Improving The Quality Of Nigeria's Agbaja Iron Ore Through Biosorption Of Phosphorus Using *Aspergillus Niger*

By

O. W. Obot
Department of Mechanical Engineering, Faculty of Engineering, University of Uyo, Uyo, Nigeria.

C. N. Anyakwo
Department of Metallurgical and Materials Engineering, Federal University of Technology, Owerri, Nigeria.

Abstract

Experimental studies on bio-sorption of phosphorus from Nigeria's Agbaja iron ore was carried out in the laboratory using Aspergillusniger as the degrading agent. Working with the submerged culture technique and the microorganism being part of the microflora found on the crushed ore samples, 60% phosphorus bio-sorption was achieved in 10 weeks in malt extract broth medium. Also, the pH result shows that the filamentous fungus degraded the ore in a continuously increasing acidic medium, while the analyses with UniCamSolaar 969 AA spectrophotometer on some heavy metals concentration in the final substrate revealed a preferential up-take of Zn, Mn and Pb found in the ore and a release of Cu, Cd and Ni back into the medium. The growth of microorganism maximized between weeks 3 and 4 averaging 2.880 g dry weight from an initial 1 g dry weight of inoculums plummeting to 0.507 g dry weight by the 10th week. The metabolism of toxic wastes in the submerged culture particularly, 43% Pb, might have been the reason for the microbial lysis, culminating in the decline of microorganism population in the broth culture and consequently, led to the reduced phosphorus degradation overtime.

1. Introduction

The amount of natural resources available in Nigeria if properly tapped and efficiently managed is enough to place Nigeria on the map of the very wealthy nations of the world. Apart from the vast crude oil and the natural gas deposits, in the solid minerals sector alone, iron ore deposits number over twenty[1]. The Lokojaoolitic ironstone deposit alone covers about 400 km^2 and is estimated at 2.3 billion tones[2]. The Agbaja-Mt Patti area of the Lokoja ironstone with an inferred estimate of 1,250 million tones has been acknowledged as the country's largest[3]. This reserve is noted for having high-phosphorus and high-alumina contents and not amenable to conventional beneficiation techniques such as froth flotation, gravity concentration and magnetic separation[3, 4a, 4b]. The associated problems with high-phosphorus in iron and steel such as; the effect of steel brittleness coupled with the effect of strong primary segregation during solidification of castings and the formation of high phosphorus brittle streaks between metal grains which impede plastic deformation[5], are well known to metallurgists. These undesirable influences should be minimized in high quality steels as much as possible and in fact a range 0.020 - 0.030 Wt. % has been documented[5]. Researchers are currently finding an alternative route to solving the global problem of high-phosphorus mines[6, 7, 8, 9]. It is in this regard that biodegradation route quickly avails itself. This route is gaining popularity because it is environmentally friendlier and cleaner than traditional physical and chemical routes.

In this current undertaking, the mobilization of *Aspergillusniger* is proposed for the Agbaja iron ore with analysis by volumetric titrimetry[10]. The pH and population of viable cells shall be carefully monitored during the process.

2. Materials and Methods

The iron ore was obtained from Agbaja community near Lokoja in Kogi State of Nigeria, Plate 1.

Plate 1. Map of Nigeria showing Kogi State(Source: Map data 2013 Google)

Initially the ore was analyzed for elemental composition, crushed, and Shital test kit was used to sieve 0.50/0.25mm particle size for the experiment. The microbes cultured for later use in the experiment were the nascent ones found on the iron ore. 10 g of the ore particle size fraction was weighed using Adventurer - AR3130 (with readability 001g) and placed in 90 ml of sterile water in 250 ml conical flask and then serially diluted to 10^{-6}. Using a pipette 1 ml from the final dilution was taken to seed a sterile Petri dish and then 20 ml of mineral oil medium was added, swirled and allowed to stand for 14 days. Two batches of 6 Petri dishes each were allowed to stand aerobically and anaerobically. At the end of this duration, growth colony of microbes was observed.

