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# ECONOMIC PREFERENCES OF MECHANICAL ACTIVATION OVER MINERAL BENEFICIATION FOR PHOSPHATE ROCK DIRECT APPLICATIONS

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The direct application of phosphate rock seems to offer a better alternative in terms of low cost, least energy-intensive and sophistication of processing of the phosphate ore to produce soluble fertilizers. On the other hand, lower sensitivity to the ore quality offers a big advantage and the presence of impurities, which may play a positive significant role in the process in addition to the technique flexibility in utilizing of some useful elements needed for plant growth. All these factors can be expressed in terms of the economic advantage of the mechanical activation technique. In this study, Red Sea phosphate ore was subjected to the mechanical activation treatment with and without the beneficiation. Various products before and after activation were compared in terms of solubility and the process economy. The results showed that the mechanical activation is economically preferable.

*key words: mechanical activation, crystal lattice imperfection, phosphate fertilizer, surface reactivity*

## INTRODUCTION

Mineral fertilizers account for approximately 80% of phosphate use in the world, shared with detergents (12%), animal feeds (6%) and specialty applications (3%), e.g.

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food additives, metal treatment etc. More than 99% of all phosphate fertilizers are derived from phosphate rock, a relatively small quantity being supplied in the form of basic slag, a by-product of the steel industry (Maene, 1999).

World phosphate rock production capacity in 2006 is estimated at about 168 Mt. North America remains the world leader with 50 Mt, or nearly 33% of the world total. Africa accounts for 40 Mt, or about 25% of the total. With 26 Mt of capacity, Socialist Asia is the third largest producing area with about 17% of the world total capacity. Led by expansions in Morocco and China, world phosphate rock production is forecast to increase. Construction is under way on new mine capacity also in Canada and Australia (Maene, 1999). Table 1 shows the world fertilizer consumption by region and Figure 1 shows the world fertilizer consumption by type. About 2% of the rock is applied directly, without processing, most of the remainder being solubilized with mineral acids. Two thirds of the phosphate fertilizers are derived from rock treated with phosphoric acid; during the past 30 years, a large proportion of the net addition to phosphate fertilizer production has been in the form of phosphoric acid based products. About 90% of the world phosphoric acid output is used for fertilizer production (Fig. 1.).

