PHOSPHOGYPSUM UTILIZATION

IN

SYRIA

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INTRODUCTION

As is well known to Syrian officials, the process selected for TSP production produces a highly impure phosphogypsum. One of the advantages of the TSP process is that low-grade phosphate rock can be utilized. However, the end-product necessarily reflects the quality of raw materials, in this case a low BPL rock high in fluorine; cholorine and sodium.

In addition, selection of di-hydrate process (rather than hemi-hydrate) must necessarily result in a gypsum of maximum impurity, contaminated by co-precipitated calcium bi-phosphate ($CaHPo_4$) and with small difficult-to-filter crystals coated with rock.

While there are a variety of processes available to purify this polluted gypsum (Nissan, Nipon Kokan, Mitsubishi, etc.) these are capital intensive and cost approximately 5 times the investment for a di-hydrate process (as $10 million vs. $ 2 million installed). It is assumed that the Syrian government wishes to avoid additional heavy capital investment for purification purposes, and to make the best of its present TSP plant, knowing full well the limitations of the waste phosphogypsum.

In other words, if we are successful in finding <u>any</u> uses for the phosphogypsum, we may consider ourselves "ahead of the game." This conclusion is underscored by the fact that millions of tons of phosphogypsum are refused each year and go unutilized in the U.S.A. There, all potential users prefer to employ quarried (natural) gypsum. This is also true in many other countries.

There is hope, however, since Syria's conditions are different than for the U.S. or Europe, and may rule in favor of limited uses for waste phosphogypsum. This will be discussed in the text following and by means of detailed ("pro-con") analysis or exhibits for each major use. To correlate all these matters, a logic flow chart is submitted (Exhibit A), which illustrates the proper order of actions required to reach sound conclusions and decisions.

LOGIC CHART FOR PHOSPHOGYPSUM DECISIONS

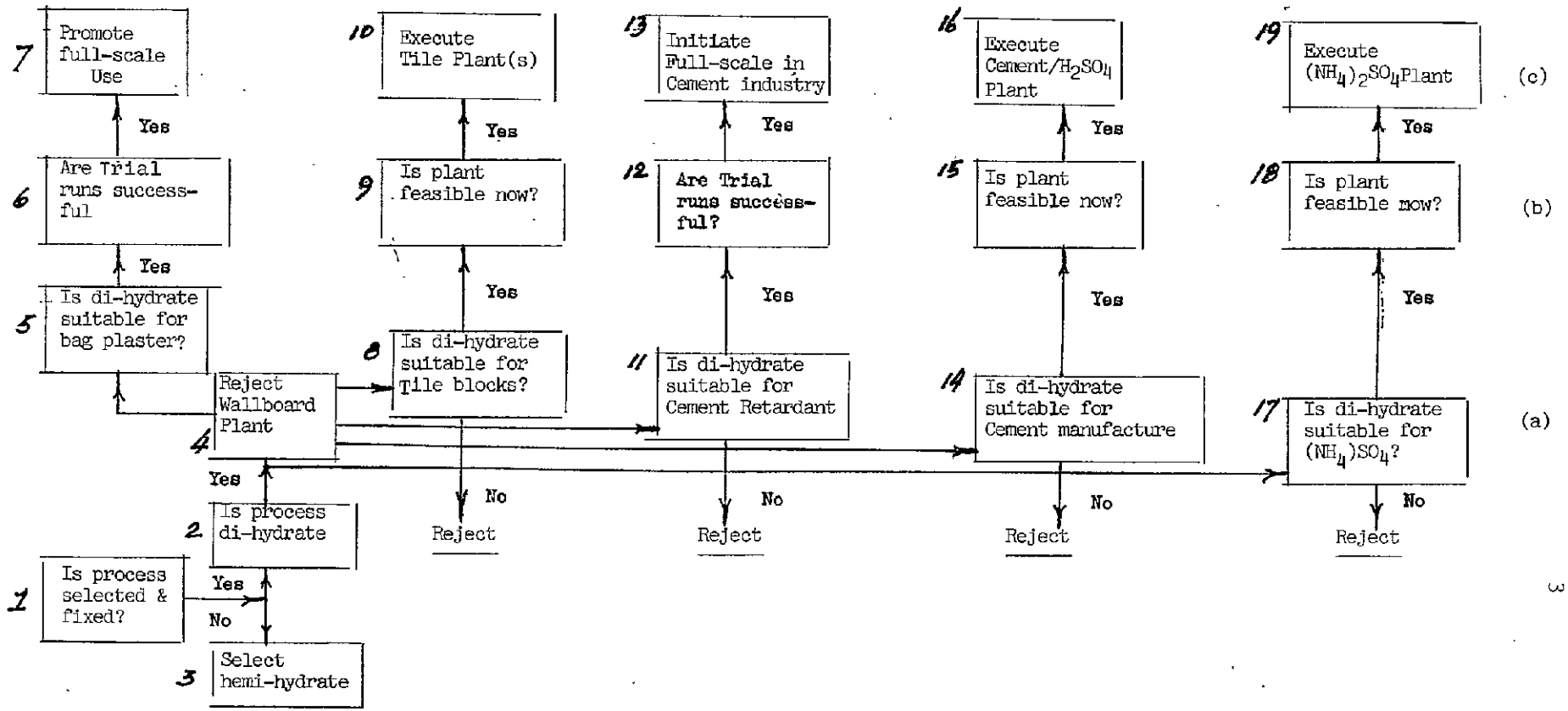
A logical approach, or framework, for reaching sound decisions on phosphogypsum utilization (Exhibit A) provides for accumulation of certain key information.

