

**UNITED NATIONS**  
**ECONOMIC AND SOCIAL COUNCIL**

Distr. : LIMITED  
E/ESCWA/NR/1993/WG.2/6  
13 September 1993 c. 2  
ORIGINAL : ENGLISH

**ECONOMIC AND SOCIAL COMMISSION**  
**FOR WESTERN ASIA**

Workshop on Integration of Science &  
Technology in the Development Planning  
and Management Process  
27 - 30 September, 1993  
Amman - Jordan

**UN ECONOMIC AND SOCIAL COMMISSION**  
**FOR WESTERN ASIA**

**OCT 11 3 1993**

**LIBRARY & DOCUMENT SECTION**

**Techno-Economic Assessment of  
Domestic Resources  
A Model of Interaction Between  
R&D Institute & Industry**

By

**Prof. Dr. A. K. Ismail**

Central Metallurgical R&D Institute (CMRDI)  
Egypt

**Co-sponsors : United Nations Industrial Development Organization (UNIDO)**  
**Higher Council for Science & Technology (HCST)**  
**Islamic Foundation for Science & Technology Development (IFSTAD)**

- The Views expressed in this report are those of the author and do not necessarily reflect those of the United Nations Economic and Social Commission for Western Asia.
- This paper has been produced without formal editing.



**TECHNO-ECONOMIC ASSESSMENT OF DOMESTIC  
MINERAL RESOURCES  
A MODEL OF INTERACTION BETWEEN  
R&D INSTITUTE AND INDUSTRY**

*By*

***Prof. Dr. A.K. Ismail***  
*Central Metallurgical R&D Institute,  
P.O. Box 87 Helwan, Cairo, Egypt*

**ABSTRACT**

The development of mineral industry in Egypt and the utilization of local raw materials as substitutes for imports are among the major national objectives of the country.

The Central Metallurgical Research and Development Institute was established as an application - oriented research and development organization to cope with these objectives.

The institute was established in the heart of the metallurgical industry in Helwan. Its board comprises chairmen of the major industrial metallurgical companies; which allows continuous awareness with industry problems and directs R&D activities towards solving it through contract-based projects in which the end user is contributing effectively.

A system was developed in CMRDI for techno-economic assessment of mineral resources. The system is based on conducting laboratory and pilot-scale continuous

testing, carrying out the basic engineering design of the production unit and performing feasibility studies.

Establishment of prototype plants, sometimes within the end user premises, would be required for technology derivation, appropriateness and innovation.

The work is carried out in a close cooperation with the end user, which results in the creation of R, D&E centers in the concerned industries and expansion of its activities. The contribution of the end user during the various phases of the project improves the performance considerably.

The paper reviews the mechanism of the interaction between R, D&E centers and industry. Examples are given from STC-funded projects in the areas of phosphate and bentonite industries.

Emphasis is made on the impact of these projects on national economy as products from these domestic raw materials would be used as substitutes for imports and can compete with foreign products in both quality and price.

## INTRODUCTION

Mineral resources are the backbone of the mineral, metallurgical, chemical and allied industries. Its development is one of the major factors upon which the country economy is based. Generally speaking, developing countries possess the major mineral commodities of the world and consequently an efficient system of its evaluation and utilization should be among the top priorities of R&D organizations.

Egypt, as all other developing countries, possess huge potentials of mineral resources both metallic and non-metallic. Nevertheless, very limited number is being exploited for metallurgical, ceramics and chemical industries. Meanwhile, there is a big need in the country for metal products to cope with the rapid development in many industrial domains. Currently, most of the mineral industry products are imported against hard currency. The absence of an efficient and applied-oriented R&D organization for evaluating the utilization of the mineral resources is among the reasons of its abandonment. Thus, establishing an applied-oriented R&D institute to serve the mineral and metallurgical industries became a necessity.