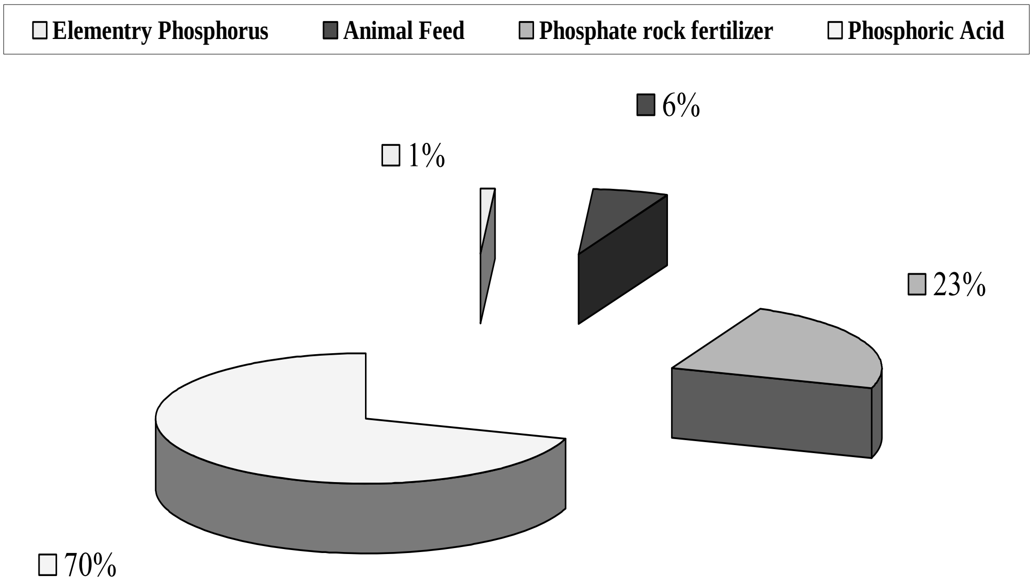

Fig. 1. Phosphate rock products

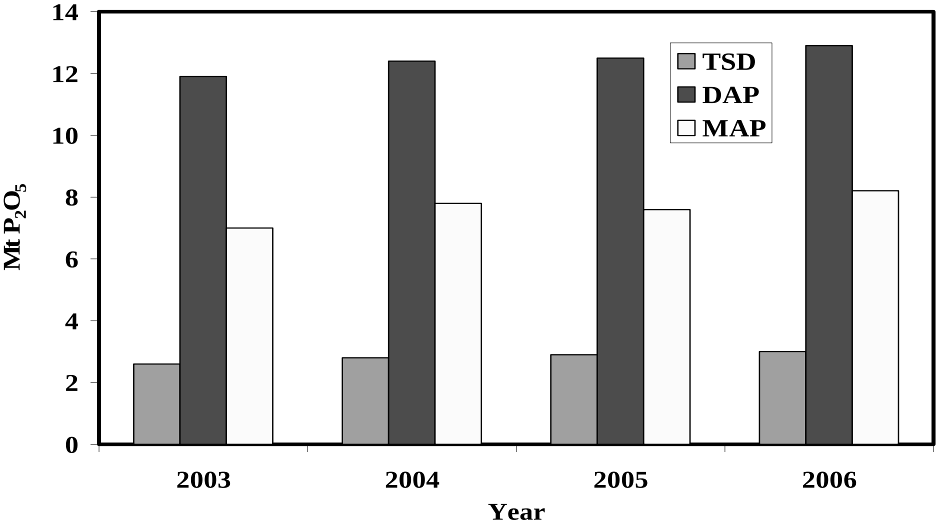

Fig. 2. World phosphate fertilizer production (IFA, 2006). DAP = diammonimum phosphate, MAP = monoammonium phosphate, TSP = triple super phosphate

Phosphoric acid is produced by either a dry or a wet process. In the dry process, phosphate rock is treated in an electric furnace to produce a very pure and more expensive phosphoric acid (frequently called white or furnace acid). In the wet process, the phosphate rock was treated with acid producing phosphoric acid (also called green or black acid) and gypsum, which is removed as a by-product (Maene, 1999).

Table 1. World phosphoric acid production

| Country | Production, Mt | |
|---|---|---|
| | 2003 | 2006 |
| USA | 11 | 11.5 |
| China | 4 | 4.5 |
| Morocco | 2.5 | 5 |
| Russia | 2.5 | 1.5 |
| Tunisia | 2 | 3 |
| Others | 8.9 | 9 |
| Total | 30.9 | 34.5 |

World processed phosphate trade has increased substantially. Total exports of phosphoric acid, ammonium phosphate and triple superphosphate increased from an average of 8 Mt P2O5 between 1984 and 1986 to 15 Mt P2O5 in 1998, despite a fall in total phosphate consumption during this period. Today, ammonium phosphate accounts for approximately 60% of the world processed phosphate trade and in 1998, the USA accounted for 60% of world exports of ammonium phosphate, mostly as DAP. Asia is the biggest importing region, for ammonium phosphate, followed by West Europe and Latin America (Isherwood, 2000).

Table 2. World phosphoric acid, supply/demand, 2004 to 2007 (Alley and Spargo, 2007)

| Item | Phosphoric acid (million tons $P_2O_5$) | | | |
|---|---|---|---|---|
| | 2004 | 2005 | 2006 | 2007 |
| Supply | 28.5 | 29.1 | 30.4 | 30.4 |
| Demand | 27 | 27 | 29.1 | 30.2 |

These balances do not take into account the permanent closures in Western Europe and the USA and the temporary closures, which could be reactivated when market conditions permit. In addition, they do not take into account capacity that was under-utilized in 1995, for example in Russia. They explain the oversupply and pressure on prices, which developed especially in 1999 (Isherwood).

Because various phosphate (P) fertilizers differ widely in their solubility, it is commonly observed that crop response to P fertilizers varies under the same soil and crop conditions (Alley and Spargo, 2007; Chien et al., 1990). Furthermore, a major problem encountered in the methods for determination of the relative effectiveness (RE) of water-insoluble P fertilizer (e.g., phosphate rock) with respect to water-soluble P fertilizers, e.g., single superphosphate (SSP) and triple superphosphate (TSP), is that their growth response curves are usually nonlinear and often do not share a common maximum yield. In this paper, we review and discuss the advantages and disadvantages of the three most commonly used methods for calculating the RE of phosphate rock with respect to TSP (or SSP). The three methods are vertical comparison, horizontal (substitution rate) comparison, and linear-response comparison (Chien et al., 1990).

