...0 pounds of dyes ...s are reused ...otable inter- ...gallons of un- ...which contain 732 pounds of B.O.D. .

In Table 15.2, we present a raw material balance justification which compares the raw material quantities and costs for the five separate plants manufacturing at distant locations and manufacturing within the EBIC. These data, although obtained and referenced only from authentic literature, show the cost advantage of this textile EBIC.

In addition, environmental costs would have to be considered. Within the industrial complex, we are presuming no external environmental costs are needed. As separate plants operating at distant locations from each other, environmental costs would include both domestic and industrial waste treatment charges as well as any measurable adverse environmental impact costs of the residual effluent wastes. These additional costs are currently being assessed by the authors.

From Table 15.2, it is apparent that the cost savings of the industrial complex from a material balance alone is \$6,726 minus \$6,093.75 or \$623.25 per day which represents a savings of \$52.69 per 1,000 pounds of finished cotton fabric.

From a preliminary study, the total environmental savings appear to be greater than \$1248 per day, which represent the average costs of treatment for separate greigh goods and finishing mill wastes. To both savings we must add the savings from transportation of raw cotton and sized, woven goods. Presuming transportation cost is \$0.026 per pound of cotton transported, we can estimate the additional cost due to transportation as \$343.2 per day.

References

[1] Nemerow, N.L. and A. Dasgupta, (1985), "Zero Pollution for Textile Waste", Proc. 7th Alternative Energy Sources Conference, Miami, Florida, December 1985, Vol. 6, pg. 499, 1987, Hemisphere Pub. Co.

[2] Brandon, C.A., and J.J. Porter, (1976), "Hyperfiltration for Renovation of Textile Finishing Plant Wastewater", EPA-600-2-76-060, 157 pgs.

15.9 Fertilizer-Cement Complex

Fertilizer Plant Wastes and Production

It has been reported and generally accepted that phosphate mining in Central Florida accounts for about 75% of the U.S. needs and one-third of the world's supply. This alone makes it a vital industry not only to Florida, but also to the United States and the world.

After the rock is extracted, slurried and separated from the clay and sand by screening and flotation, it is used to produce wetprocess phosphoric acid. The rock is digested by sulfuric acid to produce a slurry of contaminated gypsum ($CASO_4.2H_20$) and phosphoric acid. The slurry passes over a rotating disc filter where the calcium sulfate and acid are separated. The gypsum is pumped to holding ponds, whence it represents a major disposal problem for the fertilizer industry. Since 4.5 to 5 tons of gypsum are formed during the production of each ton of phosphoric acid, the industry has a formidable volume of phosphogypsum (PG) waste with which to cope.

Any recovery and reuse system for the phosphogypsum will free up reclaimable land for productive purposes by the industry or by other private or public landowners. Further benefits can be derived from the elimination of adverse environmental consequences of leachates from the gypsum heaps. Leachates carry phosphate and other mineral nutrients which could contaminate drinking water supplies and cause algal blooms (red tide) in recreational waters. Direct reuse of PG presents the potential problem of incorporating radioactivity into building or road products.

It is quite likely that the direct reuse of this PG within a closed industrial complex in making cement could eliminate all of the above problems. In addition, it anticipates a lowered production cost for both the fertilizer and cement plants for reasons already mentioned.
tioned.

One other area of waste recovery that should be mentioned is "heat" energy. A phosphate complex generates and must dissipate large amounts of energy as waste heat. The recovery and utilization of much of this energy is a very real success story. Efforts are continuing to recover even more of the "waste" energy from the more difficult to recover sources, and there is no doubt that an even greater percentage of the available "waste heat" will be put to profitable use in the future.