Commencing with box 1, the question is asked (unknown to author before arrival in Syria) if a final selection has been made as to type of TSP rpocess (di-or hemi-hydrate). Since this decision appears irrevocable, the possibility of a gypsum wallboard plant (accounting for almost 90% of U.S. use of gypsum) is ruled out (also, on the basis that Syria lacks an extensive pulp and paper industry and does not use wood frame construction.)

Lacking this possibility, a series of questions is then asked relating to different possible uses of phosphogypsum, namely for bag plaster (5), tile blocks (8), cement retardant (11), cement manufacture (14) and ammonium sulfate manufacture (17).

Exhibit A

LOGIC CHART FOR PHOSPHOGYPSUM DECISIONS



In order to obtain answers to these questions, it will be necessary (as soon as possible) to secure a large sample of phosphogypsum made from Syrian rock phosphate (Exhibit B). This should be submitted to one or more of the following laboratories for detailed examination, characterization of crystal structure, and experimentation for each of the uses in question:

Rhone Poulenc
Paris, France

Gerlach
Frankfurt, F.R.G.

Portland Cement Association
Skokie, Illinois, U.S.A.

Testing will be free at first two laboratories and will involve fees at third laboratory, depending upon applications examined.

Assuming positive results are obtained there is yet another hurdle to cross before sound decisions can be assured. This is the feasibility study step in (Exhibit A - boxes 9, 15, 18), or in some cases experimental trials on a full-plant scale (boxes 6 and 12). These feasibility studies should be commissioned with terms of reference based upon the results of laboratory testing mentioned above. They should include attention to the related questions of plant crop agronomy and soil chemistry as well as the market for products and technology of manufacture.

If negative answers are received at the level of laboratory tests, further work or feasibility studies are unnecessary and the projects should be dropped or rejected. If results are positive, the way is open to seek financing and favorable decisions to build plants (boxes 10, 16 or 19), or to promote full-scale use of products in construction (box 7) or in cement manufacture (box 13).