The fungi colonies were sub-cultured into Sabouard dextrose agar and incubated for 7 days. These microbes were preserved for subsequent use in the experiment. Using the standard manuals for fungal identification[11] the developed growth colonies were characterized and identified.

The ability of the microbial isolates to utilize the ore as their sole source of energy for growth was determined by the method of[12] and[13], using the mineral salt medium (MSM) of[14]. Briefly 10 ml of MSM were dispensed into each test tube and then 2% (0.2 g) of the iron ore sample was added. The ore-supplemented medium was then sterilized by autoclaving at 121^{o}C for 15 minutes at 15 psi atmospheric pressure. Thereafter 1g wet weight of fungi was aseptically seeded into the ore-supplemented MSM and then incubated undisturbed at 28±2 ^{O}C for three weeks. Un-inoculated tubes were included for the test isolate to serve as controls. The surface mycelia spread of the fungi was used as the index of ability to utilize the ore medium for growth. The growth rate of the isolates was graded as high (+++), moderate (++), minimal (+) and no growth (-). Among the isolates with strong capability to utilize ore based substrate for growth, *Aspergillusniger*was moderately prevalent and was subsequently selected for the P removal studies.

1g wraps in aluminium foil of the selected particle size was prepared and stored in 250ml beaker. Malt extract broth was prepared to standard and 100ml was taken in 250ml conical flasks. Both the conical flasks content and beaker with wraps of ore were autoclaved at 121 ^{O}C under 10 psi for 40 minutes. After cooling, a loopful of test organism was used to inoculate each of the conical flasks in which a wrap of ore was placed for reaction to take place. Controls were also prepared. Weekly samples were taken out and analyzed for phosphorus by titrimetry, while all liquid samples were analyzed with the use of UniCamSolaar 969 AA spectrophotometer.

3. RESULTS AND DISCUSSION

The result of iron ore compositional analysis is presented in Table 1. This result shows a 1.25% P_2O_5 and 34.77% Al_2O_3 contents in the Agbaja iron ore which corroborates the high phosphorus and high alumina status also earlier observed by[15].

Table 1. Nigeria's Agbaja Iron Ore Composition Analysis, (%)

Entries	%, Content
Fe_T(total iron)	51.50
SiO_2	0.57
P_2O_5	1.25
MgO	0.08
Cu_2O	0.005
ZnO	0.091
S	3.25
MnO_2	0.001
Al_2O_3	34.77
Miscellaneous	8.483

The degradation of phosphorus in the ore by *A. niger* for 10 weeks is presented in Figure 3.1.

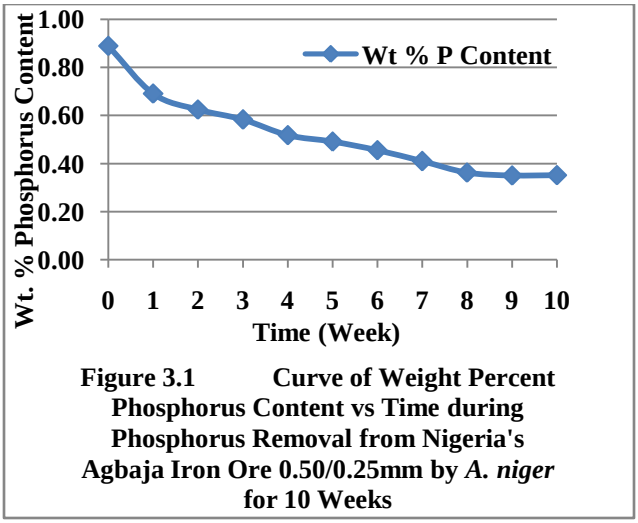

Figure 3.1 Curve of Weight Percent Phosphorus Content vs Time during Phosphorus Removal from Nigeria's Agbaja Iron Ore 0.50/0.25mm by *A. niger* for 10 Weeks

The growth profile of *A. niger*for 10 weeks in the MEB medium under submerged culture conditions is presented in Figure 3.2.