As early as 1968, it was reported that many firms in the U.S. had innovated processes for manufacturing useful products such as H_2SO_4 and *cement* from waste gypsum [11]. Nothing would be gained by reporting here the numerous papers which have been published describing the potential or actual use of gypsum in cement making. However, a few representative ones are in order. The British Sulfur Corp., Ltd., reported that the MASAN product transformed from PG by the Brussels based company, Ultra International SA, is a useful cement or plaster [12]. It was reported to possess a compressive strength 3 to 4 times that of Portland cement (1100 kg/cm^2 as compared to 300-400 for Portland cement). Moreover, the cost of cement from PG was $10/ton as compared to $30–$40/ton for Portland cement at that time..

Ellwood describes a chemical process for converting PG into *hemihydrate* powder as a cement strong enough to compete with cement in applications such as sound proof dividing walls [13].

More recently, Carmichael reported two Belgium plants which are using the Central-Prayon process for converting PG to the hemihydrate form of $CASO_4$ [14]. The gypsum is then suitable for direct use in the plaster industry or as a cement retarder.

Bhanumathidas and Kalidas reported the conversion of Anhydrite I grade of PG to calcine at 950°C to obtain a product similar to Portland cement [15]. They claim that the product "has shown remarkable cementitious behaviours in parallel to that of White Portland cement."

Clur claims that the Fedmis (South Africa) fertilizer plant disposes of about 25% of its PG production as soil conditioner, cement clinker and cement retarder [16]. "The quality of the cement compares favourably with that of local limestone-based cements, and is used in all classes of building construction and civil engineering." Clur also reports that "the technical problems of producing a good quality cement from PG have largely been solved, the future of the process would seem to depend mainly on economic and environmental factors."

Cement Plant Raw Materials and Wastes

Portland cement is made by mixing and calcining calcerous and argillaceous materials in the proper ratio [17]. The Table 15.3 summarizes the raw materials consumed in 1972.

Table 15.3 Raw Materials Consumed for Portland C[ement] in U.S. (1000's of short tons)

Cement rock	[illegible]
Limestone	[illegible]
Marl	[illegible]
Clay and shale	[illegible]
Blast furnace slag	[illegible]
Gypsum	[illegible]
Sand and sandstone	[illegible]
Iron materials	[illegible]
Miscellaneous	[illegible]

One can observe in Table 15.3 that limestone repre[-]sents the majority mass of cement raw materials. Re[-]placement of some or all of this calcareous materia[l] with PG would reduce the production cost of the ce[-]ment as a result in savings of raw material.

Unit processes involved in cement manufacturing es[-]sentially include *storage and mixing of raw materials, drying, grinding and crushing, calcining, clinker stor[-]age, finishing additives and ball milling, and packing for delivery*. Although dry processing is practiced more than wet processing, both are shown in the following flow charts (Fig. 15.7 A & B) to provide the reviewer with a visual aid for cement production.

For each 376 barrels of finished cement by the dry process, 1,120,000 Btu of fuel are required as well as 24.1 kWh of electricity, 30 gallons of water, and 0.17 hours of direct labor. Also required are 498 pounds of limestone, 124 pounds of shale, and 16 pounds of gyp[-]sum [17].

It should be mentioned here that Nemerow, as far back as 1944, developed a wallboard for Johns Man[-]ville Corporation. This board was made of asbestos fi[-]bres and gypsum formed under high temperature and pressure.

Statement of Problems and Objectives

The problems are twofold: (1) to lower production costs, and (2) to eliminate adverse environmental impacts of industrial plants. These problems are especially severe or extensive when the particular industry is highly competitive, such as fertilizer and cement plants proposed in this research, and when these same plants produce significant wastes which pollute the environment (air, water and land).