By this logical approach, costly mistakes may be avoided, and one or more positive uses for phosphogypsum hopefully found. Analyses of each of these potential uses is provided as follows:

Exhibit C	Gypsum Tile Plant
Exhibit D	Gypsum as Cement Retardant
Exhibit E	Cement from Gypsum
Exhibit F	$(NH_4)_2SO_4$ from Gypsum

Exhibit B

PHOSPHOGYPSUM SAMPLE SIZES

AND TEST COSTS

Company \ Process	Gypsum Purification Process Selection	Gypsum Blocks/Tiles	Cement Retardant	Cement/H_2SO_4 From Gypsum
Rhône-Poulenc Division Chimie Minirela 25, Quai Paul - Doumer 92408 Courbevoie France Telex: ROGIL X 61500F Tel: 776-41-51 (Michel Bourillet, Chemical Engineer)	30-50kg laboratory 3-5 tons pilot plant Cost: None	50kg lab 3-5 tons pilot plant Cost: None	—	—
Dr. Gerlach & Soehne D-717 Schwaebisch Hall Postfach 244 Telex: 074892 Gerlach-D Tel: (0791)7811	—	1,000kg minimum* Cost: None	—	—
Portland Cement Association Old Orchard Road Skokie, Illinois 60076 U.S.A. Tel: (312)966-6200 (Walter Kunze Director, Research & Development)	—	—	70kg Gypsum 35kg Silica Sand 35kg Clay Cost: $6,000-7,000	70kg Gypsum Cost: $15,000 minimum

* Hemihydrate form specified

GYPSUM BUILDING BLOCKS OFFER NEAR-TERM APPLICATION

One of the most promising and immediate applications for phosphogypsum is in the fabrication of gypsum blocks or tiles. Here, impurities are not expected to play an important role. On the other hand, there is a potential wide demand for these blocks or tiles, as a substitute for conventional concrete blocks which require plastering on the indoor side.

As summarized in Exhibit C-1, there are far more significant advantages that disadvantages for this application, not the least of which is a potential savings of up to 50% in unit prices (Exhibit C-2) of finished masonry. The big savings, of course, is in the fact that plastering becomes unnecessary, since the blocks are already made of gypsum plaster.

Since it was realized early that gypsum tiles would be an important method of utilization, considering the limitations imposed by phosphogypsum impurities, extra time was devoted to checking this application. To this end, a panel of six (6) Syrian architects (or civil engineers) was interviewed for recommendations and criticisms. This is especially important, since such architects would have to specify these gypsum blocks as a substitute for conventional concrete blocks in order to insure widespread utilization. This panel is identified in Exhibit C-3.

In no case was there a dissenting vote on the desirability of this building material for Syria, and in most cases a strong desire to try out the blocks in sample buildings. In fact, certain of these individuals expressed interest in participating in a joint venture to finance one or more plants, considering the potential market, low costs and prospective profits involved.

Although this is not the largest potential user of phosphogypsum tonnage (35,000 to 70,000 tons per annum estimated), it is clearly one of high cost-effectiveness or potential profit. If the Syrian government does not wish to take the lead in this application, favorable treatment of private investors could readily lead to private sector involvement at an early stage. If so, smaller plants would be preferred to minimize financial risks and labour problems. A plant site at Homs, near the point of waste phosphogypsum generation, would present attractive logistics, being located in the midst of three major cities: Damascus, Homs and Aleppo. Alternatively (as in France), separate smaller plants could be located at strategic points to serve regional markets only (as Aleppo or Damascus), with raw phosphogypsum shipped from Homs.