## STORY OF CMRDI

The United Nations Industrial Development Organization (UNIDO) together with the Egyptian Government established the Central Metallurgical Research and Development Institute (CMRDI). The institute is situated in Helwan, some 40 km south of Cairo, close to the Iron and Steel Complex in the heart of the metallurgical industries. It started with pilot plant operation while laboratory work was carried out in the laboratories of the Metallurgy Department of the National Research Center. This department was the nucleus of CMRDI. The human resources were developed through efficient training in industrial R&D organizations in Europe. Foreign experts from

various industrial sectors were invited to conduct on-the-job training for institute's staff and their industry counterparts. The experts also started effectively identifying industrial problems and contributed to their solutions.

After 10 years of hard work, the institute acquired a pronounced industrial reputation, not only locally but also in the region. At present, CMRDI is carrying out R, D&E projects in the major areas of mineral beneficiation, extractive metallurgy, foundry and metal technology as well as welding. The four pilot plant sheds of mineral beneficiation, extractive metallurgy, foundry and metal technology enable CMRDI to conduct proper service to the industry till the stage of plant design and feasibility study.

### **LINKAGE OF CMRDI WITH INDUSTRY**

According to the constitution of CMRDI, the Board of Directors comprises 5 chairpersons of the most powerful metallurgical companies. This allows continuous awareness with country problems and efficient follow-up of the running projects so that the activities of the institute are mainly directed towards solving the problems of industry.

Within the managerial structure of the institute, there is a technical committee which comprises representatives from the various industrial companies together with their counterparts from the institute. This committee meets frequently for follow-up actions and exposure of new problems. This allows cooperation between the companies themselves and the institute.

In frequent cases, R&D projects are implemented in the end-user side which allows closer interaction between the institute's staff and the company experts which generates new ideas for new projects.

Needless to say that the methodology of conducting an industry-oriented R&D project and developed by CMRDI is the main factor for establishing and strengthening the linkage with industry.

### **HOW DOES CMRDI CONDUCT AN INDUSTRIAL R&D PROJECT**

Generally speaking, a project is successful if its objectives are realized to the satisfaction of the end user. For example, a new product with acceptable quality at a reasonable price is the shortest way to convince the customer. Therefore, CMRDI projects should end with a feasibility study. The methodology practiced in CMRDI for R&D projects in the area of techno-economic assessment of mineral resources could be described as follows :

1. Characterization of the raw material.
2. Laboratory scale batch tests to obtain the optimum operating conditions.
3. Continuous bench scale process in which the raw materials are fed continuously 24 hr/day to the system and the products are similarly continuously discharged. This simulates the real industrial operation conditions.
4. Continuous pilot plant operation to assure the optimum performance of the equipment at the steady state and obtaining the operation parameters. Through pilot plant operation, it would be possible to produce amounts of the product sufficient for industrial testing.
5. Extrapolation of the pilot plant data to the full scale plant level.
6. Process design as applied to the proposed plant capacity. This includes calculations of material and heat balances along the different streams of the processing flow sheet. Environmental aspect is a major part of the flow sheet for which a special attention is given.
7. Preparation of equipment list with detailed specifications.

8. Basic engineering design of the equipment with emphasis on increasing local fabrication potentialities.
9. Cost estimates and feasibility study of the project assuming that the selling prices of the product is less than the price of the imports.

### **COST/BENEFIT STUDIES**

Economic evaluation of the R, D&E projects is not recommended to be performed at the final stages of the projects but rather throughout the project life span. The methodology adopted in such projects uses the economic evaluation outcome as to help making decisions to stop the project or go for further steps.

Two main stages can be identified namely, the economic evaluation of the project idea (preliminary cost/benefit studies) and the project formulation, evaluation and investment (feasibility studies).

#### **Preliminary Cost/Benefit Study**

This study which is usually performed right at the onset of the project or in its very early stages is rather sketchy in nature and rely more on aggregate estimates than on detailed analysis. Materials and utilities consumptions are roughly estimated while cost data are usually taken from comparable existing projects. The study will identify the investment opportunity of the project idea by analyzing the following :

- Natural resources with potential for processing and manufacture.
- The current and future demand for the product.
- Possible interlinkage with other industries.
- Possibilities for diversification.



- Cost and availability of production factors.
- Export possibilities.

This study can also be performed to identify the most promising processing route from various manufacturing techniques. Positive results give a green light for the project to proceed to the laboratory and pilot plant tests whereas negative result implies that the project idea is not economically viable.