The overall objective of this research is to determine

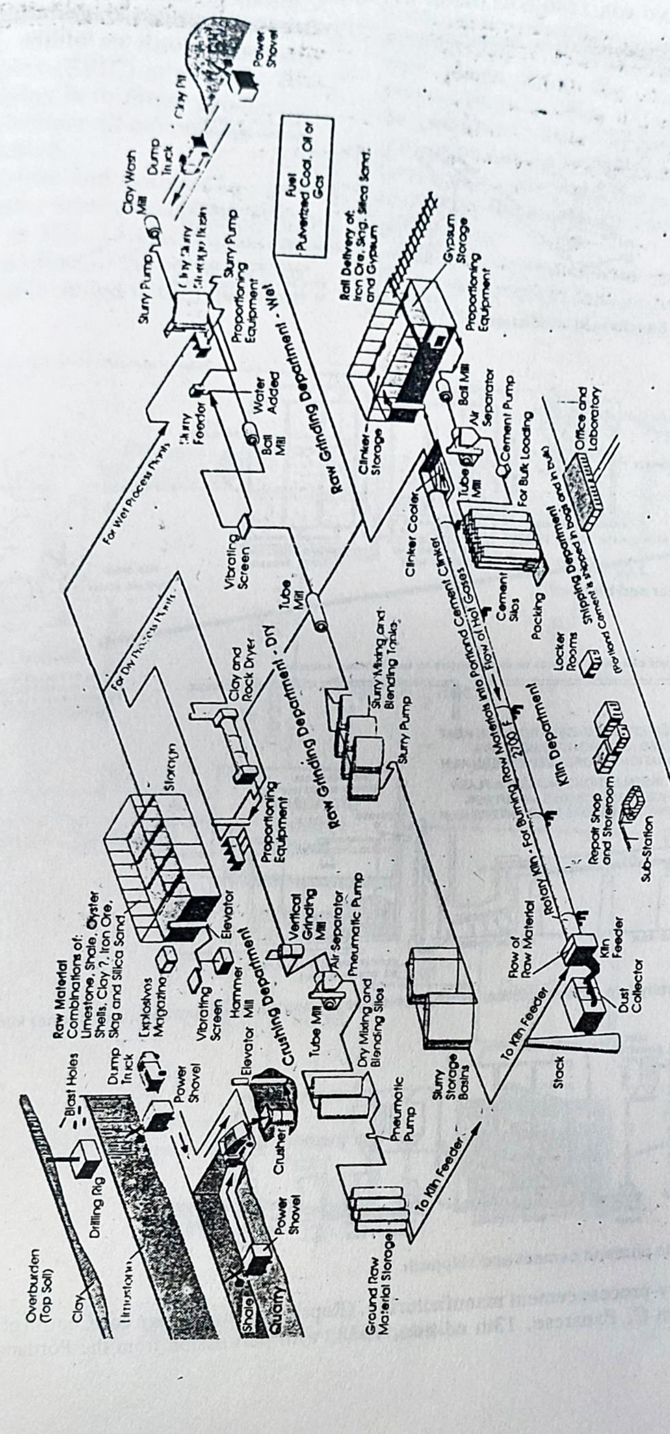

Fig. 15.7A Isometric Flow Chart for the Manufacture of Portland Cement by Both Dry and Wet Processes.

the feasibility of locating, building and operating a two-industry complex, consisting of a phosphate fertilizer and a cement plant, within an Environmentally Balanced Industrial Complex (EBIC) at one site. The ultimate goal of this complex is to *lower production costs* at both plants *and eliminate all adverse environmental impacts* at the same time.

Further study should analyze and evaluate in depth the practicality of the complex briefly described above and shown schematically in Fig. 15.8A. More precisely, it is necessary to determine (a) the optimum size for each manufacturing plant included within the complex; (b) the suitability of the by-products (wastes) for recovery and reuse as raw materials for ancillary adjacent plants within the complex (compatibility of plants); (c) the velidity of total waste elimination from the two plants involved within the complex; and (d) the cost of production of the prime goods when manufactured at distinctly separated plants and compared to the same when manufactured within the complex as shown in Fig. 15.8B.