USE OF PHOSPHOGYPSUM IN BUILDING BLOCKS

FAVORABLE

1. Uses major domestic resource

   1.1. Minimizes imports and foreign exchange requirements for concrete

2. Provides significant cost savings vs conventional plastering concrete blocks.

   2.1. Eliminates plastering step in conventional method

   2.1.1. Eliminates 2 weeks drying time between plaster coats.

   2.2.2. Saves 30-50% of total cost (per square meter)

   2.2. Reduced labour cost (faster installation)

   2.3. Low cost raw material (waste)

3. Help reduce effects of cement shortage

   3.1. Replaces concrete blocks and indoor plaster

4. Weight (shipping) and space savings vs. concrete block

   4.1 Reduces transport costs
   4.2 Increases useable space inside rooms (thinner).

5. Dryclimate may allow exterior use in Syria.

   5.1. Slightly water soluble in rain

   5.2. Trial use will establish exterior potential

6. Standardization in sizes may be possible

   6.1. Floor to ceiling tile sizes

   6.2. Military construction use facilitates standadization

   6.3. Results in further cost savings (see # 2 above)

7. Aesthetics of gypsum panels preferred to plastered concrete blocks

   7.1 Color can be added at tile seams

LIMITATIONS

1. High impurities may prevent usage

   1.1. Laboratory & pilot plant tests will determine treatment required

   1.2. Concern over presence of Uranium

2. Not yet proven in Syria practice

   2.1. Needs trial building program

   2.1.1. To check problems, if any

   2.1.2. To gain popular approvals

   2.1.3. To prove actual costs.

   2.2. Architect(s) ready to try

   2.2.1. "After one year trial, all Damascus will use"

   2.2.2. Tiles can be imported or made from Syria Phosphogypsum

3. Limited to non-bearing walls

   3.1. However, these are common in Syria construction (unlike Western world).

4. Edges of gypsum tiles are fragile

   4.1. Require patching before painting, in place

   4.2. Simple operation to patch

   4.3. Face of gypsum block will be smooth, flawless

7.2. Color can be added to pre-mix

8. Training needs minimized

8.1. Grooving facilitates easy assembly

8.2. Same mason skills as presently practiced

8.3. Gypsum tiles may be cut to size

8.4. However, more cleanliness required

Exhibit C-2

PRESENT UNIT COSTS

CONCRETE BLOKS

	Per Square Meter	
Concrete Blok	12 S.P.	29.0%
Joint Compound (material between bloks)	3	7.5
Plastering (2 sides, blok)	20	49.0
Labour	6	14.5
Total, before painting	41 S.P.	100.0%
After painting	50+	

EXHIBIT C-3

ARCHITECTS/ENGINEERS INTERVIEWED

ON GYPSUM BLOCKS

Damascus

Firm	Architects/Engineers
1. Bureau Chatta Fardoss St. Tel: 110047 336183 P.O. Box 4588	Ezzat Chatta, Civil Engineer-Architect Rafaat Chatta, Architect
2. Bureau Sayegh Tel: 559575 P.O. Box 981	Albert E. Sayegh, Civil Engineer-Architect
3. U.S.A.I.D.	Moustafa Bel kasem (Formerly Architect for Planning & Building Design, Ministry of Petroleum, Electricity & Mineral Resources)

Homs

4. Bureau Messie Damascus: Tel: 221319 P.O. Box 5846 Homs : Tel: 22055 P.O. Box 133	Fouad Abdul Messie Civil Engineer

Aleppo

5. Bureau Adli Qudsi Tel: 194860 14845	Giovanni Rizzardi Architect Rome, Italy Tel: 06/84.41.506
6. Dr. Leon Fahdi, M.D.M.R.C.P. Costaki Homsi Str. Tel: 20567	Mrs. Laila Rustom Fahdi Architect

In the event that laboratory tests (recommended elsewhere) raise doubts about this application, there is still the possibility of using quarried (natural) gypsum--again, an excellent use of an abundant Syrian natural resource.

How advantageous in cost savings is the use of phosphogypsum? Unit costs are compared in Exhibit C-2 with conventional concrete blocks, plastered on indoor side. Architects consulted agree that the savings should be substantial, considering the low-cost (or no-cost) source of gypsum, the elimination of plastering, and a possible savings in labour. In addition, architects interviewed generally appreciated the aesthetics of color that are possible with such blocks either by adding color pigments to the wet phosphogypsum before block fabrication, or the use of a colored joint compound between blocks.

In Senegal, during August, 1978, I had the opportunity to visit the local fertilizer factory, Societe Industrial Engrais Senegal (Mr. M. Bernos, President & General Manager). Here, TSP and by-product phosphogypsum are made, together with the production of gypsum ceiling tiles. Except for this single product, all remaining phosphogypsum is disposed of in the sea. Mr. Bernos explained that efforts were being made to develop a market for wall tiles as well, but this had not yet been accomplished. Panels or tiles are fabricated with Cerphos equipment from Morocco (O.C.P.), and are sundried before shipment.

