a screen vibrator for 25 min at 1 mm amplitude. The amount of material retained on each screen was weighed and recorded.

2.3 Analysis of Data

The percentage precipitation of arsenic (PoAs) in the solution is depicted in Equation 3.1, where I_{As} and F_{As} are the respective arsenic contents before and after Actiflo^{TM} simulation. The densities of the various sands (DoS) were determined as shown in Equation 3.2, where (W) g is the weight of the sand and V_1 cm^3 and V_2 cm^3 are the volumes of water used before and after the experiment.

$$PoAs(\%) = \frac{I_{As} - F_{As}}{I_{As}} \left(\frac{mg/L}{mg/L} \right) \qquad [3.1]$$

$$DoS\left(g/cm^3\right) = \frac{W}{V_2 - V_1} \left(\frac{g}{cm^3} \right) \qquad [3.2]$$

3 Results and Discussions

3.1 Sand Characterisation

The specific gravities (SG) of all the sands were analysed using the Marcy scale. The results are presented in Figure 1. The cumulative percentage passing the various sand are also presented in Figure 2.

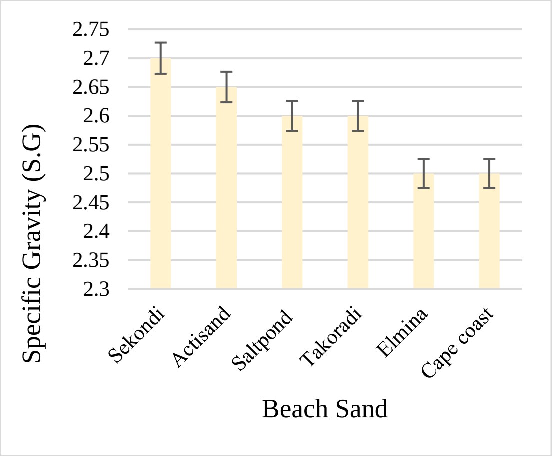

Figure 1 Specific Gravity Results of Beach Sand

From the results, the sands from Saltpond, Sekondi Takoradi and Actisand^{TM} had SG of 2.6-2.7, whilst Elmina and Cape Coast sands had SG of 2.5.

From Figure 2, which shows the particle size distribution of the sands, Actisand^{TM} being the reference point has particle size distribution midway those of the local beach sands. Whereas the Elmina and Cape Coast sands had relatively coarser particle distribution, the Saltpond, Sekondi and Takoradi sands matched up with Actisand^{TM} in their particle distribution.

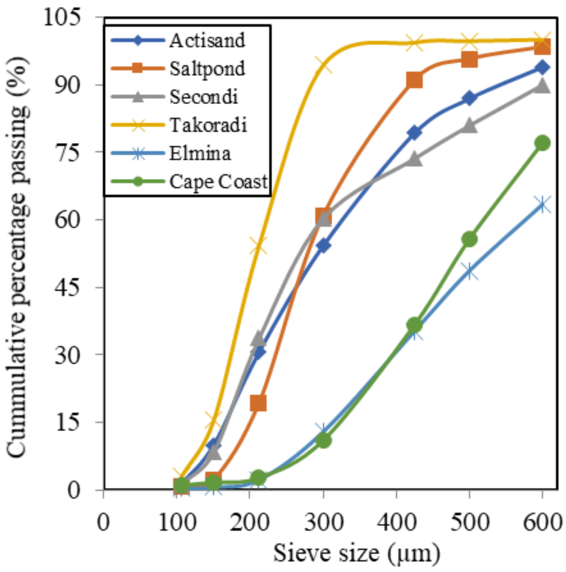

Figure 2 Particle Size Distributions of Beach Sands

A corelation between the SG and the particle size distribution was observed. Samples from Elmina and Cape Coast, having coarser particle size, had relatively lower SG compared to beach sand with finer particle size.

3.2 Precipitation of Arsenic by the Various Sands

Figure 3 shows the percentage of arsenic precipitated from the effluents by the various beach after the AAS analysis.

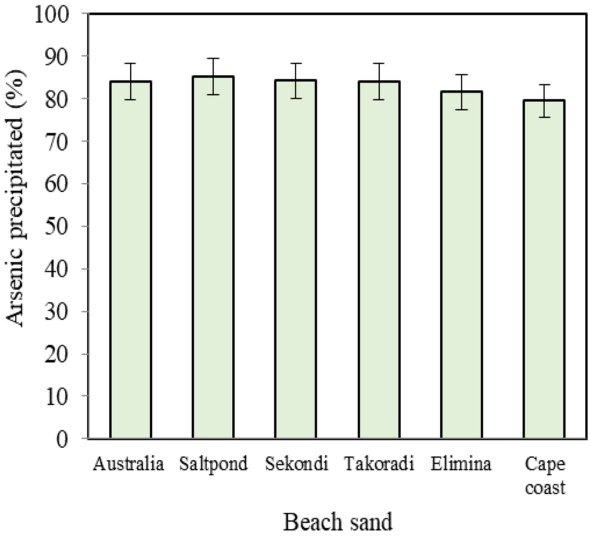

Figure 3 Arsenic Precipitation by Beach Sands

It is clear from Figure 3 that, from the arsenic concentration of about 4.2 ppm in the feed to the Actiflo^{TM} plant, at least 80% precipitation was achieved for each sand, Actisand^{TM} included.

The average arsenic concentration in the effluent after treatment with the local sand was in the range 0.62-0.86 ppm, as against 0.67 ppm in the case of the Actisand^{TM}. More than 50% of the sands investigated competed favourably with the Actisand^{TM} for arsenic precipitation. These were Saltpond, Sekondi and Takoradi which accounted for 85.2%, 84.2% and 84% respectively of arsenic precipitation as against 84% recorded for Actisand^{TM}.

Effluents treated with beach sand with finer particle size distribution observed higher levels of arsenic removal compared to effluents treated with beach sand from Cape Coast and Elmina which had relatively coarser particle size. The correlation between SG and particle size was also observed with arsenic removal, as beach sand with coarser size and lower SG had effluents with comparatively the least arsenic removal.

4 Conclusion

The study evaluated the possibility of using beach sand as a floc seed Actiflo^{TM} plant to complement the use of important Actisand^{TM}. The results indicate that more than half of the sands tested competed favourably with Actisand^{TM} for arsenic precipitation. The differences in particle size distribution and specific gravities of the various sands might also be related to the difference in percentage arsenic removal from solution. The ability to generate flocs with subsequent arsenic precipitation improves with higher specific gravity and finer particles sizes. It is thus feasible to use local beach sand for arsenic precipitation in the Actiflo^{TM} plant.

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