### **Feasibility Study**

This phase is usually performed at the end of the project where more detailed information about the project parameters are made available. At this stage the following economic alternatives are examined :

- demand, sales and market study
- plant capacity and production programme
- location and site.
- materials input.
- processing technologies.
- equipment list and specifications
- labour and staff
- overheads (factory, administrative and sales)
- investment costs
- proposed financial structure
- production costs

The above mentioned items are elaborated using financial and economic formulae in order to derive some financial statements and profitability measures such as :

- income statement
- resources and uses statement
- cash-flow statement
- profitability ratios, e.g.
  - internal rate of return
  - net present value
  - benefit/cost ratio
  - pay-back period

The information elaborated at this stage will help determining whether the investment opportunity is so promising that an investment decision can be taken on the basis of the outcome of this study.

On the other hand, several social effects may have its impact on the decision of the implementation of the project. Some of them are :

- introduction of a new industry
- feeding of downstream industries
- development of capabilities of technical staff
- formation of communities in new areas

### **HOW CAN CMRDI SERVE INVESTORS**

CMRDI is currently tackling a new area that is technology transfer of small-scale industries. In addition to all the steps mentioned before, detailed engineering of the plant will be done assuming that the plant capacity is small (1-2 tons/day). In this sense, CMRDI would be ready to provide investors with bankable documents covering the know-how and detailed feasibility study. CMRDI will be ready to recruit local

contractors for construction of the plant. Supervision of operation over a certain period of time is also guaranteed.

### **HOW DOES CMRDI DEAL WITH FUNDING**

Funding is the most critical part of the project. CMRDI develops an in-house funding system for funding the basic studies of the project. These studies are more or less of academic nature and may - or may not - lead to positive results. It is thus not recommended to approach an end user asking for funding such basic studies. Industry should not be asked to fund a project unless positive indications are already obtained.

Normally, the project budget is divided into three equal portions, one portion is added to the institute's budget as overhead; the second is allocated for materials and supplies for the project and the third is given to the research staff (including company personnel) as incentives.

A constant revenue is obtained from selling of know-hows or selling a test-product, this is treated in the same way.

### **INVOLVEMENT OF END USER**

The involvement of the end user during all the phases of the project is very essential. This is of a special importance if the end user has an R&D department. The end user should have a very distinctive role in the project. There are different steps at which the end user is involved e.g.

- Formulation of the project proposal
- Assessment of the quality of end product

- Design and fabrication of pilot plant items
- Engineering design
- Feasibility studies

## **CASE STUDIES**

The Science and Technology Cooperation Programme (STC) of the Egyptian Academy of Scientific Research and Technology is funding R, D&E projects with the above-mentioned criteria i.e. projects which results in improving productivity, developing new products and processes. Among these projects awarded to CMRDI are :

1. Modification of production technology of phosphoric acid at Abu-Zaabal Fertilizers and Chemicals Company.
2. Production of activated bentonite from local ores.

The first project is concerned with a large production capacity of 400 tonnes/day, whereas the second is dealing with a proto-type plant of about 5 tonnes/day capacity. In the following is given a short review of these project applying the methodology described before and emphasising on the role of the end user.

## **CASE STUDY NO. 1**

### **MODIFICATION OF PRODUCTION TECHNOLOGY OF PHOSPHORIC ACID**

Phosphoric acid is the basic intermediate in the production of phosphatic fertilizers. It is currently produced at the Abu-Zaabal Fertilizers and Chemicals Company at a rate of 400 tonnes/day applying the conventional technology (dihydrate). The phosphate concentrate is finely ground and treated with sulphuric acid to produce dilute phosphoric acid which is then concentrated by evaporation to produce the concentrated acid.

The great demand for phosphoric acid and phosphoric acid-based fertilizers and chemicals both in the local and international markets urged the company to plan for duplication of the phosphoric acid plant capacity using a more economic new process (hemihydrate-dihydrate). In the conventional process grinding and evaporation are the most troublesome, energy consuming steps. In the new process, these two steps are cancelled. Coarse rock can be used and concentrated acid can be produced directly.