## SUBSTITUTION RATES AS MEASURES OF THE RELATIVE EFFECTIVENESS OF ALTERNATIVE PHOSPHORUS FERTILIZERS

A procedure for representing the effectiveness of fertilizers relative to a standard fertilizer by the estimation of substitution rates is demonstrated with yield data from a fertilizer experiment with triple superphosphate and a partially acidulated rock phosphate. The substitution rate is estimated by an iterative regression procedure and the accuracy of the estimate indicated by a 5% confidence interval. The use of substitution rates to evaluate fertilizers depends on the assumption that the standard and alternative fertilizers differ in their effects on crop growth only because of differences in content of available nutrient. This assumption is tested as a statistical hypothesis. Substitution rates calculated from experimental data with rates of application of the fertilizers represented in terms of chemical analysis of the fertilizers indicate the usefulness of the analyses as measures of the available nutrient content of the fertilizers (Colwell and Goedert, 1988).

A greenhouse study was conducted to determine if soil pH affects the requirement for water-soluble P and the tolerance of water-insoluble impurities in TSP fertilizers. Two commercial TSP fertilizers were selected to represent a range in phosphate rock sources and impurities. Phosphate fertilizer impurities were isolated as the water-washed fraction by washing whole fertilizers with deionized water. TSP fertilizers with various quantities of water-soluble P (1.2 to 99% water-soluble P) were simulated by mixing the water-washed fertilizer fractions or dicalcium phosphate (DCP) with reagent-grade monocalcium phosphate (MCP). The fertilizers were applied to supply 40 mg AOAC available P $kg^{-1}$ to a Mountview silt loam (fine-silty, siliceous, thermic *Typic Paleudults*). Wheat (*Triticum aestivum* (*L.*)) was harvested at 49 and 84 days after planting. Soil pH values at the final forage harvest were 5.4±0.16 and 6.4±0.15. At a soil pH of 5.4, the TSP fertilizers required only 37% water-soluble P to reach maximum yields while at pH 6.4 the fertilizers required 63% water-soluble P. Results of this study show that higher levels of water -insoluble P can be tolerated in TSP fertilizers when applied to acidic soils. Phosphorus uptake was not affected by soil pH, but for the mixtures containing the fertilizer residues the source having the lowest level of Fe and Al had a higher relative agronomic effectiveness (Mullins and Sikora, 1994 ).

Table 3. Water-soluble & available phosphate % in common fertilizer sources

| $P_2O_5$ Source | | $P_2O_5$ | | |
|---|---|---|---|---|
| | N | Total | Available | Water Soluble* |
| | % | | | |
| Superphosphate (OSP) | 0 | 21 | 20 | 85 |
| Conc. superphosphate (CSP) | 0 | 45 | 45 | 85 |
| Monoammonium phosphate (MAP) | 11 | 49 | 48 | 82 |
| Diammonium phosphate (DAP) | 18 | 47 | 46 | 90 |
| Ammonium polyphosphate (APP) | 10 | 34 | 34 | 100 |
| Rock phosphate | 0 | 34 | 3-8 | 0 |

*Water-soluble data are a percent of the total $P_2O_5$

Source: Ohio Agronomy Guide. Ohio Cooperative Extension Service Bull.472.

Elemental impurities in mono-ammonium phosphate (MAP) fertilizers, such as Fe, Al, Ca, Mg, and F, result in compounds other than $NH_4H_2PO_4$. The phosphorus availability of the impurity compounds was determined in 3 commercial MAP fertilizers produced from North Carolina, Florida, and Idaho phosphate rocks. Soluble compounds, including $NH_4H_2PO_4$, were washed out of the fertilizers, and the water-insoluble fraction was collected. The North Carolina, Florida, and Idaho MAP fertilizers contained 13, 16, and 17% water-insoluble fractions, respectively. Availability of phosphorus in each MAP fertilizer and water-insoluble fraction was determined in a greenhouse pot study using sorghum-sudangrass (Sorghum bicolor) as the test crop. There were no differences in dry matter weights or phosphorus uptake between reagent grade MAP and each MAP fertilizer. Lower dry matter weights and phosphorus uptake were produced from the water-insoluble North Carolina, Florida, and Idaho fractions (NC greater than FL greater than ID). Chemical analysis and characterization with optical microscopy, infrared spectroscopy, and X-ray diffractometry indicated 77.3, 73.8, and 73.6% $NH_4H_2PO_4$ in the North Carolina, Florida, and Idaho MAP fertilizers, respectively. $MgAl(NH_4)_2H(PO_4)_2F_2$, $AlNH_4HPO_4F_2$, and $FeNH_4(HPO_4)_2$ were identified as water-insoluble phosphorus compounds. There was a significant negative correlation between the percent phosphorus present as $MgAl(NH_4)_2H(PO_4)_2F_2$ and the phosphorus (Sikora et al., 1989).

