Journal of Basic and Environmental Sciences 4 (2017) 247-252

ISSN
Online: 2356-6388
Print: 2536-9202

Research Article Open Access

UPGRADING OF LOW GRADE EGYPTIAN KAOLIN ORE USING MAGNETIC SEPARATION

Nagui A. Abdel-Khalek*, Khaled A. Selim*, Khaled E. Yassin*, Ahmed Hamdy* and Mohamed A. Heikal**
*Central Metallurgical Research and Development Institute (CMRDI), Helwan, Egypt.
**Faculty of Science, Chemistry Department, Benha University, Benha, Egypt

Abstract

Kaolin is a clay mineral that has a wide application in the industry, depending on its purity. The quality of kaolin mined around the world is depleting especially with depth and rate of mining. Consequently the usability of this mineral is threatened by the presence of some inherent impurities. Beneficiation enhances kaolin applications; hence, it becomes imperative to understudy comparative means of upgrading kaolin, for the process integration and optimization. The amenability of using magnetic separation for removing the iron oxide and titanium oxide impurities from the Egyptian Kaolin has been studied. Different variables affecting of magnetic separation process such as solid percent, magnetic field, matrix loading capacity, and retention time were studied. The results indicated that substantial decrease in iron oxide (from 1.69 % to 0.75 %) and TiO_2 (from 3.1 % to 0.71 %) contents as well as improving iso-brightness (from 63.76 % to 75.21 % and whiteness (from 79.85 % to 86.72 %) of the product could be achieved.

Keywords: Kaolin, titanoferrous minerals, beneficiation, magnetic separation, attrition scrubbing, classification
Received; 11 May. 2017, In Revised form; 5 Jun. 2017, Accepted; 5 Jun. 2017, Available online 1 July, 2017

1. INTRODUCTION

Kaolin ores are present earthy materials preponderantly containing the mineral china stoniest. it's a hydrous aluminum salt (Al2O3•2SiO2•2H2O) and features a wide range of business applications, because of its distinctive physical, physiochemical and chemical properties [1-2]. Clays are processed by mechanical ways, reminiscent of crushing, grinding, and screening, however, as a result of clays are utilized in such a good vary of applications, it's typically necessary to use alternative mechanical and chemical processes, reminiscent of drying, calcining, bleaching, and extruding to organize the fabric to be used [3]. Distinctive geology, morphology, chemical and physical specifications of china stone makes its versatile staple applicable for several completely different applications [4-5].

Kaolin is employed in several industrial applications adore hygienically ware, table ware, ceramic, paint and paper industries. Typical impurities gift in clay ore square measure quartz, iron oxides, titan ferrous minerals, mica, feldspar, organic matter, etc. for many of the economic applications, clay ought to be processed to get refined clay thus on match with commonplace specifications. as an example, paper and paint industries want clay with terribly high brightness and low yellow [6]. The iron removal processes will be categorized as physical, chemical, or a mix of each [7]. Physical approaches embrace intense magnetic separation that able to take away iron and metal impurities, gravity separation, and hydro-cyclones [4].

The flotation method could also be conceptualized in terms of an oversized variety of sub-processes, most of that square measure still rather poorly understood. Thanks to the very difficult physico-chemical-mechanical conditions existing within the flotation method, the issues related to the presence of fine particles square measure most pronounced in flotation. There’s a general agreement that flotation decreases with a decrease of size within the fine particle vary [8-11].

Conventional and superconducting magnetic separations area unit generally utilized units with 1-2 Tesla and 2-5 Tesla magnetic fields, severally. The ready clay sample with a 15%-25% solid content is fed through a high gradient flux created round the magnetism chrome steel wool fiber. The magnetic separations area unit typically operated as a batch unit with 10-20 min cycles betting on the dimensions of the units, feed rate, solid content, impurity content, applied light-emitting diode, machine capability, etc., [8]. Subtle ore dressing flow sheets area unit well established, significantly in Georgia, USA and Cornwall, UK, to achieve the specified specification for good quality kaolin concentrates. However, the Egyptian kaolin isn't subjected to any mineral {processing mineral dressing ore processing ore dressing extraction} process and also the Egyptian corporations apply selective mining followed by, in some localities, crushing and size reduction solely. Such low quality kaolin is employed primarily in refractory and pottery production as a result of its quality doesn't satisfy the wants for the white ware and paper industries, [9].

