Final Report

UTILIZATION OF POLYMERS AS SOIL CONDITIONING AND WATER RETENTIVE AGENTS

Phase-I

by

M. ASLAM
Principal Investigator

PAKISTAN COUNCIL OF RESEARCH IN WATER RESOURCES AND USAID PROJECT

October, 1990

FINAL REPORT

UTILIZATION OF POLYMERS AS SOIL CONDITIONING AND WATER RETENTIVE AGENTS : PHASE I

Sponsored by

PAKISTAN COUNCIL OF RESEARCH IN WATER RESOURCES AND US AID

M. Aslam, M.Sc., B. E. Chem. (Calif) C. Chem. FRSC (London), FPAS
Chairman (retired) PCSIR; Technology & Industrial Consultant
Principal Investigator
in Collobaration with
PCSIR Laboratories Complex, Karachi

October, 1990

67/C, F.B. Area, Karachi-38

UTILIZATION OF POLYMERS AS SOIL CONDITIONING AND WATER RETENTIVE AGENTS

CONTENTS

Executive Summary 1
Introduction 3
Project Objectives 4
Project Planning Chart 5
State of the Art Study 6
Research and Technology Development Plan 8
Setting–up of Laboratory and Testing Facilities for Soil Conditions and Soil 11
Hydrolyzed Polyacrylonitrile (HPAN); Product Development 15
Polyvcrylamide (PAM) Soil Conditioner: Product Development 24
Polyrinyl Alcohol (PVOH) Soil Conditioner: Product Development 25
Exploratory Field Evaluation of Soil Conditioners 28
Prefeasibility Studies: Manufacture of Soil Conditioners 34
Scope of Application of Soil Conditioners in Pakistan 41
Indentification of Organizations for Collaboration During Phase II 49
APPENDIX: Biodata of Professional Manpower Associated with the Project 50

EXECUTIVE SUMMARY

By the close of the 1930s, it was established that the beneficial effects of the age-old practice of adding organic matter to the soil for obtaining favourable soil structure/tilth was due to the formation of polymeric substances by the soil organisms. It was then natural that research effort would be directed to synthetic polymers, which could prove more effective. With the commercial introduction of polymers for soil conditioning, U.S. Federal Trade Commission in 1954 defined a soil conditioner as, 'any synthetic organic chemical substance or chemically modified natural substance which is represented as having a primary function of forming and/or stabilizing soil aggregates to which it has been applied and thereby improving the resistance of such soil to the slaking action of water, increasing its water and air permeability, improving the resistance of its surface to crusting, improving its ease of cultivation and/or otherwise favourably modifying its structural or physical properties.'

Research proposal entitled, 'Utilization of polymers as soil conditioning and water retentive agents' was submitted to PCRWR/USAID in November 1987 against the Competitive Grants Program of the Irrigation Systems Management Research Project. It was approved in June 1988, financial allocation being Rs. 383000.

Broad objectives of this study were, (a) to undertake 'state of the art study' on R&D effort, production and usage of polymers for soil conditioning with a view to identify polymers and products of possible interest to Pakistan, (b) to undertake R&D activity needed for the development of technology for their manufacture, (c) to prepare prefeasibility studies for polymers/products whose technology is developed and (d) to identify specific areas of application where these products need to be field tested and the agencies and organizations with whom collaboration need to be established during the next phase.

Highlights of the results of the study presented in this Final Report are summarised below:

1. A 24'x24' laboratory has been set up for chemical studies; 1- litre reaction flask and 5 and 30-litre reactors are available for preparative studies of the soil conditioners. A 24"x12' laboratory has been set up for the equipment for testing soils and the efficacy of the soil conditioners.
2. Following Publications/Reports have resulted during the execution of this project.
   - 'State of the Art Study : Polymers as soil conditioning and sealing materials & their potential in Pakistan' Monograph published by Pakistan Academy of Sciences, 66 pp (1990).
   - 'Research and Technology Development Plan for Polymeric Soil Conditioners' Project Report, 16pp (1989).
   - 'Methodology for laboratory evaluation of soil conditioners; a review' Project Report, 13 pp (1989).
3. Literature survey showed that polyacrylamides (PAM), hydrolyzed polyacrylonitriles (HPAN) and polyvinyl alcohols (PVOH) have a potential for application as soil conditioners. While the PAM and HPAN can be used for a larger variety of

soils, scope of PVOH is limited. Both the PAM and HPAN categories are anionic and can be interchanged. PAM has already made commercial appearance, because it gives the cheapest products. During our investigation, we have discovered that a by-product of the textile industry based on acrylonitrile fibre offered the best chance for HPAN category of product, which could be produced cheaper than PAM.

4. Because of the availability of the by-product in the country and as well as in the international market, HPAN category of polymer was accorded a high priority for in-depth study. Products have been successfully developed, which have given comparative results with the PAM and have been field tested with vegetables. Product based on PVOH has also been formulated, while exploratory work on the preparation of PAM has also been carried out.
5. Pre-feasibility studies for the manufacture of these soil conditioners were also undertaken. HPAN based on the by-product is the most economic product, which can sell at about Rs. 15/kg. Costs of other soil conditioners have also been worked out.
6. Increasing productivity of vegetables and cash crops like cotton and possibly sugarcane offers a very promising outlet for the use of the soil conditioner. Other applications which deserve further studies are, (a) reduction in losses of irrigation water from runoff and excessive evaporation, (b) reclamation of saline/sodic soils, (c) moisture conservation in barani areas, and (d) field drainage.
7. Organisations which can be involved in the second phase of the project have been identified; several farmers in the private sector have offered full cooperation in studying increase in agricultural productivity.

INTRODUCTION

The farmer's responsibility is to make the best use of his land without damaging its long term production potential. To do this he has to understand the properties of the soil and know how to maintain cultivated soils in optimum physical condition. This is a fundamental long-term task, just as plant maintenance is a fundamental, long-term task in a factory.

Value of adding organic matter to the soil in the form of animal manures, green manures and crop residues for producing favourable soil structure/tilth has been known since ancient times, but the mechanism by which it functions was not understood till the 1930s. The discovery that naturally occurring polymeric materials like polyuronides and polysaccharides produced by the soil micro-organisms were the most active materials in the aggregation and stabilization of the soil, stimulated research for synthetic polymers that could be more effective than natural products.

With the commercial introduction of polymers as soil conditioners in 1952, U.S. Federal Trade Commission in 1954 defined soil conditioner as, ' any synthetic organic chemical substance or chemically modified natural substance which is represented as having a primary function of forming and/or stabilizing soil aggregates to which it has been applied and thereby improving the resistance of such soil to the slaking action of water, increasing its water and air permeability, improving the resistance of its surface to crusting, improving its ease of cultivation and/or otherwise favourably modifying its structural or physical properties'.

Products introduced by Monsanto under the trade name of '*Krilium*' in the early 1950s were a failure due to a number of factors, more important being very high costs and unsatisfactory application methods. Interest revived in the late 1960s as the seriousness of deleterious effect of intensive arable farming began to be recognised. Emphasis then was on achieving the desired results with much lower concentrations of the polymers by resorting to surface treatments. Commercial products began to make their appearance in the mid-1980s, as polymer treatment of certain soils proved effective and economically viable.

Research Proposal entitled, 'Utilization of Polymers as Soil Conditioning and Water Retentive Agents' was submitted in November 1987 to PCRWR/USAID against the Competitive Grants Program of the Irrigation Systems Management Research Project. It was approved in June 1988; duration of the project being two years and financial grant, Rs. 3,83,000.00. Project was delayed by three months due to initial teething administrative problems, but thereafter the project progressed smoothly and was completed by September 30, 1990.