Enroute to Damascus, a visit was scheduled with the Rhône Poulenc Company in Paris, manufacturers of equipment for this process. A discussion was held with the Chemical Engineer responsible, and prices obtained for license and plant. For a 100,000 ton per year plaster plant, a license cost of $ 1.2 million is anticipated, or about 2/3 of this price for a 50,000 ton plant. For a production plant of 100,000 tons, assume a capital cost of $15 million (± 20%), less 15% for air-drying. This includes all equipment, piping, electricity, instruments, insulation, painting, buildings, engineering, erection and civil works. Freight is assumed only to a European port, however. Preliminary laboratory work (recommended elsewhere) is without charge.

The Rhône-Poulenc process has been sold to Finland, Austria, Roumania, Brazil, with Poland and Yugoslavia also considered candidates. An alternative supplier of this technology is Guerlach of Germany, which is (incidentally) praised by Rhone-Poulenc for its block extrusion equipment.

It is to be hoped that phosphogypsum can be employed as a cement reaction rate controller, or retarder, in cement manufacture. As shown in Exhibit D, this is problematic, and will require extensive laboratory and pilot plant testing before an affirmative decision to use can be made in confidence. Excessive impurities and fines present an important obstacle to use. However, by diluting with quarried gypsum, these problems may be possible to overcome. Modification of cement factory feed equipment would be necessary to accommodate phosphogypsum fines (5% by weight), unless this material was compacted in advance by the Onada (or other equipment.

Only adequate laboratory testing can provide an answer to this possible application. A feasibility study would not appear necessary in this case, providing laboratory and plant tests are successful, since no new plant is involved.

On the other hand cement manufacture from phosphogypsum with H_2SO_4 as a by-product, offers far more problems and costs than it does advantages. This situation is summarized in Exhibit E. While more than adequate technology is available, from several countries, capital costs are unduly high for the cement recovered and impurities in phosphogypsum present a formidable challenge to clean up or use as is. Particle size is also against phosphogypsum for this application, and could require agglomeration equipment. The process is described as an "economic nightmare" by the cement division of U.S. Steel.

Nevertheless, it is possible to submit a sample of Syria phosphogypsum for testing to a laboratory such as the Portland Cement Association in the U.S. to settle this question (Exhibit B). A feasibility study is also a "must" before such a plant were to be undertaken.

Exhibit D

USE OF PHOSPHOGYPSUM AS
CEMENT CONTROLLER

Favorable

1. Substantial use for phosphogypsum.

   1.1 5% addition (as $CaSO_4$) for cement reaction control.

   1.2 Rises from 50,000 to 300,000 tons/yr., as 1979-1992.

2. Technology is available (Merseberg Process)

3. By-product $CaCO_3$ is obtained.

   3.1 Use in cement sugar, dry ice, soda ash manufacture.

   3.2 Use to neutralize waste phosphogypsum.

4. Limited data shows cements from phosphogypsum acceptable.

   4.1 Volume stable

   4.2 Nominal set characteristics.

   4.3 Fast, setting if PH of Phosphogypsum low.

   4.3.1 Avoid by washing or ponding, then filter pressing.

   4.3.2 Avoid (alternatively) by neutralizing.

   4.4 Reference: A. Das Gupta, Chemical & Metallurgical Design Co. (P) Ltd., New Delhi 24.

Limitations

1. Excessive Fines probably require compaction.

   1.1 Fines difficult to handle

   1.2 Cement industry (U.S.) prefers prescreened (non-dusty) gypsum rock ($\leq$ 2 cm. $>$ 1 cm.).

   1.3 Onada Cement Co. (Feeders) process agglomerates fines (Japan)

   1.3.1 Requires capital equipment

   1.3.2 Requires energy expenditure

   1.4 Possible to modify materials handling equipment to handle fines (no compaction)

   1.5 Possible to mix phosphogypsum fines with ground gypsum rock

   1.5.1 Reduces usage of phosphogypsum, if necessary.

2. Excessive P_2O_5 considered undesirable

   2.1 0.85% actual vs. 0.2% minimum to 0.5% P_2O_5 maximum from hemihydrate

   2.2 Lowers concrete strength

   2.3 Endagers set control

   2.4 Increases difficulty in handling

3. Not accepted in U.S.A.

   3.1 American Cyanamid could not sell waste gypsum for this application (example)

Exhibit E

USE OF PHOSPHOGYPSUM FOR CEMENT MANUFACTURE

FAVORABLE

1.0 May use appreciable quantities Phosphogypsum

- 1.1 Gypsum can supply 50-60% of CaO requirement
- 1.2 However, dilution may be necessary with 80% quarried (natural) gypsum (impurities)