The work was done by a joint-team from the institute and the company. STC imported some equipment required for the continuous bench scale unit already present in CMRDI. STC arranged also several visits in USA and Europe for industrial production and engineering companies as well as industrial R, D&E institutes. Members of the research team from the institute and the company benefited from these visits.

The work was carried out in 4 phases, namely :

- Bench scale studies
- Pilot plant studies.

- Process design and engineering.
- Economic feasibility studies

The work was finished in 3 years, 12 progress reports and 5 technical reports were submitted in addition to 67 basic engineering design drawings of the different units of the new plant.

A short review of the project phases is given with emphasis on the role of end user in each phase.

### **Bench Scale Studies**

5 tonnes representative sample was collected by the end user and its suitability for the new process was tested using a semi-pilot continuous unit 12 kg rock/day. The unit was operated intermittently (12 hrs/day) for 13 days (total 180 hrs) and continuously (24 hrs/day) for 10 days (total 240 hrs).

### **Pilot Plant Studies**

A continuous pilot plant 0.25 tonnes/day capacity was used which corresponds to 20 folds extrapolation of the semi-pilot unit. The company staff was contributing in the design and fabrication of the pilot plant. The results obtained from the continuous semi-pilot and pilot plant studies are comparable and proved the suitability of the raw material for the new process.

During bench scale and pilot plant studies, 6 production engineers from the company were involved even during night shifts. Their suggestions especially during

pilot plant operation improved the performance considerably. Quality assessment of the end product was carried out parallelly in the institute and in the company too.

### **Process Design and Engineering**

This phase was carried out almost exclusively by company staff. The data from pilot plant were extrapolated to the full scale plant level of 400 tonnes/day. The mass and heat balances were calculated together with utilities consumption (Fig. 1, Table 1). An elaborated equipment list with detailed specifications was prepared. The basic engineering design drawings of 67 equipment which could be fabricated locally was produced.

### **Feasibility Study**

In this part of study the end user provided all information about cost estimates. Various contacts were made through the end user to obtain prices of equipment to be imported. Evaluation of utilities and raw materials costs as well as selling price of the product were done by end user. The project showed positive feasibility parameters with internal rate of return IRR of 15%.