Based on historical trends of gross energy requirements, it was calculated that in 2001, that global energy embedded in fertilizer consumption amounted to 3660 PJ, which represents about 1% of the global energy demand. Total energy demand has increased at an average rate of 3.8% p.a. Drivers behind the trend are rising fertilizer consumption and a shift towards more energy intensive fertilizers. Our results show that despite significant energy efficiency improvements in fertilizer manufacture (with exception of phosphate fertilizer in the last 20 years), improvements in energy efficiency have not been sufficient to offset growing energy demand due to rising fertilizer consumption. Furthermore, it was found that specific energy consumption of ammonia and urea developed in close concordance with the learning curve model, showing progress ratios of 71% for ammonia production and 88% for urea. This suggests an alternative approach for including technological change in energy intensive industries in middle and long-term models dealing with energy consumption and $CO_2$ emissions, while few learning curves exist for energy efficiency of end use technologies (Ramírez and Worrell, 2005).

There have been several plant closures in Western Europe, where phosphoric acid production capacity and output have fallen by 60% since 1980, for economic and environmental reasons. The latest announced closure is that of the Norsk Hydro phosphoric acid plant at Vlaardingen in the Netherlands, due largely to problems related to the treatment of by-product phosphogypsum (Maene, 1999). The "reserves" of phosphate rock, i.e. deposits that are or could be profitably mined under prevailing costs, market prices and technology, are rather limited. However, the "resources" which are at present not economically exploitable, but which could potentially become so, are very large (Table 4).

Table 4. Phosphate rock reserve base in terms of cost (billion tones) (Maene, 1999)

| Cost ($/tones) | Below $40 | Below $100 |
|---|---|---|
| North America | 1.4 | 4.7 |
| North and West Africa | 7.2 | 22.1 |
| Middle East | 0.1 | 1.9 |

However, the trends move again towards using raw phosphate rock to reduce the cost. From one side this is due to the high expenses of the production of the fertilizers either by dry or wet processes. From the other side, it was found that the highly soluble fertilizers which have expensive manufacturing costs lead to the lack of micronutrients. The problem was found to be iron, zinc and manganese being tied up by phosphate.

In Zimbabwe, using phosphate rock appears to halve the cost of imported fertilizers. The main disadvantage of using the phosphate rock is its low solubility and consequently the low availability of the P for the plant growing. Therefore, the mixing of the rock phosphate with highly soluble fertilizers shows that the savings are impressive. In Kenya, a mixture of 90 percent local phosphate rock is blended with just 10 percent imported fertilizer (Morris, 1988).

Grinding of ordinary phosphorite powder of Central Kyzylkum with urea nitrate and ammonium carbonate salt to the particles size less than 0.16 mm leads to significant increase in content of $P_2O_5$ in the form consumable by plants (Seitnazarov et al., 2007).

Thermochemical synthesis offers possibility of getting effective compound fertilizers from low-grade poorly enrichable mineral raw materials. Agricultural field tests demonstrated that the compound fertilizers developed are much more effective than equivalent doses of the starting components equalized in terms of nitrogen and potassium. Consequently, apatite-based compound fertilizers can be used to radically improve soil fertility phosphoritization with simultaneous improvement of the nitrogen-potassium regime (Latkin and Samatova, 1998).

## PHOSPHATE ROCK FOR DIRECT APPLICATION

It is clear from the abovementioned that if the solubility problem of the rock phosphate can be solved then the rock phosphate will be ready to be used for direct applications as a fertilizer. On the way to solve this problem and increase the rock phosphate solubility, highly intensive size reduction equipment like vibrating, centrifugal, jet and other types of mills were employed in the tribo-mechanical treatment of phosphate rocks (Heinike et al., 1977; Kolosov et al., 1979; Paudert et al., 1978; Kozlov and Kozyrev, 1982; Gock et al., 1986). However, many disadvantages in the comminution process were recorded (Gock et al., 1986; Kurrer and Gock, 1986).Perhaps, that is why such grinding machines did not achieve economical advancement in the domain of phosphate activation under the mechanical forces (Gock et al., 1986).

To overcome the disadvantages of the tribo-mechanical treatment, the development of the principle of rotary-chamber vibrating mill is based upon the introduction of such freely moving chamber wheel in the milling tube. Caking of the ground product in such a mill is avoided by the paddle mixer. Beyond the surface expansion which occurs through the vibrating tube mill, the high collision energy conveyed by this method induces lattice defects through disintegration. These lattice defects, which deviate from the initial lattice structure, lead to a growth of free enthalpy (Kurrer and Gock, 1986). The decreasing activation energy related to this exerts a decisive influence on the reaction kinetics of rock dissolution (Kurrer and Gock, 1986).