2.0 By-product H_2SO_4 useful for TSP manufacture

- 2.1 However, U.S. firms had to sell cement at loss, just to insure H_2SO_4 supply
  - 2.1.1 Quickly saturates economical cement market (within 330 Km radius)
- 2.2 Cement and H_2SO_4 very costly to store

3.0 Technology widely available

- 3.1 Austrian
- 3.2 American
- 3.3 French
- 3.4 German
- 3.5 Britain
- 3.6 Indian
- 3.7 Poland

ADVERSE

1.0 Presence of impurities may eliminate this application

- 1.1 Excessive P_2O_5 weakens cement
  - 1.1.1 Presence highly critical
  - 1.1.2 Expensive purging (purification) may be required
  - 1.1.3 Dilution with quarried (natural) gypsum may permit use.
- 1.2 Excessive Flourine not difficult to purge.

2.0 Requires energy to dry wet Phosphogypsum slurry

- 2.1 Indirect drying needed to eliminate air entrainment.
- 2.2 More expensive than direct drying

3.0 Requires energy to agglomerate (pelletize) Phosphogyp fines

- 3.1 Screen size-325 mesh; mostly in 20 micron particle size range
- 3.2 However, may be unnecessary to agglomerate (testing required)

4.0 Fuel useage high in combined cement-H_2SO_4 plant

- 4.1 Approximately 50% higher than for individual plants of same capacity

5.0 Capital Cost Cement Capacity (for combined plant) high vs. Cement plant only

- 5.1 Requires 2X clinkering capacity (1/2 through put rate)
- 5.2 Chemical reaction involved

6.0 Coke or charcoal (reducing agent) expensive to import

- 6.1 Possibility of refinery bottoms recovery

7.0 Cheaper to use quarried (natural) gypsum in U.S.A. than to purify phosphogypsum

8.0 Described as "economic nightmare" and "on balance, dreadful" (U.S. conditions)

SULFATE OF AMMONIA PLANT ADAVNTAGES APPEAR SIGNIFICANT

As illustrated by Exhibit F, manufacture of fertilizer-grade Ammonimum Sulfate offers important advantages for Syria, in addition to utilizing phosphogypsum and excess ammonia capacity. These are important enough, of course, since at only 50% of total recommended nitrogen applications, production of ammonium sulfate could consume the entire 1.3 million metric tons per year of phosphogypsum. Until Syria's agriculture applies these recommended dosages of nitrogen (50% to 300% above present practice per Exhibit G), the quantity of phosphogypsum required would be correspondingly less.

It is true that urea alone is not an adequate source of nitrogen for Syrian crops and soils. Under conditions of low cation exchange capacity soils, and especially those of high alkalinity (pH) such as in the Homs and Aleppo areas, urea can lose ammonia without fertilizing crops. Likewise, in the high pH, high salinity Ghab area, the ammonium form of N offers nutrient advantages over urea. In the Ezraa area, urea is desirable, since the soils have high cation exchange capability, which retains NH_4^+ ion in the soil. In the Euphrates area, salinity problems and excessive use of irrigation can lead to high N losses. Under these conditions, either urea of ammonium sulfate can be lost. Therefore, use of the lower N concentration fertilizer (21% sulfate of ammonia vs. 46% urea) will lead to smaller losses. Slow-release fertilizers would be advantageous in this instance, but their cost is greater than either urea or sulfate of ammonia.

Obviously, in the short term, ammonium sulfate will act as a competitor to urea. More attention may, therefore, need to be paid to developing an export market for this high N fertilizer, although international competition can be stiff. Nevertheless, for the long-range good of Syria's agriculture, ammonimum sulfate is seen as an important addition to the inventory of available fertilizers.