### **Impact on National Economy**

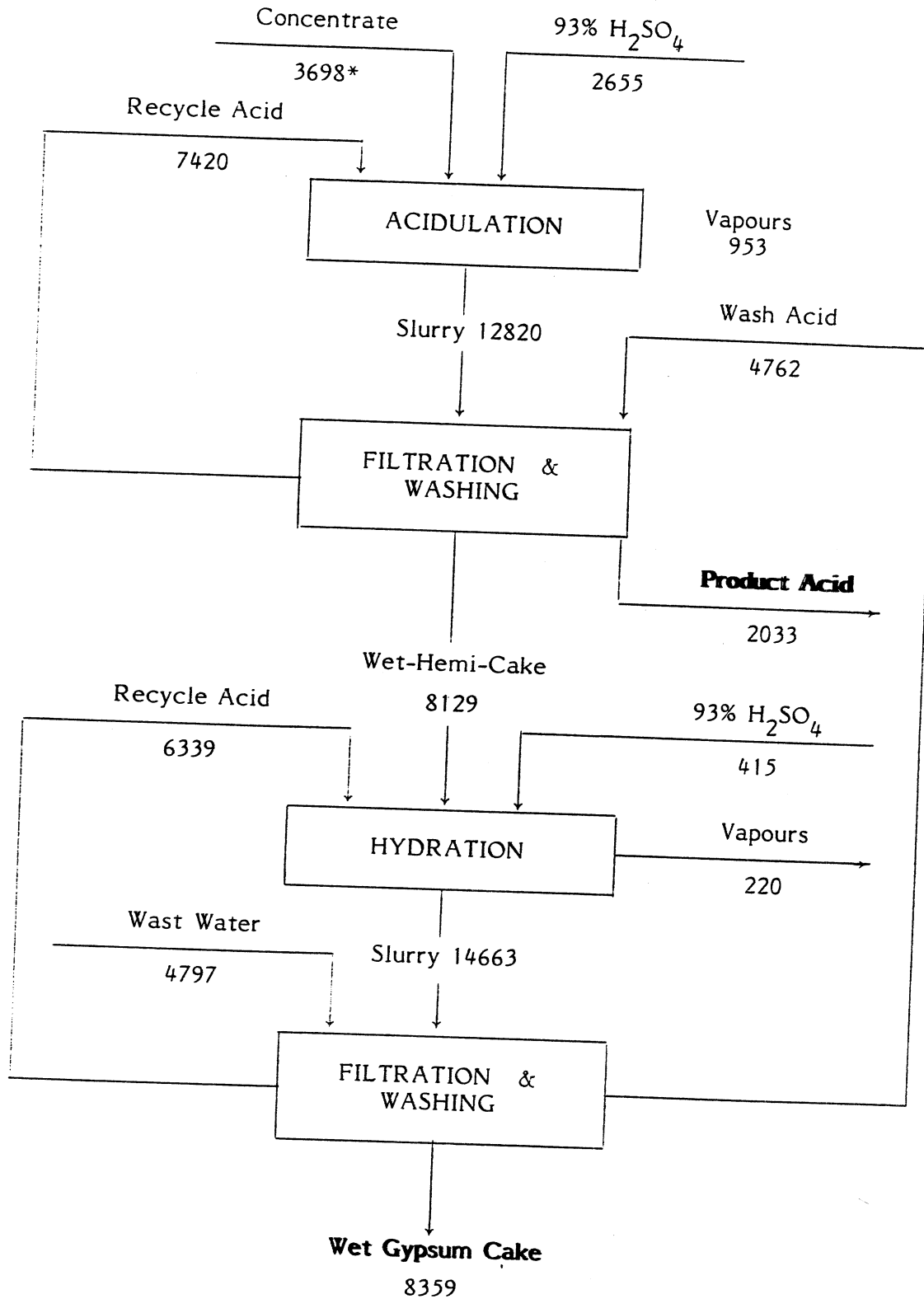
The new phosphoric acid line will contribute to the national economy by 18 millions US\$ annually. The project will create also new job opportunities. The new expansion of phosphoric acid will consequently create new industries e.g. polyphosphates for detergents and corrosion inhibition, calcium phosphates for cattle fodder and compound and mixed fertilizers. All these chemicals are currently imported.

**Table 1 : Raw materials and utilities consumption of new and conventional processes.**

<i>Item</i>	<i>New Process</i>	<i>Convenvtional Process</i>
<b>1. Raw Materials</b>		
Phosphate concentrate (dry basis), tonne	3.67	3.74
Sulphuric acid (93-98%, 100% basis), tonne	2.86	2.97
Defoamer, kg	5.00	2.88
<b>2. Utilities</b>		
Process water, m <sup>3</sup>	4.80	5.64
Cooling water, m <sup>3</sup>	27.0	70.0
Steam (L <sub>p</sub> ) : Process, tonne	0.10	0.15
Evaporation, tonne	-	1.75
Electric Energy :		
Grinding, kwh	-	20.0
Process, kwh	90.0	90.0
Evaporation, kwh	-	10.0

*Figures given/tonne P<sub>2</sub>O<sub>5</sub> produced.*





**Fig. (1) : Overall material flow sheet for HDH process.**

**Basis : 1 tonne  $P_2O_5$  as product acid**  
**\*All values in kg**

## **CASE STUDY NO. 2**

### **PRODUCTION OF ACTIVATED BENTONITE FROM LOCAL ORES**

This project is a model of small scale industry as its objective is to establish a prototype unit for production of activated bentonite with a capacity of 1800 tonnes/year. The project is based on laboratory and bench scale studies carried out previously by CMRDI for different end users.

Bentonite is a type of clay minerals having physical properties rendering it suitable as a binder for foundry sand mould, as a drilling mud and as a bleaching agent for edible oils. If these properties are originally poor, it could be improved through a chemical treatment process called activation. Bentonites used for foundry and drilling muds are activated with alkalis; those used for oil bleaching are activated with acids.