Various investigations have already been done on the possibility of influences on the leaching–velocity of phosphorites, especially in connection to the aforesaid improvement of starting-effect by their direct application as fertilizer (Paudert et al., 1978). It has been thereby ascertained, that phosphorites of sedimentary origin are in comparison to the apatites of magmatic origin, fundamentally better suitable for a mechanical activation, because they show a high grade lattice distortion due to the partial substitution of the phosphate ions by carbonate ions in the initial ore. An economic processing of the Kola-apatites through mechanical activation has so far been considered impossible, because of the high expenditure of the necessary energy by applying vibration mill. The same method applied for the sedimentary phosphorites of Morocco, is, compared to the other commercial fertilizers like superphosphate as well as double-superphosphate, supposed to be more economical.

The technology of tribo-mechanical activation of phosphate rocks for direct application purposes may open the way, when thoroughly understood, for utilization of indigenous ores in so many developing countries and serve captive regional markets when arbitrary grade specifications do not apply.

## MECHANICAL ACTIVATION OF PHOSPHATE AS A SOLUTION FOR THE DIRECT APPLICATION OF THE EGYPTIAN RED SEA PHOSPHATE, CASE STUDY

The mineralogical investigation of the worldwide phosphate deposits has shown that the general fluorapatite composition applies more closely to igneous and high grade metamorphic deposit types than to sedimentary phosphates (McClell and Gremillian, 1976). The composition, high crystallinity and low reactivity of such igneous apatites of Kola, former USSR and Phalaborwa, South Africa make them virtually useless for direct application (McClellan and Gremillian, 1976).

Sedimentary phosphate rocks contain apatitic phosphates of more complex chemical composition following, in general, the francolitic-type formula suggested by Lehr and McClellan (1973). The carbonate apatite in most sedimentary phosphate rocks is submicrocrystalline and occurs in several varieties of complex aggregates (McClellan and Gremillian, 1976).

Red sea phosphate grains are amorphous and cryptocrystalline cellophane. The ore is characterized by rounded, elongated and irregular grains of different sizes (50 to 200 µm). Biodetrital phosphate in the form of bone fragment, vertebrae and teeth are also identified in Red Sea phosphate cemented with calcareous siliceous matrices. The calcareous cement, most probable dolomite, is observed partially replacing the bone fragments and cellophane especially along the borders in the Red Sea sample.

Red sea phosphate was taken as an example on the possibility of the application of the mechanical activation to prepare the rock phosphate for direct application. Tables 5 and 6 depict the chemical analyses of both the raw and treated samples as well as their size distribution before activation. All the mechanical treatment tests were carried out using the pilot scale, circulating oil lubricated, three tube rotary chamber, type “Palla U 35”, Humboldt Wedage AG vibrating mill of “Institut fur Aufbereitung, Technische Universitat”, Berlin, Germany (Fig. 3.).

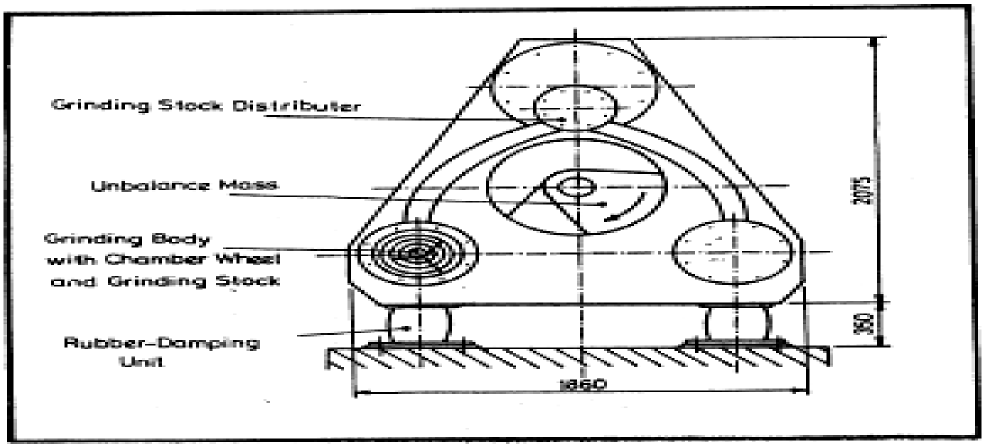

Fig. 3. Rotary-chamber vibrating mill

Mechanical activation of phosphate in highly intensive size reduction equipment, such as modified vibrating mill should result on an increase in degree of dispersion of the milled product (Gock and Jacob, 1984). Figure 4 illustrates the size distribution of the ground end products (after 90 min). Gradual increase in the %$D_{90}$ values with increasing milling time for raw and concentrate samples is indicating the limited advantage of increasing time.