This paper aims to study the amenability of beneficiation of an Egyptian kaolin ore of El-Teih locality, Sinai, to be suitable for different industrial applications. Attrition scrubbing and classification followed by magnetic separation are applied to remove the associated impurities. Attrition scrubbing and classification are used to separate the coarse silica and feldspars. Wet high intensity magnetic separation was applied to remove colored contaminants such as iron oxide and titanium oxide.

2. MATERIAL AND METHODS

2.1. MATERIALS

The sample about 500kg was collected from plateau of EL-tih in Sinai from (Sinai manganese company) Primary crushing reduces material size from as much as one meter to a few centimeters in diameter and typically is accomplished using jaw crusher. These samples were divided to different weights and backed to beneficiate it. Small amount of sample grind by ball mill to analysis it by XRD or XRF

2.2. METHODS

2.2.1. Identification of the Kaolin Sample

A Philips PW 1730 powder X-ray diffract meter with metallic element filtered Co (K-alpha) run at thirty kV and twenty am was wont to examine single mineral. Infrared undulation spectra were recorded on a Nicolet Magna 750 Fourier-transform mass spectrometer. for every sample, twenty eight scans were accumulated over the four000-400 cm–1 spectral vary using the coefficient mode and a resolution of 4 cm–1. The ironed KBr disc utilized for this purpose was ready mistreatment zero.4 mg of sample and two hundred mg of KBr. selected samples were determined on broken surface below a JSM-6400 scanning microscope (SEM) to look at the morphology of single mineral. X-ray visible light (XRF) to work out the geology and chemical compositional optical device particle size instrument "FRITSCH" model "Analysts 22", was utilized for size analysis of the pure mineral samples.

2.2.2. Wet High Intensity Magnetic Separation of Kaolin Sample.

Wet high intensity magnetic separation of kaolin samples was conducted using “Boxmag Rapid” LHW magnetic separator. The separating box (canister) was packed with stainless steel wool (sp.gr. 7.13 gm / cm3). The separating box was rectangular in shape, having the dimensions of 37 mm width X 82 mm length X 190 mm height with actual filling volume of 600 mm. The experiments were performed at the following pre-determined optimum conditions: matrix wire diameter 300µm, 2.5 % loading capacity, retention time 150 seconds and magnetic field intensity 14.000 K guass. The feed rate of slurry to the canister was controlled by a peristaltic pump.

2.2.3. Sample and Feed Preparation

Primary crushed kaolin lumps were further crushed in a “Denver” pilot jaw crusher to yield a product less than 25 mm. Attrition scrubbing of secondary crushed product was carried out using50 liter rubber lined “Denver” attritioner. It consists of two chambers; each one has an impeller with two rows of plates of different inclination to keep the material under motion. These plates help also in moving the slurry up and down between them and shifting from one chamber to the other to increase the attritioning retention time. Batches of 25 kg secondary crushed samples are fed with the same volume of water to maintain 1:1 solid liquid ratio inside the attritioner. Autogenous and Semi- Autogenously attritioning by adding certain weight of gravels (5 kg of >2cm grain size) were conducted. The material was subjected to attritioning for a time periods, 30 min. The products were evaluated through sizing by screens and hydrocycloning for sub screen fractions. Size distribution of the hydrocyclone over flow products were measured using "FRITSCH" model "Analysts 22". The degree of whiteness was measured by DR LANGE Whiteness Tester, Germany [1, 12]. Settling behavior of the cyclone over flow product as well as at various medium pH values was measured. Dispersing reagents e.g. Na–hexa Meta phosphate (SHMP) and Na silicate (SS) were tried to increase the stability of the sample slurry.

3. RESULTS AND DISCUSSIONS

3.1. Characterization of Kaolin Ore Sample

Complete chemical analysis of the kaolin sample was performed using XRF, the results of which are depicted in Table 1. The kaolin sample contains high amounts of Al_2O_3 (32.11 %) and SiO_2 (46.06 %).The sample has a relatively high content of TiO_2 (3.19 %). It has a lower percentage of Fe_2O_3 (1.69 %) and loss of ignition, L.O.I. (13.8 %) indicating the presence of calcite as one of the associated impurities. These results are in agreement with XRD analysis which confirms the presence of kaolinite associated with calcite, quartz and anatase, Fig. 1. SEM was used to reveal the morphology and particle size of kaolinite crystals. SEM micro images indicated that kaolinite has a well-defined crystal structure revealed by its hexagonal plates with micro edges, Fig.2.