Egypt imports about 30,000 tonnes of alkali activated and 7,500 tonnes of acid activated totaling about 9 millions US\$ hard currency. Although local bentonite is available in many localities, its quality is inferior. Previous studies indicated that the ore responds to the activation process and satisfactory quality could be obtained for certain applications through simple activation processes.

The end users of this project are :

1. Mining company that mine the ore.
2. Foundry shop.
3. Water drilling and civil engineering companies.
4. Oil bleaching company.

### **Role of End Users**

1. The mining company offered free of charge all the samples required for the study and for production (about 500 tonnes).
2. The foundry shop carried out quality assessment of alkali activated ore as binder for sand moulds. Performance tests were carried out also in the foundry.
3. The water drilling and civil engineering companies carried out quality assessment of alkali activated bentonite as a drilling fluid. Drilling test for water well was also performed.
4. The oil bleaching company carried out quality assessment of acid activated ore for bleaching of cotton seed oil in addition to a performance bleaching test.

All the performance tests in the companies were carried out on the plant level which requires great amounts of the product prepared by pilot plant operation. About 50 tonnes of activated bentonite were produced for industrial performance tests.

In addition, one of the end users, the iron and steel company contributed to the project by preparing all basic and detailed engineering design of all the equipment of the proto-type plant.

### **Alkali Activation Plant**

The prototype plant has a capacity of 1200 tonnes/year. The process involves compaction of the ground ore with soda at certain moisture content in a pug mill, then the product is dried in a continuous belt drier, ground and packed. The mining company provided already ground ore. The capacity of the pug mill is 0.5 tonne/hr and that of the drier is 0.25 tonnes/hr. These two units together with belt conveyors were designed and fabricated locally.

### **Acid Activation Plant**

The plant has a capacity of 600 tonnes/year. The process involves treatment of the ground ore with hydrochloric acid in 2.5 m<sup>3</sup> reactor, settling and decantation. Then the acid activated ore is freed from residual acidity by continuous counter-current washing system 3 m<sup>3</sup> capacity. The product is eventually filtered on drum filter, dried and packed. All the plant units including heating facilities were designed and fabricated locally.

The materials and utilities consumption for the two lines were calculated (Figs. 2, 3, Tables 2,3). The detailed engineering design drawings were produced and within the coming few months the plants will be constructed.

### **Feasibility Study and Impact on National Economy**

A prototype plant for production of 1200 tons alkali activated bentonite was taken as the basis for calculating material, energy and utilities consumption figures. The proposed equipment list was used for estimating the machinery and equipment cost and consequently the overall investment costs amount L.E. 490,000. The variable operating cost amounts about L.E. 94,000 whereas the fixed operating cost was about L.E. 81,000 per year. The production cost was estimated at L.E. 146 per ton. Income statement and cash flow table were derived and it was found that in order to achieve an internal rate of return of 20%, the produced alkali activated bentonite has to be sold at L.E. 230 per ton.

Similar calculations have been performed for a prototype plant producing 600 tons annually of acid activated bentonite. The investment cost was estimated at L.E. 884,000. The annual variable operating costs was L.E. 338,000 while the fixed operating cost was L.E. 125,000 per year. The production cost of one ton acid activated

bentonite was calculated and given as L.E. 771. The income and cash flow statements were established and used for calculating the sales price of acid activated bentonite in order to achieve an internal rate of return of 20% and acceptable profitability ratios. The calculated sales price was L.E. 1086 per ton.

The proposed sales prices are actually lower than bentonite prices in local market and consequently the produced activated bentonite can be easily marketed.

The expected income from these two prototype plants amount 1,680,000 L.E. annually.