USE OF PHOSPHOGYPSUM FOR $(NH_4)_2SO_4$ MANUFACTURE

FAVORABLE	LIMITATIONS
1.0 Utilizes excess capacity NH_3	1.0 Establishes competetive N Source to Urea
1.1 Syria needs outlet for surplus NH_3	1.1 Forces increased attention to Urea expert
2.0 Utilizes significant quantities of Waste phosphogypsum (estimated)	2.0 Direct application NH_3 to land or irrigation water possible
2.1 300,000-600,000 tons/year 1979-1984	2.1 Provides NH_4^+ ion without Sulfate of ammonia
2.2 600,000-1,400,000 tons/year 1987-1992	2.2 However, application equipment subject to maintenance neglect
3.0 Syrian agriculture requires greater total applications of N	2.3 However technical knowledge for operation may be lacking
3.1 Application levels well below recommended standards (Exhibit G)	3.0 Export market may exist for NH_3 as alternative
3.2 Intensive cultivated acreage scheduled to increase*	3.1 Jordan Fertilizer Company as one candidate customer suggested.
3.2.1 600,000 hectars 1978-1979	3.2 Charter NH_3 tankers common in international commerce
3.2.2 1,200,000 hectares 1987-1995	4.0 Higher transport costs for $(NH_4)_2SO_4$
3.2.3 3,190,000 hectares feasible for intensive agriculture	4.1 Less concentrated source of N than urea or calcium ammonium nitrate.
3.2.4 8,500,000 hectares total cultivatable land	5.0 NH_4NO_3 offers alternative source to $(NH_4)_2SO_4$
4.0 Syria agriculture needs more N in $(NH_4)_2SO_4$ form*	5.1 Alternate form of ammonium ion (NH_4+) for soil needs.
4.1 High pH, low cation exchange capacity soils of Homs/Aleppo require.	5.2 Presumably available from petrochemical complex.
4.2 High pH, high salinity Soils of Ghab area require	
4.3 Under present management conditions $(NH_4)_2SO_4$ preferred form for Euphrates valley	
4.4 Urea justified in Ezraa area (high cation exchange soils)	
5.0 Calcium Cartonate ($CaCO_3$) by product may be useful	
5.1 In sugar refining	

FAVORABLE	LIMITATION
5.2 To neutralize Waste Phosphogypsum, if necessary	
5.3 To manufacture CO_2 (dry ice; sodium Carbonate, urea, etc.)	
5.4 As a prime raw material for cement manufacture	
5.4.1 Providing purity level sufficient	

* Source: Arab Centre for the studies of Arid Zone and Dry Lands, Soil Chemistry and Plant Nutrients Dept., Damascus

Exhibit G

NITROGEN APPLICATION

RATES IN SYRIA AGRICULTURE

(Estimated)

Crop	Farming Practice	Tons N/Hectar Actual	Recommended	PerCent increase
Wheat	Dry, rain-fed	0.08	0.120	+50%
Cotton	Irrigated	0.10	0.20-0.70	+100% to200%
Sugar	"	0.075	0.150-0.20	+100% to 300%
	Average	0.085	0.20	

Source: Compiled from data furnished by the Arab Centre for the Studies of Arid Zone and Dry Lands, Damascus, 1978.

CONCLUSIONS

1. Gypsum block factory most immediate application for phosphogypsum.

   1.1 Architect panel favors application in Syria
   1.2 No overriding problem areas (Exhibit C-1).
   1.3 Advantages far outweight few disadvantages
      1.3.1 Established in other developing countries.
      1.3.2 Estimated cost savings 30-50% (Exhibit C-3).
      1.3.3 Syrians can "identify" with this type construction.
   1.4 Final decision depends upon laboratory tests and market trials.

3. Sulfate Ammonia plant nost promising outlet for phosphogypsum
   2.1 Strong need for $(NH_4)_2 SO_4$ in Syrian agriculture.
   2.1.1 50-300% more total N needed (Exhibit F).
   2.1.2 $(NH_4)_2SO_4$ required in place of urea for many areas.