Table 1. Chemical analysis of Kaolin Sample

Oxide	Concentration %
MgO	0.195
AL_2O_3	32.117
SiO_2	46.064
SO_3	0.039
CaO	2.284
TiO_2	3.194
Fe_2O_3	1.697
P_2O_5	0.134
L.O.I	13.80

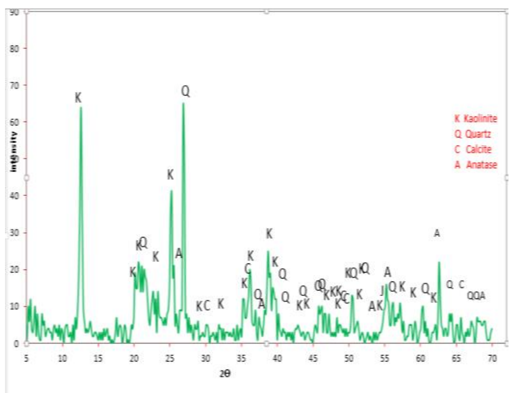

Fig.1. XRD Pattern for Kaolin Ore

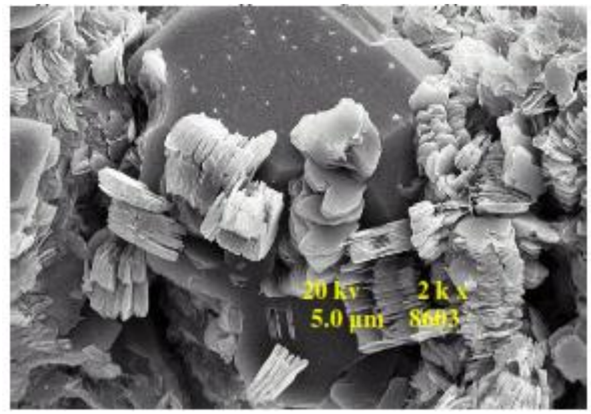

Fig.2. SEM Image of Kaolin

3.2. Beneficiation of Egyptian Kaolin

3.2.1. Preparation of Kaolin Pre-Concentrate (Attrition Scrubbing)

The primary crushed ore sample was subjected to attrition scrubbing, using a pilot scale plunger, at high solid liquid ratio for an hour, after which the scrubbed ore was delivered to a screen (0.074 mm) for its degritting. The oversize was dumped, as tail fraction, while the undersize fraction was further classified using a 3” hydro cyclone unit. Both overflow and underflow fractions of the hydro cyclone were collected, filtered and weighed. The hydro cyclone overflow was taken as a pre-concentrate for further upgrading tests. The size analysis of such pre-concentrate showed to has a very fine grain size distribution where about 75 % by weight are below ~ 2μm

3.2.2. Wet High Intensity Magnetic Separation of Kaolin Suspension

Maximum removal of iron oxide reached 55.8% while TiO_2 removal reached 77.8 % with a better degree of iso-brightness (75.21%) at a magnetic field intensity of 14 K Gauss. Optimum separation efficiency was observed at retention time equals 2 min. at material feeding rate of about 240 ml/min., Fig. 4. The concept of retention time involves the control of flow rate in a canister to balance the viscous drag of the medium on the suspended particles in slurry against the force of magnetic attraction induced in the matrix by the background field. Control of retention time is still the crux of the entire process, where it governs the product quality and the production rate [14-15]. The results showed also that at such conditions, it is possible to remove 55.8 % of associated iron oxide and about 77.8 % TiO_2 with a concentrate assaying 0.75 % and 0.71 % of Fe_2O_3 and TiO_2 respectively and the maximum iso-brightness was 75.21%.

Figure 5 illustrates the relationship between the solid % and the magnetic separation efficiency. As shown from the Figure, the removal efficiency increases with increasing the solid percent starting from 2.5 till reaching the most efficient separation at solid % 7.5 % where the iron oxide removal reached 55.8% (0.75% Fe_2O_3) and TiO_2 removal reached

In a trial to decrease the iron oxide contents of the kaolin pre-concentrate, the hydro cyclone overflow product was subjected to magnetic separation tests using “Boxmag Rapid” wet high intensity magnetic separator. The magnetic attractive force is a function of the volume and magnetic susceptibility of the particle as well as the magnetic field intensity and gradient. The opposing force is the hydrodynamic drag force while the magnitude of the external applied magnetic field is an important factor; it is the matrix that provides the potential force separation [12-13]. Figure 3, illustrates the relationship between the magnetic field strength and the magnetic separation efficiency of the sample. Maximum separation at certain magnetic field could be attained. It could be concluded that by increasing the applied magnetic field, there is a remarkable increase in the upgrading degree of the product.