Table 5. Chemical analysis of red sea phosphate samples

| Constituents, % | Raw | Concentrate |
|---|---|---|
| $P_2O_5$ | 23.48 | 28.40 |
| CaO | 38.05 | 43.45 |
| $Fe_2O_3$ | 1.61 | 1.12 |
| $Al_2O_3$ | 2.38 | 1.05 |
| MgO | 2.64 | 1.72 |
| $SiO_2$ | 10.14 | 5.61 |
| $CO_2$ | 6.35 | 5.58 |
| Humidity | 3.83 | 3.88 |

Table 6. Size Analysis of Primarily Crushed Samples, (Mill Feed)

| Size, mm | Wt.%, Raw | Wt.%, Concentrate |
|---|---|---|
| >2.00 | 8.09 | 12.42 |
| -2.0+0.80 | 19.36 | 16.16 |
| -0.80+0.50 | 8.96 | 10.34 |
| -0.50+0.315 | 12.72 | 13.91 |
| -0.315+0.20 | 8.96 | 10.78 |
| -0.20+0.15 | 9.83 | 8.91 |
| -0.15+0.10 | 8.67 | 7.15 |
| -0.10+0.063 | 17.34 | 11.65 |
| <0.063 | 6.07 | 8.69 |

Evidently, symptoms of agglomeration were recorded after 60 min. The progressive structural changes in the apatite lattice with time are proving that dispersion is not necessarily the main process affecting rock reactivity during mechanical activation.

The absolute solubility index (ASI) of Red Sea phosphate raw and beneficiated sample in 2 % citric acid, CA and neutral ammonium citrate (NAC) were measured, Figs 5 and 6.

A substantial increase in the dissolution rates of the activated products was recorded, indicating the efficiency of the mechanical activation process. Gradual improvement in the ASI values of the milled products with increasing milling time signifies the advantage of the grinding over longer time.

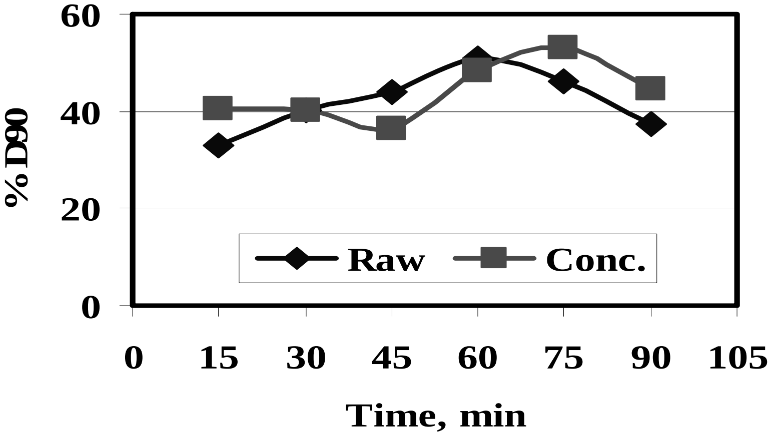

Fig. 4. Effect of milling time on % $D_{90}$ of the ground products

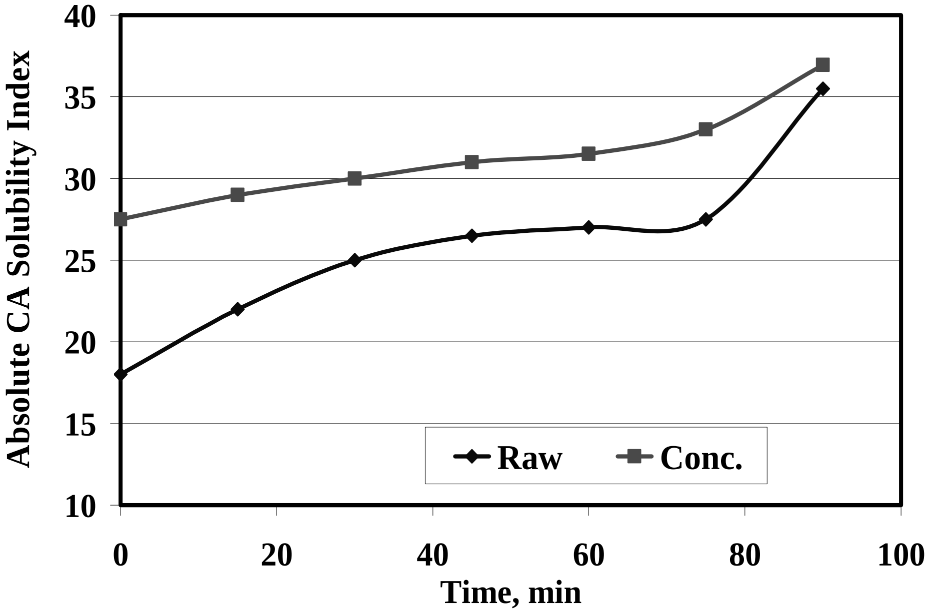

Fig. 5. Solubility index of phosphate samples in 2% citric acid at different milling times