   2.2 Correlative need to develop urea export trade.

5. Cement Plant appears undesirable alternative for phosphogypsum
   3.1 Disadvantages far outweight advantages (Exhibit E).
   3.2 Test program includes comgressive strength test.
   3.2.1 ASTMC-109 (U.S. Code for strength @ 1-28 days)

   3.2.2 Impurities may be overcome by mixing with quarried gypsum. (20% phosphogypsum).

4. Partial use of phosphogypsum as cement set retarder appears as desirable end-use.
   4.1. Outlet for 70,600 tons/yr.phosphogypsum near-term (50% $CaSO_4$)
   4.2 Outlet for 340,000 tons/yr. long-term
   4.3 Useage depends upon laboratory and plant tirals (Exhibits A and B).

2. Use of phosphogypsum in bagged wall plaster likewise a near-term use.
   1.1 Phosphogypsum impurities may not be disadvantageous.
   1.1.1 Can actually help trowelling characteristics.
   1.2 Represents substitution for existing locally used product.
   1.3 Laboratory and architect trials needed. (Exhibits A and B)

6. Phosphogypsum not readily applicable to porcelain future plant (Hama).
   6.1 Uses only 600-700 tons/yr gypsum
   6.1.1 Was imported from France
   6.1.2 Now using Syrian quarried gypsum.

   6.2 Demanding physical properties probably exclude impure phosphogypsum
   6.2.1 Die separation
   6.2.2 Solidification time
   6.2.3 Water absotption

7. Miscellaneous Uses may also be investigated:

7.1 "Bladex" type fertilizer/pesticide pellets.
7.1.1 Could provide needed slow-release N fertilizer for Euphrates irrigated lands.
7.1.2 Other slow-release feritilizers available.
7.2 Road patching material
7.2.1 Temporary road repair
7.2.2 Satisfactory for 2 years use

7.3 Filler and coatong agent for writing papers

8. Wallboard plant must be excluded from phosphogypsum.
8.1 Largest single use in U.S. (90%±)
8.2 Not applicable to Syria conditions
8.2.1 Di-hydrate unsatisfactory (paper baking peels, core too soft).
8.2.2 No wood frame construction in Syria.
8.2.3 No low-cost source of paperbacking in Syria.

RECOMMENDATIONS

1. Arrange immediate shipment Syrian phosphate rock to Roumania for manufacture of phosphogypsum sample

1.1 Should be representative sample
1.2 Tonnages required per Exhibit B.

2. Provide samples of phosphogypsum to appropriate laboratories and pilot plants for testing and evaluation.

2.1 Formal identification of impurities and technical properties (optical polarization microscopy, X ray diffraction, porosily measubements granulometry thermic studies, mechanical strength and hardness of tile samples, etc.).
2.2 Select one or more testing aoganizations:
   2.2.1 Rhône-Poulenc, Division Chimic Minerale, Courbevoie, Paris.
   2.2.2 Dr. Gerlach & Sohne, Schovaebisch Hall, Postfach,FRG.
   2.2.3 Portland Cement Association, Skokie, Illinois, U.S.A.)

4. Retain international engineering consultant to elaborate feasibility studies

   4.1 Sulfate of Ammonia plant appears most likely, from presently known facts.
   4.2 Cement plant appears least desirable, from presently known facts.
   4.3 Terms of reference dependent upon results of laboratory tests (Recommendation 2).

RECOMMENDATIONS (2)

5. Contract for construction and equipment by international tender for selected plants.

   5.1 Base final decisions on feasibility study results.

   5.2 Consultant can draw terms of reference for Architecturial and engineering tender.
   5.2.1 Alternatively, consultant may desire to bid on contract himself.
   5.2.2 In this case, Government of Syria should draw up own specifications for services.

3. Initiate plant and market trials using phosphogypsum sample
   3.1 Providing laboratory tests positive
   3.1.1 Provide sample gypsum tiles to select architects for trial building use.
   3.1.2 Furnish sample bag plaster to same architects for trial building use.