77.8 % (0.71% TiO_2). After that the removal efficiency started to decrease gradually till solid % of 15 %.

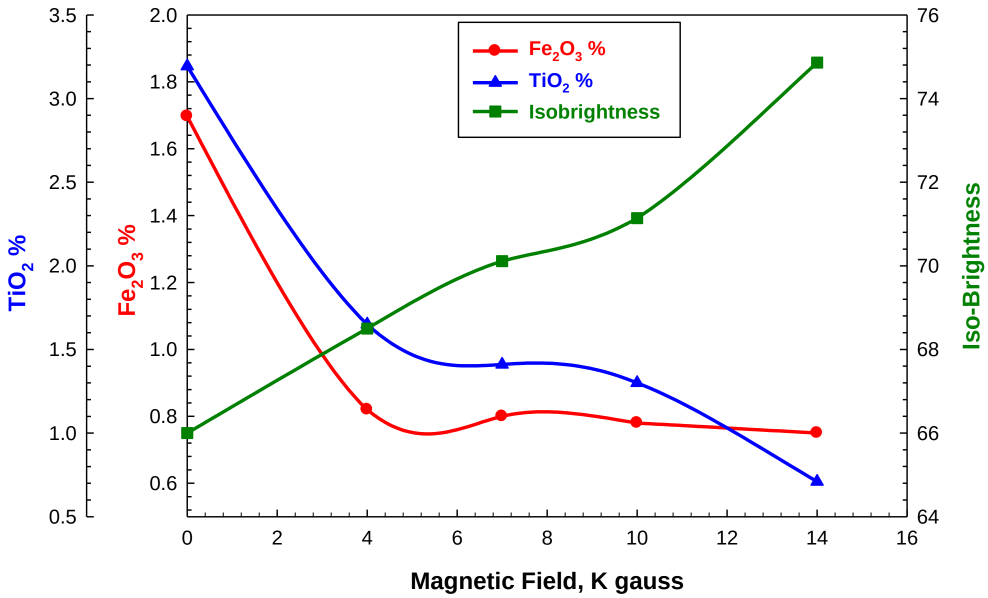

Fig.3. Product Grade as a Function of Magnetic Field Strength

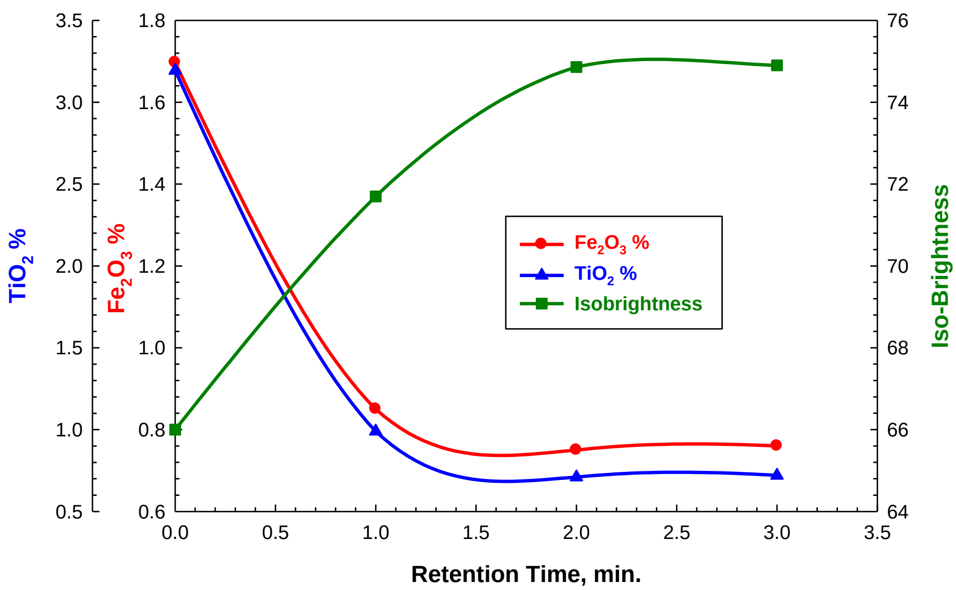

Fig.4. Product Grade as a Function of Retention Time

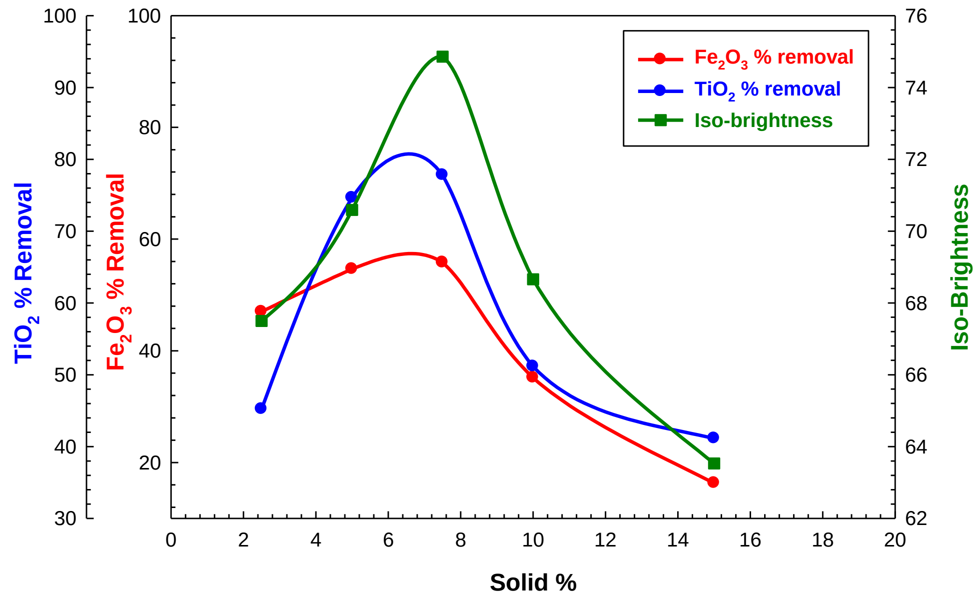

Fig.5. Product Grade as a Function of Solid Percent

Different beneficiation techniques were suggested such as attrition scrubbing, degritting and multiclassification using hydrocyclone. Using these techniques helped in removing coarse grit of silica and carbonates [16]. Successful separation of iron