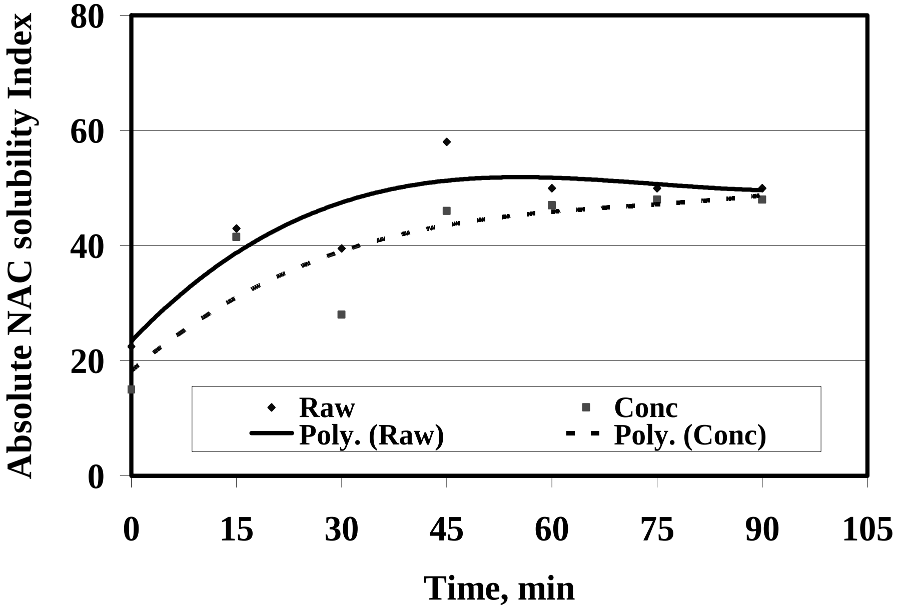

Fig. 6. Solubility index of phosphate samples in neutral ammonium citrate at different milling times

## MECHANICAL ACTIVATION- ENERGY MEASUREMENTS

Table 7. The Solubility Tests of Different Phosphorites with the Mechanical Activation (kWh/t.) by using 2% Citric Acid

| Phosphorite Types | $P_2O_5$-content | 0 kWh/t | 25 kWh/t | 50 kWh/t | 100 kWh/t |
|---|---|---|---|---|---|
| Hyperphos (commercial prod.) | 31.7% | 33.5% | 36.1% | 45.3% | 49.6% |
| Saphos (commercial Red Sea prod.) | 28.6% | 30.4% | 34.6% | 40.2% | 43.8% |
| Abu Tartur (conc.) | 30.0% | 25.9% | 33.5% | 44.2% | 49.4% |
| Sebayia (crude ore) | 21.5% | 29.2% | 33.7% | 37.1% | 40.7% |
| Arad (conc.) | 32.0% | 34.9% | 39.1% | 40.9% | 43.7% |
| Morocco (conc.) | 31.0% | 29.0% | 33.2% | 34.2% | 35.7% |
| Togo (conc.) | 34.2% | 18.2% | 23.6% | 25.6% | 28.9% |

The solubility behavior of raw, either unactivated or activated samples in the alkaline medium was altered (Fig. 6.). Treated raw sample showed increase in the leaching efficiency in all the milling experiments.

The optimum solubility was found to be at milling time of 45 mins in NAC, Figure 7. This trend is identical with that of the change in %$D_{90}$ of the phosphate samples by increasing in activation time which indicates the effect of the sample size on its solubility in NAC.

## EFFECT OF PH ON MECHANICAL ACTIVATION

The influence of the mechanical activation was correlated to the pH-values (Gock and Jacob, 1984). It was shown that within a pH-range between 5 and 7, which is of great importance for the Egyptian cultivated lands, a good initial leaching velocity can be achieved, which, however, increases strongly with the progressive mechanical activation (Gock and Jacob, 1984). In addition to the leaching velocity, the phosphorous-equilibrium-concentration is also important for the fertilizing effect. Hence, further investigations are necessary to establish the existence of a relationship between the mechanically activated phosphorite and the phosphorous- equilibrium of the refined phosphate fertilizer (Gock, Jacob, 1984). A large proportion of potentially arable land in the tropics is strongly acidic and tends to be extremely deficient in phosphorus, a case which could be typical for natural phosphate application

## IMPURITIES EFFECT

Most of the phosphate ores contain impurities, which may affect the mechanical activation process either positively or negatively. The prevailing impurity, in most of the phosphate ores, is silica. In case of adding the raw phosphate as a fertilizer, the silica impurities does not harm the soil because of it represents one of the soil components.