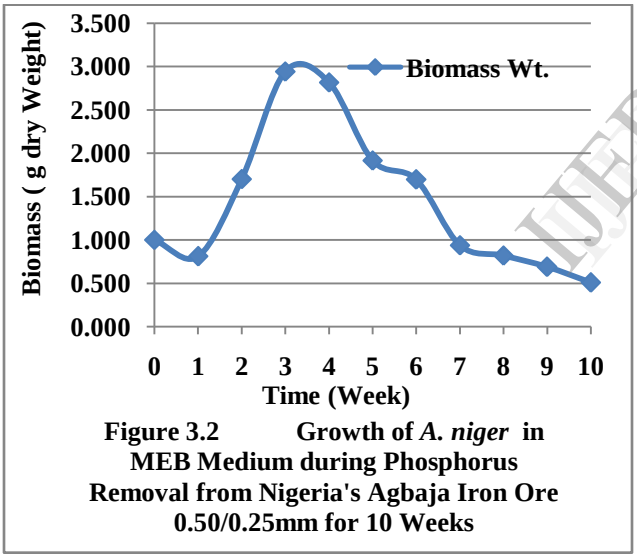

Figure 3.2 Growth of *A. niger* in MEB Medium during Phosphorus Removal from Nigeria's Agbaja Iron Ore 0.50/0.25mm for 10 Weeks

The curve of the substrates pH vs time during phosphorus removal from the ore for 10 weeks is presented in Figure 3.3.

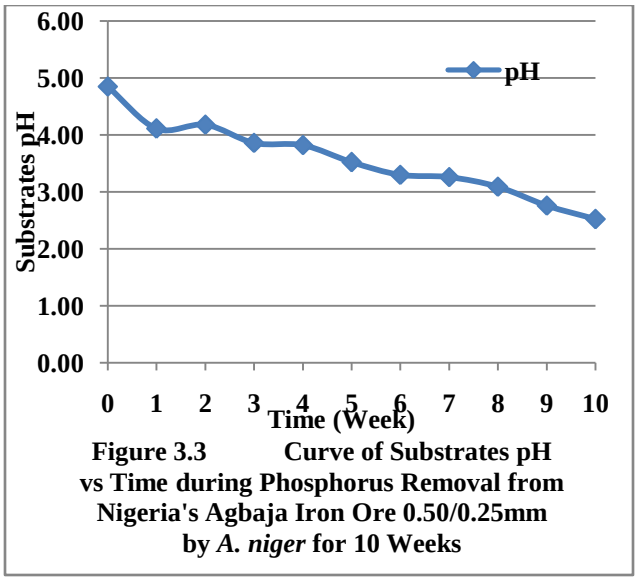

Figure 3.3 Curve of Substrates pH vs Time during Phosphorus Removal from Nigeria's Agbaja Iron Ore 0.50/0.25mm by *A. niger* for 10 Weeks

The variation of the weight percent phosphorus content, the substrates pH and the biomass weight of *A. niger* during phosphorus bio-sorption from the ore for 10 weeks is presented in Figure 3.4. It shows that a rapid drop in the ore phosphorus content from 0.89 wt. % to 0.691 wt. % by the end of Week 1 had occurred and that a smooth reduction also occurred thereafter till Week 8, when the process stagnated at 0.352 wt. % till the end of the experiment in Week 10. During this period, the pH of the MEB cultures starting 4.85 remained permanently in the acidic region ending 2.52 whereas, the biomass weight which experienced an initial drop from 1 to 0.809 g dry weight at the end of Week 1, later showed a rapid growth till its climax at 2.943 g dry weight in Week 3, which later dropped to 0.507 g dry weight in Week 10. The filamentous fungus achieved 60% phosphorus reduction in 10 weeks.