oxides to enhance the iso-brightness of the kaolin product could be achieved using magnetic separation. Applying such a combined beneficiation Flowsheet, Fig. 6, succeeded in producing a high grade kaolin concentrate (~75 wt. % below 2 µm) low in both iron oxides (0.75 %) and TiO_2 (0.71%) with a significant improvement in its whiteness to 86.72 % and iso-brightness to 75.21 %.

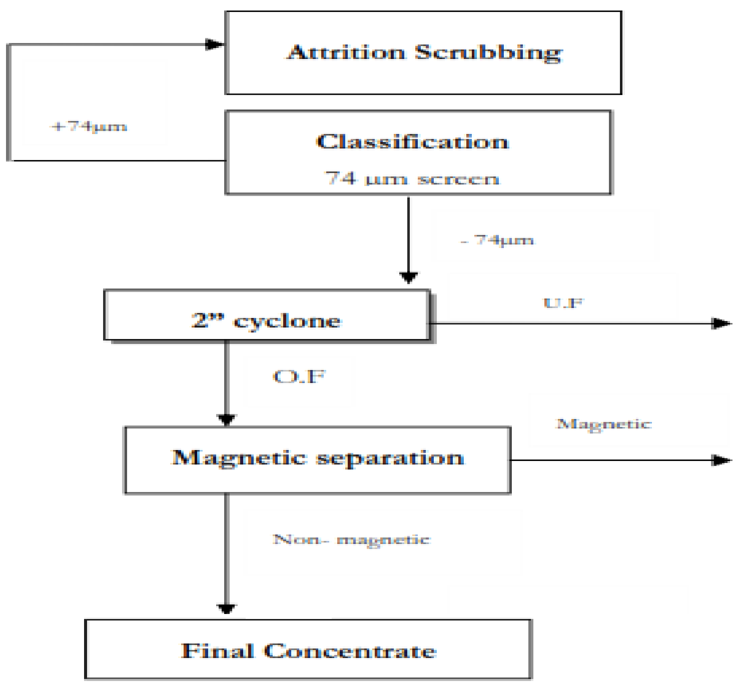

Fig 6: Tentative Flow sheet for Beneficiation of Kaolin Sample

4. CONCLUSIONS

The amenability of using magnetic separation for removing the iron oxide and titanium oxide impurities from the Egyptian Kaolin has been studied.