In regard to mechanical activation process, the effect of tribomechanical activation of Red Sea phosphor-concentrate, after such a change in its chemical and mineralogical characteristics, should be interesting, where it showed lower tendency to the mechanical activation compared to the raw ore. Such behavior may be ascribed to its exo-gangue minerals contents, mainly silica and silicates. They seem to play an important role in the process. The same conclusion was reached by Malchikov et al. (1983) who got better activation results by adding silica to some phosphate ores (Malchikov et al., 1977).

## ECONOMIC PREFERENCE OF MECHANICAL ACTIVATION

The comparison was carried out between the costs of mechanical activation of the phosphate ore with the running of different beneficiation steps to produce a concentrate suitable for the production of the phosphoric acid, which is an intermediate step of all the fertilizer manufacturing process. This comparison shows that the activation will lead to substantial savings. Initially, the saving is due to the reduction in the capital and operating costs of the beneficiation steps. Moreover, the same thing will happen to the wet process that cost much more than beneficiation processes due to dealing with acids (i.e., one ton of sulfuric acid costs about 700 $) and the corrosion problems, which increase the maintenance costs too.

Table 8. Costs of mechanically activated raw- and the processed phosphate fertilizers

| Costs/ton | Processed phosphate fertilizer | Raw-phosphate fertilizer |
|---|---|---|
| Mining | 70-80 $ | 70-80 $ |
| Processing | 50-60 $ Min. $P_2O_5$= 32% | ------ |
| $H_2SO_4$ | 700 $ | ----- |
| Energy | 35$ (350 kWh/t) | 2.50 $ (25kWh/t)<br>8.0 $ (80 kWh/t) |
| Market price/ton | 1000-1200 $ | 400 $ |

- calculations based on 10 cents/ kWh

The 2006 price of residential electricity in the United States is 10 cents per kWh. In Egypt, under the new system, the price of electricity will also be from 5 to 7 cents per kWh for medium power consumers (Mixed Reactions to New Energy Pricing Strategy, Reem, 2007).

## CONCLUSIONS

The paper revisited the phosphate fertilizers industry in terms of world consumptions and their energy constraints. It is noted that the raw phosphate rock is coming into the picture to be used as an alternative to the current phosphate fertilizers due to costs and energy limitations.

One of the reasons behind the rare use of the phosphate as direct application fertilizer is its solubility. To overcome this limitation, the mechanical activation was tried and has achieved a marked increase in the reactivity of the treated phosphate samples. The chemical reactivity of activated raw samples in 2% citric acid and neutral ammonium citrate showed improved leaching characteristics for all the milling times tested.

The comparison of the production costs of the current fertilizers at different stage from mining until marketplace with the phosphate rock shows the preference of the mechanical activation in terms of energy and economics.

Therefore, the technology of tribomechanical activation of phosphate rock for direct application may open the way for utilization of indigenous ores in many developing countries and serve capital regional markets when arbitrary grade specifications do not apply.

The simple technology of mechanical activation, for production of the fertilizer from domestic Egyptian phosphorites, will meet the local needs of the developing-country like Egypt, and would give the security to be independent of the international chemical concerns.

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Bezpośrednie zastosowanie rudy fosforanowej wydaje się być lepszą alternatywą pod względem niższych kosztów, mniejszego zużycia energii niż skomplikowany proces produkcji nawozu mineralnego z rudy fosforanowej. Dodatkowo, mniejsze wymagania dotyczące jakości rudy przynoszą dodatkową korzyść dla samego procesu oraz wprowadzają zanieczyszczenia, które odgrywają pozytywna rolę w procesie, dostarczając użytecznych składników koniecznych dla wzrostu roślin. Wszystkie te cechy można przełożyć na korzyści ekonomiczne wynikające z procesu mechanicznej aktywacji. W relacjonowanych badaniach, ruda fosforanowa z morza Czerwonego była przedmiotem działania mechanicznej aktywacji z korzyścią lub przy jej braku. Szeroka gama produktów zarówno przed jak i po procesie aktywacji była testowana pod katem rozpuszczalności oraz rachunku ekonomicznego. Otrzymane wyniki wskazują, że aktywacja mechaniczna jest procesem ekonomicznie uzasadnionym.

*słowa kluczowe: mechaniczna aktywacja, nawozy fosforowe, reaktywność powierzchniowa*