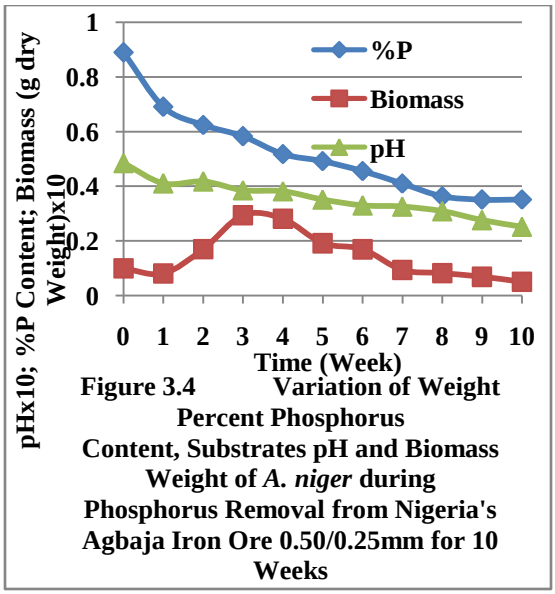

Figure 3.4 Variation of Weight Percent Phosphorus Content, Substrates pH and Biomass Weight of *A. niger* during Phosphorus Removal from Nigeria's Agbaja Iron Ore 0.50/0.25mm for 10 Weeks

The percent phosphorus bio-sorption from the ore by *A. niger* in 10 weeks in the MEB submerged ore bearing cultures is presented in Figure 3.5.

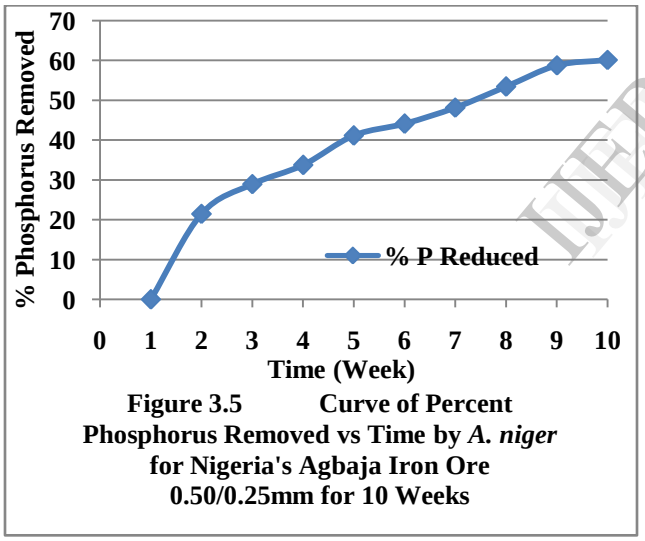

Figure 3.5 Curve of Percent Phosphorus Removed vs Time by *A. niger* for Nigeria's Agbaja Iron Ore 0.50/0.25mm for 10 Weeks

The fluctuation of the trace metals concentration during phosphorus bio-sorption by *A. niger* for 10 weeks is presented in Figures 3.6 (a) and (b). A comparison of the MEB-pure and the MEB+*A. niger* analytical results shows that *A niger* is fairly sensitive to and accumulated 32% Fe and 46% Mn from their initial respective concentrations 17.0138ppm and 0.3335ppm. On the other hand, more Cu, Cd and Zn ions were released into the broth medium by the microbes which resulted in the concentration increases of Cu from 0.1399ppm to 0.2380ppm, Cd from 0.0613ppm to 0.2872ppm and Zn from zero to 0.0059ppm. This is a clear case of *A. niger* releasing the trace metal ions since, the medium did not have iron ore in it till the time of analysis. Ni and Pb ions were absent in the media. Similarly, on comparing the initial and the final MEB+*A. niger*+Ore's analytical results, it is observed that the Fe analytical result returned zero values. This was unexpected in view of the high iron content in the ore. However, these results deserve further verification. Further observation reveals that the following trace metal ions were released into the broth and their concentrations therefore increased accordingly: Cu from zero to 0.4937ppm, Cd from 0.0584ppm to 0.0918ppm and Ni from 0.3374ppm to 0.5233ppm. It should be noticed that the two comparisons done under *A. niger* show a continuous release of Cu and Cd ions into the media which indicates that this microbe does not have a high affinity for these trace metals. However, an up-take of 64.45% Zn from 0.4655ppm, 100% Mn from 2.2132ppm and 42.50% Pb from 1.4537ppm was equally observed. Figure 3.6(b) is a scale-up modification of Figure 3.6(a) without the values for iron (Fe).