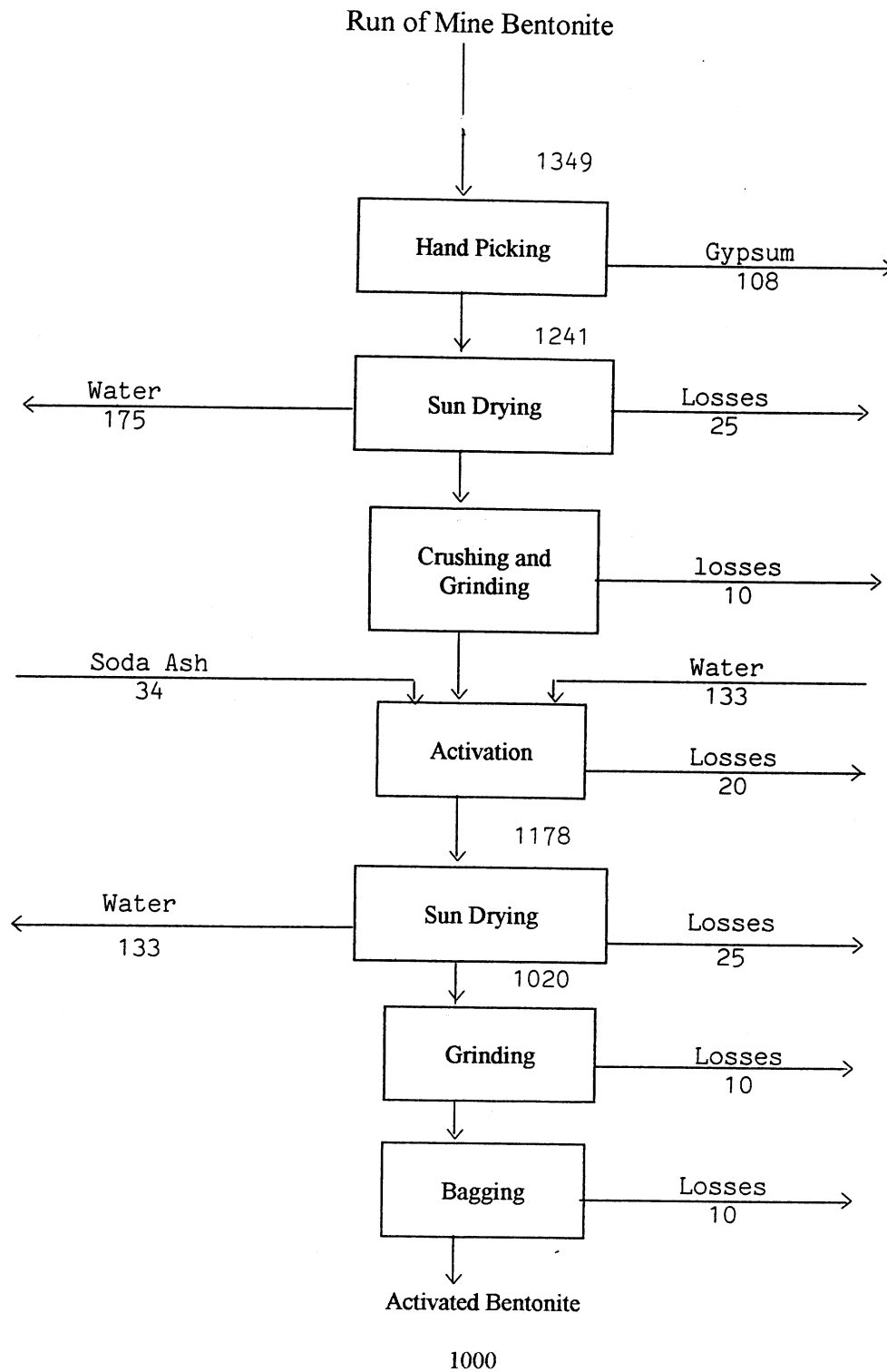
As activated bentonite is used mostly in all foundries, it is expected that each foundry could build its activation unit in the foundry itself with the required capacity.