I - PROJECT OBJECTIVES

- State-Of-The-Art-Study, through a survey of scientific and technological literature, commercial products, an assessment of the polymers studied uptodate and identification of the promising ones.
- To examine manufacturing aspects of the promising polymers and to undertake R&D activity needed for the development of technology for their local manufacture.
- To prepare prefeasibility studies on polymers/products whose technology is developed.
- To identify specific areas of application where these products can be field tested and the organisations/agencies,which are willing to collaborate.
- To prepare a proposal (Phase-II) for a pilot plant facility, which would make available sufficient quantities for field evaluation of the products, provide data for the designing of commercial plants and help refine the product specifications for different applications.

II - PROJECT PLANNING CHART

Network plan (PERT) has been constructed for the project control, Fig.1. Project activities with time estimates have been explained in Table 1.

TABLE 1. PROJECT ACTIVITIES/TIME ESTIMATES (MONTHS)

ACTIVITY	DESCRIPTION	t_e	σ
1 - 2	Scientific/technological commercial literature survey of soil conditioners	4	1/3
1 - 3	State of-the-Art-Study Setting up of the laboratory	6	1/3
1 - 4	Survey of laboratory methods for comparative evaluation of conditioners, design/fabricate, purchase set up equip	6	2/3
2 - 3	Gathering information on Pakistan soils & exploring potential application areas.	2	1/3
2 - 5	Literature survey, Polymer preparation	4	1/3
3 - 5	Exploratory labscale preparation study & develop R&D plan for technol development	2	1/3
4 - 6	Additional facilities needed for field application studies	6	2/3
5 - 7	Lab investigations to develop technical know-how for preparation of selected polymers	6	2/3
7 - 8, 11	Mini-field studies	4+4=8	2/3
7 - 9	Preparative study on mini-pilot unit & product formulation	4	1/3
9 - 10	Economic Feasibility Study on Production of soil conditioners	2	1/3
9 - 11	Identification of specific application areas, potential benefits & plans for 2nd phase of the project.	4	2/3
11 - 12	PREPARATION OF FINAL REPORT	2	1/3

NETWORK PLAN (PERT) OF THE PROJECT

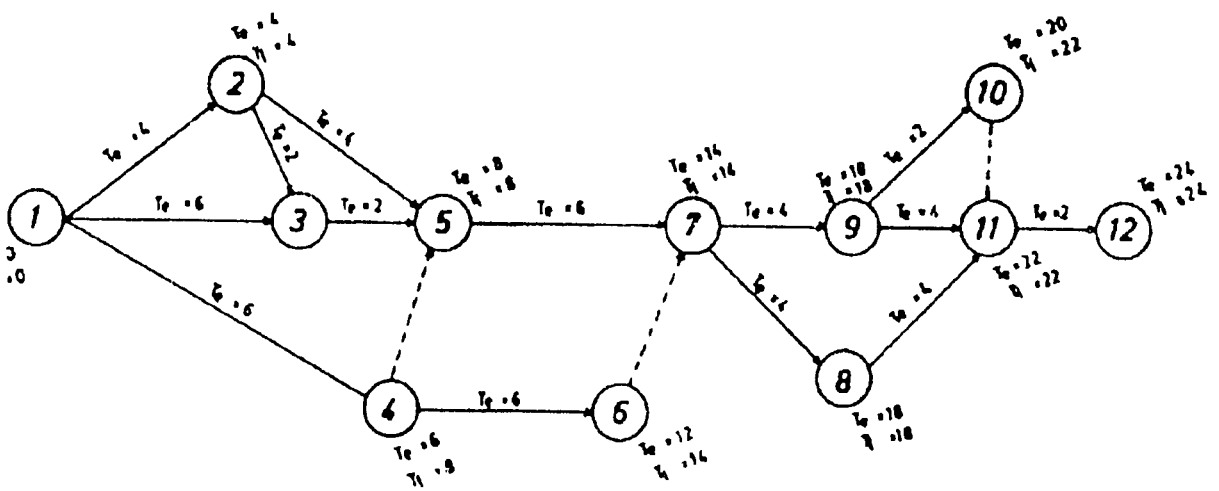


Fig. 1. Network plan (PERT) of the project

III - STATE-OF-THE-ART-STUDY

A 66 pp monograph entitled, 'Polymers as Soil Conditioners and Sealing Agents' written by the Principal Investigator has been published by the Pakistan Academy of Sciences (1990). This publication provides detailed information about:

1) All the polymers, natural or synthetic studied during the last 50 years. Natural polymers include alginates, dextran, guar gum, cellulose derivatives, starch, modified starches and their esters, lignosulfonates. The synthetics include polyvinyl alcohols (PVOH), polyacrylamides (PAM), polyacrylics (PA), hydrolyzed polyacrylonitrile (HPAN) and vinyl acetate-maleic acid co-polymer (VAMA).
2) Soils of Pakistan and important soil related problems, and
3) Discusses potential applications.

Uses of polymers for soil aggregation is still distant because of high costs and problems of application. However, their utilization for soil stabilization is proving effective and economical,– its application against capping problems particularly for vegetables is already econcmically viable in many areas of the world. Other potential areas are for reduction of soil erosion, improving drainage characteristics of soils and for the solution of soil salinity problems.

Identification of Potential Polymers

CELLULOSE XANTHATE: An intermediate product in rayon manufacture developed by Courtaulds was an effective product and the first to reach the stage of commercial utilization. Its principal drawback was that its shelf life was limited to less than a week at room temperature, and hence it gave way to more stable products.

POLYACRYLAMIDES: These are versatile water-soluble polymers of high molecular weight, in which different ionic characters can be built in and different types of polymers including non-ionic, cationic and anionic polyacrylamides can be produced for a large variety of applications, which include paper, mining, mineral and sugar industries and sewage treatment plants. Manufacture of Polyacrylamides is a well established industry and an additional product for soil conditioning purposes can be manufactured on the existing plants. It is not surprising that a polyacrylamide was the first soil conditioner to appear on the market.

Anionic category of polyacrylamide is available as a soil conditioning material, because of its applicability to a wide range of soils.

HYDROLYZED POLYACRYLONITRILE: The first soil conditioner, introduced by Monsanto in the early 1950s under the trade name of 'Krilium' belonged to this category. Quantity and cost of the product needed for aggregation purposes was very high, application methods had not been properly worked out and hence the products were withdrawn. However, the effectiveness of this polymer was never in doubt and its application has been studied extensively.

POLYVINYL ALCOHOLS: These alcohols can be prepared to give a wide range of solubilities varying from cold water-soluble, through hot water-soluble and upto insoluble and the key to these remarkable properties lies in its chemistry, for it is a polymer of a monomer, which does not exist in a free state. Thus it has to be prepared by the hydrolysis of polyvinyl acetates–degree of substitution controls the water solubility. These are effective for soil aggregation but the service life is less than the PAM and HPAN category and is applicable to a narrower range of soils.

Mode of Action of Polymers

The polymers by their adsorption and formation of interparticle bonds stabilise existing soil structures. Specific mechanisms involved in the interaction depends mainly on the chemical constitution of the polymer and the nature of the adsorbent surfaces.

HPAN and PAM are both anionic; they stabilize clay domains through electrostatic attraction with positive charges on clay particles. They can also be bonded to uncharged silica surfaces by hydrogen bonding through the silanol groups on these surfaces. These polymers are more efficient in acid soils; however, these are known to improve/stabilize aggregation in the presence of sodium below a certain critical level though the size of the aggregates may be affected; critical point is around 15% exchangeable sodium. These polymers are effective over a wide range of soil moisture content.