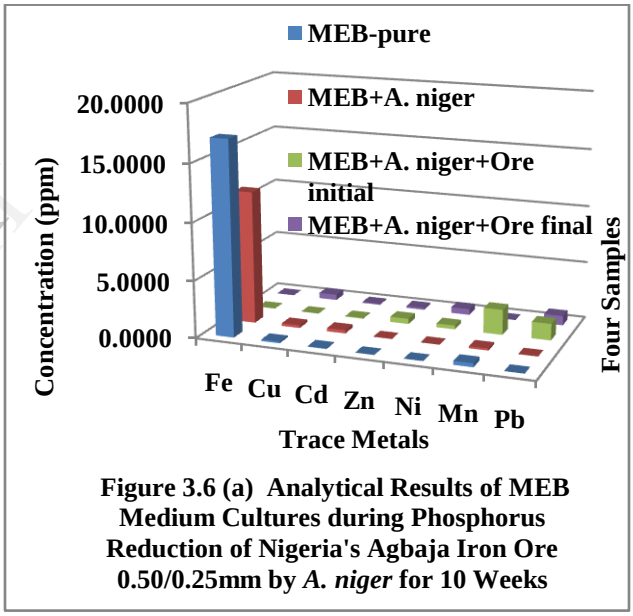

Figure 3.6 (a) Analytical Results of MEB Medium Cultures during Phosphorus Reduction of Nigeria's Agbaja Iron Ore 0.50/0.25mm by *A. niger* for 10 Weeks

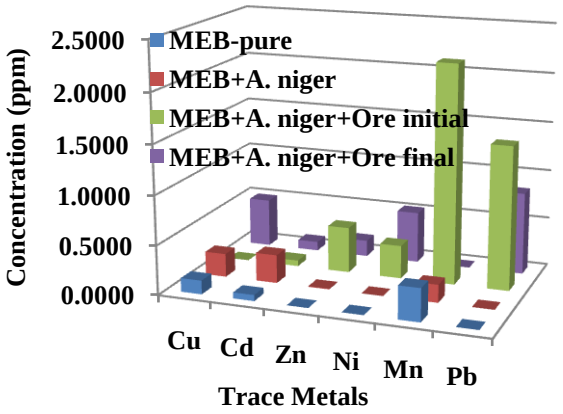

Figure 3.6 (b) Analytical Results of MEB Medium Cultures during Phosphorus Removal from Nigeria's Agbaja Iron Ore 0.50/0.25mm by *A. niger* for 10 Weeks

4. CONCLUSION

The result of the experimental work on improving the quality of Nigeria's Agbaja iron ore (reputed to be of very high phosphorus and alumina contents) through the bio-sorptive activity of *Aspergillusniger*, offers a plausible alternative to the standard practices of dephosphorization of high phosphorus ores around the world. However, the phosphorus bio-sorption is not sustainable probably, due to the decreasing population of the microorganism in the submerged culture as a direct consequence of the uptake of toxic metabolites, for instance, up to 43 wt. % Pb. If the metabolism of toxic wastes in the liquid cultures could be prevented, chances are that phosphorus bio-sorption is sustainable because of the ever-growing microbial population.

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