**Table (2) : Consumption pattern for alkali activated bentonite.**  
**Basis : 1200 tons/year.**

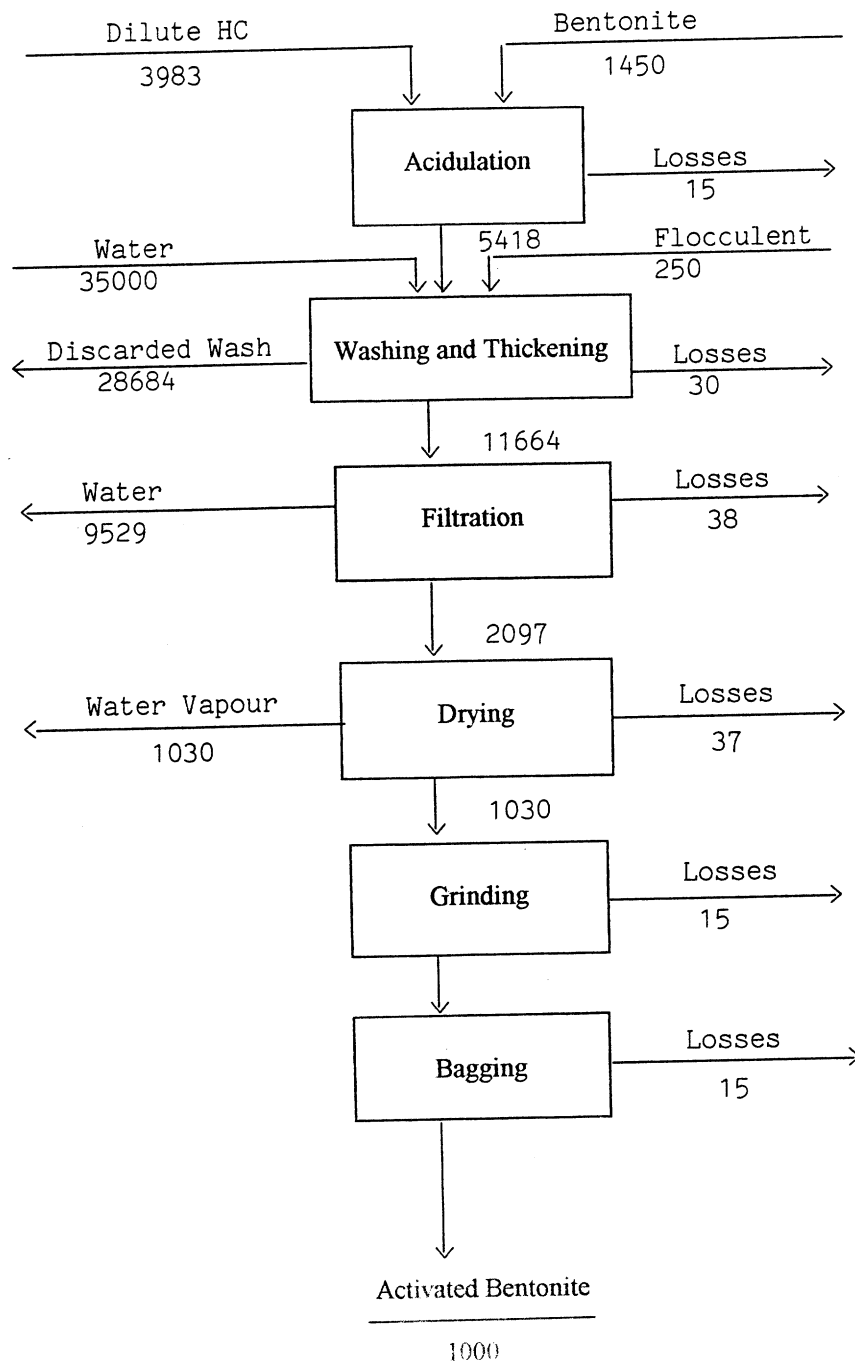
<i>Item</i>	<i>Unit</i>	<i>Quantity</i>
- Bentonite	ton	1619
- Soda ash	ton	700
- Process and operation water	m <sup>3</sup>	500
- Electric power	mwh	330
- Packing material	piece	2520

**Table (3) : Consumption pattern for acid activated bentonite.**  
**Basis : 600 tons/year.**

<i>Item</i>	<i>Unit</i>	<i>Quantity</i>
- Bentonite	ton	870
- Soda ash	ton	929
- Process and operation water	m <sup>3</sup>	500
- Electric power	mwh	660
- Packing material	piece	12600



**Fig. 2 : Material balance for alkali activation of bentonite (units in kg)**  
**Basis : production of 1 tonne activated bentonite.**



**Fig. 3 : Material balance for acid activation of bentonite (units in kg)**  
**Basis : Production of 1 tonne activated bentonite.**