PVA is an uncharged molecule; such a polymer can diffuse into soil pores more easily, as they are adsorbed by weak hydrogen bonds of Van der Waal's forces. The lower the mole- cular weight, further they can penetrate into soil crumbs. Adsorption and hence stabilization is greatly helped by drying the soil and once the polymer is adsorbed it is very difficult to desorb because of the large entropy gain due to adsorption. PVA fails to respond to soils when the adsorptive surface contains polar groups such as chlorite or gibbsite [$Al(OH)_3$].

I V - RESEARCH AND TECHNOLOGY DEVELOPMENT PLAN

Project Report-II, 'Research and Technology Development Plan for Polymers Suitable for Soil Conditioning and Sealing' by M. Aslam, S. Ashhad Mehdi and Salim Akhtar, prepared during the execution of the project (March 1989, 16pp) deals with basic raw materials, review of the methods of preparation of the polymers, basic strategy and the Research Plan.

Basic Strategy

Basic Strategy in developing Research Plan took into consideration the following parameters:

1. Starting raw materials would be commercially available monomers or polymers, which can be processed or formulated into the desired products.
2. Development of process know-how for production technology should take into consideration the complexity of the equipment that would be needed - to put it into nutshell - it should be as simple as possible.
3. Product developed should be competitive on international level; consideration such as availability of raw materials in the country would be of secondary importance.

Basic Requirements of the Products

Basic requirements which the final product should meet were identified:

1. Solubility of the product in water should be as high as possible – somewhere around 30% – which can be diluted further at the time of use.
2. Additional qualification would be if the product can also be converted into dry powder form.

Basic Raw Material

Basic raw materials required for the polymers are ethylene and propylene; sources for their production are shown in Fig. 2. Since Pakistan has no petrochemical base, it would have to look