The main thrust of future research should be to ascertain the *extent of the economic gain* by using the Complex principle. This study will be made to *include the*

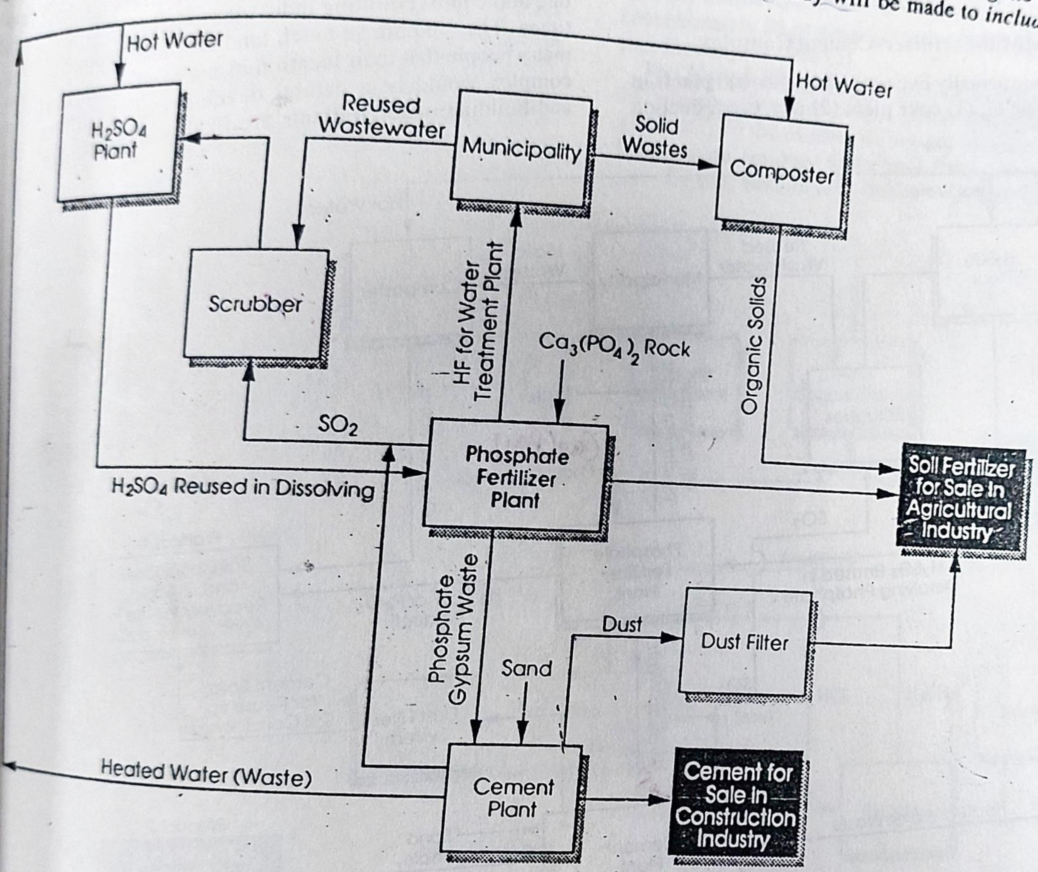

Fig. 15.8A Fertilizer Plant Complex

economic cost of environmental damage caused by wastes of all plants involved as part of the production costs.

This concept is not only a "gypsum for cement" idea, but rather a totally new balanced industrial complex plan. The question is not whether this innovation *is* economical, but rather how much reduction in cost can be obtained by this complex principle *when environmental costs* are also included and all complex plant wastes are reused including excess heat.

15.10 Steel Mill-Fertilizer-Cement Complex

Steel mills are actually five separate industrial plants in one consisting of: (1) coke plant (2) iron ore reduction plant, (3) steel production, (4) hot rolling mill, and (5) cold rolling mill. Predominant wastes originate from the coke and steel plants, although certain dusts, slag, and iron also come from the other plants.