Successful separation of iron oxides to enhance the iso-brightness of the kaolin product could be achieved using magnetic separation.

Applying a combined beneficiation Flow sheet succeeded in producing a high grade kaolin concentrate (~75 wt. % below 2 µm).

The results indicated that substantial decrease in iron oxide (from 1.69 % to 0.75 %) and TiO_2 (from 3.1 % to 0.71 %) contents.

Both of iso-brightness and whiteness values were improved (from 63.76 % to 75.21 % and whiteness (from 79.85 % to 86.72 %) respectively.

5. REFERENCES

1. R. Asmatulu ″Removal of discoloring contaminants of an east Gergai Kaolin and its dewatering″ Turkish J. Eng. Env. Sci. vol. 26,. (2002) 447-453
2. A. RefaeiD, MK. Abdelrahman, IAEldears. Ibrahim, F AT. Kandil, “Improvement the Quality of Egyptian Kaolin for Industrial Applications ″ Int J Adv Techno (2017) 8-1.
3. S. Mukherjee “Application in Industry Engineering and Environment”. The Science of Clays Springer. India. (2013).
4. Mohammed RaoufHosseini, Ali ahmadi ″Biological Beneficiation of Kaolin″: A review on iron removal Applied Clay Science vol 107 (2015) , 238 – 245
5. O. A. Ajayi , S.S. Adefila ″Comparative Study of Chemical and Biological Methods of Beneficiation of Kankara Kaolin″ International journal of Science &Technology Research volume, 1, (2012). Issue 8, Issn 2277-8616
6. F.H. Abd El-Rahiem , M.S . Hassan, K.A. Selim, N.A . Abdel-Khalek, “Evaluation and Beneficiation of Syrian Kaolin for Different Industrial Applications”, Journal of Ore Dressing, JOD, V. 10 (2008) , Issue 19, pp. 34-41,
7. M.S. Prasad, K.I. Reid, H.H. Murray “Kaolin: Processing, properties and applications”.Appl. Clay Sci. 6, (1991) 87 – 119.
8. F.H. Abd El-Rahiem , K.A . Selim, N.A. Abdel-Khalek “Some Parameters Affecting Beneficiation of Fine Kaolin Particles”, Journal of Ore Dressing, JOD, V. 11 (2009) , Issue 22, pp. 1-8,
9. N.A. Abdel-Khalek, M.A. Arafa and, F. Hassan, “ Froth Flotation of Ultrafine Egyptian Kaolin" 6th International Mineral Processing Symposium, Kusadasi, Turkey, 24–26 Sept., [In] Changing Scopes in Mineral Processing, (Eds.), Mevlut Kemal, VedatArslan, Ali Akar and MehemetCanbazoglu, Balkama,(1996) 395–400
10. P. Raghavana, S. Chandrasekhara, V. Vogt and E. Gock, “Separation of Titanoferrous Impurities from Kaolin by High Shear Pretreatment and Froth Flotation", Applied Clay Science, 25 (2004). 111 – 120
11. A.K. Panda, B.G. Mishra, D.K. Mishra,and R.K .Singh “ Effect of sulphuric acid treatment on the physico-chemical characteristics of kaolin clay″. Colloids and Surfacea A: Physicochemical and Engineering Aspects, v.10 (2010)98-104.
12. L. Vaculikova, E. Plevova, S. Vallova, I. Koutnik “Characterization and Differentiationof Kaolinites from Selected Czech Deposits Using Infrared Spectroscopy and Differential Thermal Analysis”. Acta Geodynamics etGeomaterialia v.8 (2011) 59–67
13. L.E. Yahaya, K.O. Adebowale, Olu-Owolabi, B.I. MenonA.R.R.,Rugmini, S., Chameswary, J., “Naturrubber/Organoclay Nanocomposites: Effect of filler Dosage on The Physic-mechanical Properties of Vulcanizates”. African Journal of Pure and Applied Chemistry v.4 (2010). 198–205,
14. G.I. Mathien, and L.L. Sirois “Advances in Technology of Magnetic Separation”; XVI Int. Min. Pro. Congress, (1988) pp. 937 – 951.
15. P.G. Morston “Matrix – Moving Magnetic Separators”, U.S. Patents 3, (1975). 920, 543, Nov.18
16. P.W. Harben “Industrial Minerals Handbook, a Guide to Markets, Specifications, and Prices” (1995).