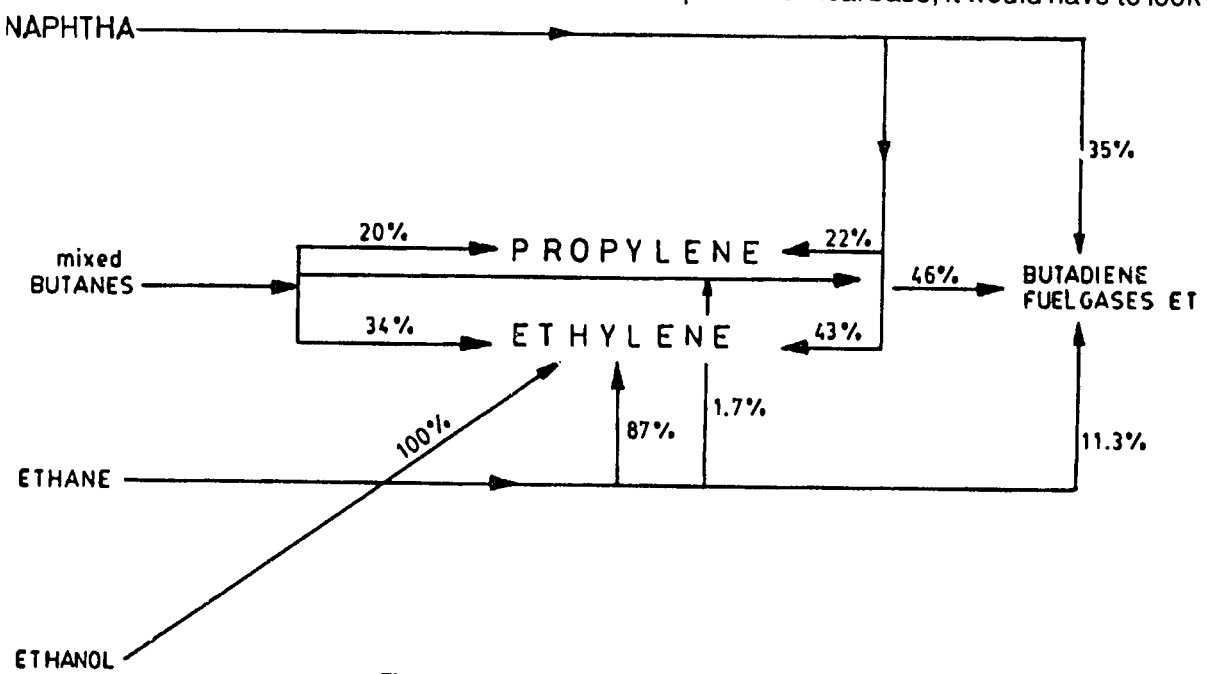


Fig. 2. Ethylene and propylene production

to ethanol for production of ethylene, for which efficient mediumscale technologies are available from Brazil. For further details, 80 pp monograph, 'Ethanol Production for Motor Vehicles and Chemical Feedstock' by M. Aslam, published by Pakistan Academy of Sciences (1987) could be consulted.

Selected Polymers

HYDROLYZED POLYACRYLONITRILE: Preparation of polymers for soil conditioning and their inter-relationships are shown in Fig.3. From this figure it can be seen that acrylonitrile monomer is the starting raw material both for HPAN & PAM. There is, therefore, no cost advantage in terms of the cost of the starting materials. Two steps are needed in each of the case. Literature indicates the efficiency of both polymers (both polyanions) is of the same order and as a matter of fact one can be replaced by the other merely on cost consideration.

During the survey and exploratory work, we discovered that a by-product of the indigenous acrylic fibre based textile industry was a promising and a cheap raw material for HPAN category of products. Over 500 tons of this material are available in Pakistan; its chemical composition which is given below is such that improved HPAN products could be produced.

Acrylonitrile Component	91.7%
Methyl Acrylate Component	8.3%

This raw material offered the best possible chance of preparing effective and economic products and hence was selected for in-depth study.

POLYACRYLAMIDE: It was decided to do some spade work so as to gather preliminary information about its preparation. We were further handicapped by non-availability of the acrylamide monomer.

