OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org
Based on the work of Gerhard Eichholz, except in fnanm, in fnanm, in fnanm, in fnam.


Final report.
PREFACE

I. RECOMMENDATIONS FOR FURTHER TECHNICAL ASSISTANCE

II. PRIORITIES FOR THE OIL-PRODUCING INDUSTRY

III. THE SCOPE OF THE INDUSTRIAL USE OF OILS

1. Raw material time

2. Processed material time

3. Sales and net time

II. LINES OF OIL-BASED INDUSTRIES

I. OILS AND RESIDUE IN EGYPT

Introduction
INTRODUCTION
This production is, however, not suitable for a small-scale operation or a pilot plant. It can never be the first production in Bhutan or similar countries. But it can be considered for Bhutan after a period of at least five to ten years. For this process a mixture of gypsum and silicate materials is necessary and all the components of the Khotakpa mine can be used. However, in order not to consume an excessive amount of high grade materials, which are the only ones usable for other types of manufacture (see table 2), stockpiling of high-grade CaSO₄ (dihydrate and anhydrate) is recommended in spite of the additional investment and operational costs.

The sulphuric acid/cement line can use all materials of the deposit whereas other production lines use only one part. Because the first product cannot be cement and sulphuric acid, one has to start with the other products but different stockpiles should be made for the future.

B. Burned gypsum line

The burned gypsum line is divided into two types. One type is burned dry, which means that the temperature used needs no other physical element, such as pressure or vapour pressure. The raw material is burned in little pieces in a rotary kiln or as powder in big pots. These types of burned gypsum are called beta hemihydrate or beta anhydrite III depending on the burning temperature. The product is a mass product, but in some cases it is possible to make a medium-scale factory, seldom a small-scale factory. Plates, paperboards, plasterboards, bricks and mortar can be made from the beta hemihydrate. It is the basis of building material industry. Since beta gypsum can be made in a little kettle, this process is especially suitable for a pilot plant production.

The so-called wet burned gypsum is always burned under pressure, mostly in autoclave treating blocks with diameters of approximately 10 to 20 cm in steam autoclaves at a temperature of about 180°C. After burning the pieces are milled down to a fine powder and are used for special purposes, for example in medicine or dentistry, modelling in a wide range of industries and for casting and moulding in the ceramic industry. This type is preferable for a small-scale industry. The product can be sold all over the world (see table 2).
<table>
<thead>
<tr>
<th>Product</th>
<th>Relative profit</th>
<th>Estimated raw material needed (tons/day)</th>
<th>Investment</th>
<th>Market (estimated)</th>
<th>Type of raw material needed (DM - dihydrate, ( \alpha = ) a hemihydrate, ( \beta = ) plaster of Paris)</th>
<th>Manpower (medium, automation if any)</th>
<th>Energy consumption</th>
<th>Grade of the specific knowhow needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct use without chemical processing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building stones</td>
<td>Small</td>
<td>1-50</td>
<td>Very small</td>
<td>India</td>
<td>x x</td>
<td>Medium to high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Sculptor stones</td>
<td>Small to medium</td>
<td>1-50</td>
<td>Very small</td>
<td>India</td>
<td>x x</td>
<td>Medium to high</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Wall plates</td>
<td>Small to medium</td>
<td>1-2</td>
<td>Small</td>
<td>India</td>
<td>x</td>
<td>Medium</td>
<td>Very low to low</td>
<td>Low</td>
</tr>
<tr>
<td>Cement additive</td>
<td>Small</td>
<td>50-200</td>
<td>Medium</td>
<td>India</td>
<td>x x</td>
<td>Low</td>
<td>Low to medium</td>
<td>Low</td>
</tr>
<tr>
<td>White pigments</td>
<td>Medium</td>
<td>1-10</td>
<td>Medium</td>
<td>India</td>
<td>x x</td>
<td>Low</td>
<td>Low to medium</td>
<td>Low</td>
</tr>
<tr>
<td>Filler</td>
<td>Medium</td>
<td>1-50</td>
<td>Medium</td>
<td>India</td>
<td>x x</td>
<td>Low</td>
<td>Low to medium</td>
<td>Low</td>
</tr>
<tr>
<td>Fertilizer (SO₃)</td>
<td>Small</td>
<td>20-100</td>
<td>Medium</td>
<td>India</td>
<td>x x</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Plaster and derived products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrate (plaster of Paris)</td>
<td>Medium</td>
<td>5-100</td>
<td>Medium</td>
<td>Bhutan and India near border</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Alpha and beta plaster blocks</td>
<td>Medium to big</td>
<td>5-100</td>
<td>Very small</td>
<td>Bhutan and India near border</td>
<td>Medium</td>
<td>Very low</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Plaster panels</td>
<td>Medium</td>
<td>50-100</td>
<td>Very small to small</td>
<td>Bhutan and India near border</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Plasterboards</td>
<td>Medium</td>
<td>50-100</td>
<td>Very big</td>
<td>Bhutan and India near border</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Slipcasting plaster</td>
<td>Medium</td>
<td>5-10</td>
<td>Very small</td>
<td>India</td>
<td>x x</td>
<td>Low</td>
<td>Low to medium</td>
<td>Low</td>
</tr>
<tr>
<td>Moulding plaster</td>
<td>Medium to big</td>
<td>10</td>
<td>Small</td>
<td>India</td>
<td>x x</td>
<td>Low</td>
<td>Low to medium</td>
<td>Low</td>
</tr>
<tr>
<td>Medicinal and dental plaster</td>
<td>Big to very big</td>
<td>0.1-10</td>
<td>Very small to medium</td>
<td>World wide</td>
<td>x x</td>
<td>Low to medium</td>
<td>Low to medium</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Large-scale chemical industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement and sulphuric acid</td>
<td>Medium</td>
<td>500-800</td>
<td>Very big</td>
<td>India</td>
<td>x x</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Lime and sulphuric acid</td>
<td>Medium</td>
<td>100</td>
<td>Very big</td>
<td>India</td>
<td>x x</td>
<td>Medium</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>Medium</td>
<td>100</td>
<td>Very big</td>
<td>India</td>
<td>x x</td>
<td>Medium</td>
<td>Very high</td>
<td>High</td>
</tr>
</tbody>
</table>
C. Raw gypsum line