Troublesome waste products include ammonia, cyanide, phenol, heat, and acidic ferrous sulphate or choloride pickle liquor. Steel mills also use huge volumes of water—mostly for cooling and quenching and produce like volumes of air, water and solid contaminants. They have developed a world-wide reputation as one of the most polluting industries existing in modern times. They require so much land area and employ so many people that their location in a separate industrial complex would be a natural development. Fertilizer and building material plants are likely candidates for

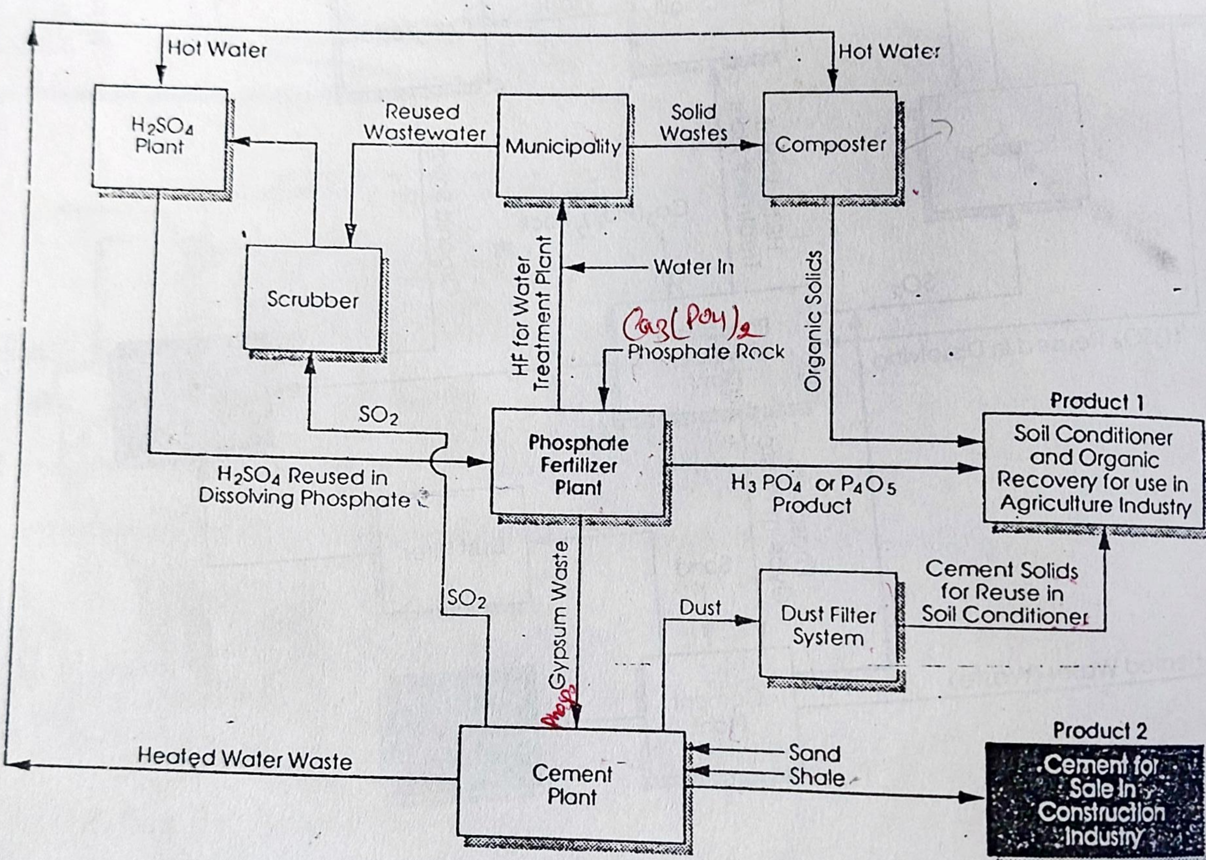

Fig. 15.8B Environmentally-Balanced Fertilizer-Cement Plant Complex-Phase 1