The first use of gypsum in Bhutan will be as a cement additive. Since the cement plant will tend to use only the part of the deposit with the highest sulphuric content, one has to pay attention. If possible, the plant should sell anhydrite of high purity and not dehydrate, which could be used much better for alpha or beta burned gypsum products. In the case of Bhutan natural anhydrite can only be used for cement/sulphuric acid line or for building stones, not for burned gypsum. If anhydrite is used, transportation will be much easier because anhydrite contains about 20 per cent more sulphate, whereas isohydrate contains 2 molecules of water.

Other ways of using natural gypsum and anhydrite have been tried out in Europe and elsewhere. The production of building stones is an example. The workability of the soft material is very good. Also, it is possible to make thin and thick, small and big plates for decoration. And it is especially good for making alabaster objects, which is a big handicraft manufacture. Nearly 3,000 people live from this handicraft in Italy and the products are sold all over the world. Because of the simple nature of the manufacture of alabaster articles they could soon be made in Bhutan, if one or two Bhutanese were sent to Italy, the centre of this handicraft in Europe. Another product of natural gypsum and anhydrite is a white pigment. In the pilot plant of alpha gypsum the white pigment could be produced too, as well as powder for use as fertilizer.

III. THE SCOPE OF THE INDUSTRIAL USE OF GYPSUM

Table 2 shows the different gypsum-based products and related technologies. The alpha gypsum and raw gypsum lines are of special interest for Bhutan. The alpha gypsum line does not require much investigation, is highly profitable, does not require many workers and the tonnage is not high, so there is no transportation problem. Apart from the use as a cement additive the raw gypsum line is of interest as sculpture stone of very good quality, for thin wall plates (similar to the use of marble in Europe, especially in Italy), and in the alabaster handicraft. Alabaster handicraft products from Italy are sold in Europe and the United States of America.
IV. PRIORITIES FOR THE GYPSUM-BASED INDUSTRY IN BHUTAN

The following priorities should be established:

(a) Cementary additive uses;

(b) Stone wall plates, which are easy to saw by hand, and alabaster handicraft, for which hardly any investment is necessary;

(c) Alpha plaster after one year (investment needed SUS 0.4 to 0.6 million);

(d) Beta plaster and plaster of Paris after about three years;

(e) Cement-sulphuric acid line in connection with ammonium sulphate line. For this production the consumption of power is enormous and hydroelectric power plants will need to be established. There is not much likelihood of being able to start this line within the next five years.

V. RECOMMENDATIONS FOR FURTHER TECHNICAL ASSISTANCE

In order to promote a stage-by-stage development of gypsum-based industries in Bhutan the assistance of the following experts is needed:

(a) Marketing expert. The expert would study the market for gypsum, plaster and the products based on these two materials both in Bhutan and in India;

(b) Expert in alabaster handicraft. The expert with experience in the carving of alabaster products - both manually and mechanically - should advise on the establishment of a handicraft industry producing mainly for export;

(c) Expert in plaster and plaster products. The expert should formulate specific recommendations for the establishment of a manufacture of plaster of Paris and of derived products, such as panels, blocks and moulding plaster.
Main possibilities in a gypsum-based industry: products made of raw gypsum

- Raw material:
  - Natural anhydrite
  - Overburden + phyllites
  - Mixed materials or low-grade materials consisting of dihydrate, anhydrite and phyllite

- Sulphuric acid line
  - Cement sulphuric acid (Muller-Kuhne process)
  - Ammonium sulphate
  - CaO(Ca(OH)$_2$) Lime-sulphuric acid

- Burned gypsum line
  - CaSO$_4$2H$_2$O
  - α-Hemihydrate (Plaster of Paris)
  - β-Hemihydrate
  - Dry burned = in kettle, rotary kiln etc.
  - Wet burned = in an autoclave (under vapour pressure)

- Reactions:
  - $\text{CaSO}_4\cdot2\text{H}_2\text{O} \xrightarrow{180^\circ\text{C}} \text{CaSO}_4\cdot\frac{1}{2}\text{H}_2\text{O}$
  - Dihydrate $\rightarrow$ Hemihydrate

- Building uses
  - Wall blocks
  - Plaster boards
  - Plaster mortar

- Medical
  - Dental
  - Models
  - Slip-casting material

- Small wallplates "Alabaster" products
- Additive for cement manufacturing
- White pigments (Colour)
- Raw gypsum fertilizer

- Building material
- Sculpture material
- Model
- "Alabaster" products
- Additive for cement manufacturing
- White pigments (Colour)
- Raw gypsum fertilizer