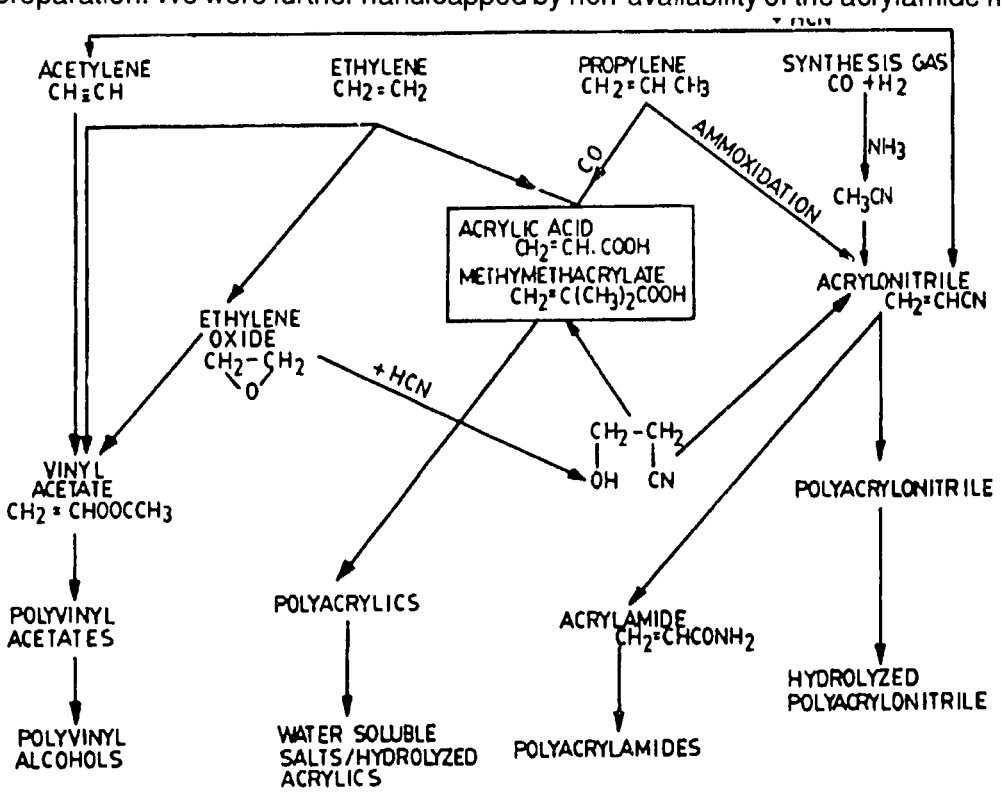


Fig. 3. Preparation of Polymers and their Inter-relationship

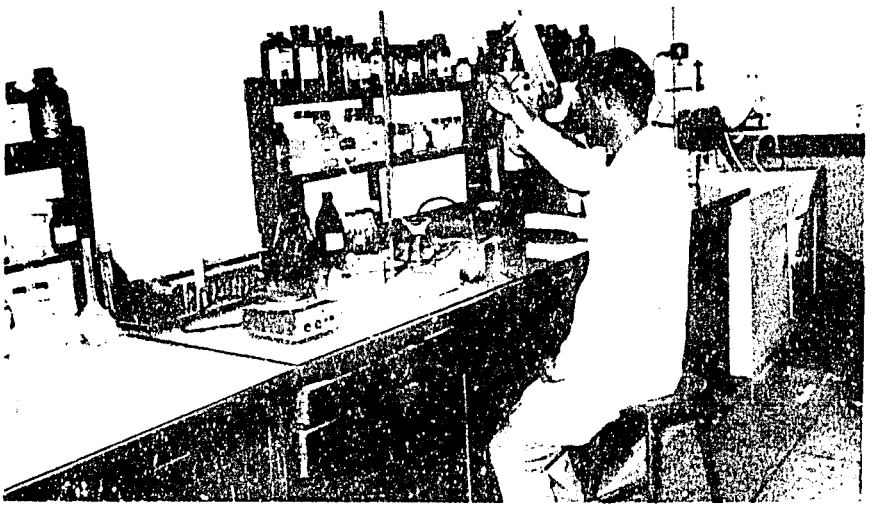
2 kg of the material which were available with the PCSIR Laboratories was used for this purpose.

POLYVINYL ALCOHOLS: A large variety of these alcohols are imported for different applications. Our objective was to examine which one of these was suitable for soil conditioning, as no product as such is marketted for this purpose. Blending of two or three of the available polymers was also to be studied. Manufacturing aspects of these alcohols was not to be investigated. Major producers of these alcohols are the following – trade names have been given in brackets:

(Elvanol)	E.I. du Pont de Nemours & Co., Inc.
(Vinol)	Air Products and Chemicals Co.
(Gelvatol)	Nippon Gohsei Co. (Japan).
(Poval)	Kuraray Co. (Japan).
(Mowioi)	Farbwerke Hoechst A.G. (Germany).

V - SETTING UP OF LABORATORY AND TESTING FACILITIES FOR SOIL CONDITIONERS & SOILS

A 24' x 24' Laboratory was set up for chemical investigations, preparative studies and other inputs needed for technological development of soil conditioners. Another Unit, 24' x 12' was set up to house the testing facilities.



A SECTION OF THE CHEMICAL LABORATORY (24'X24') SET UP FOR THE PROJECT

Soil Aggregation/Wet-Sieve Stability Test

Most important requirement initially was to select the methodology and equipment needed to determine the relative soil-conditioning effectiveness of different batches or samples collected during the progress of a chemical reaction. 'Methodology for Laboratory Evaluation of Soil Conditioners' Project Report No. III(13 pp) by S.S.H. Rizvi, Dabir Ahmad and Ahmad Saghir (March 1989) reviews the known methods. Most useful test identified related to measuring soil aggregation and stability of soil samples; equipment for which was fabricated by the Applied Physics, Computer & Instrumentation Centre of PCSIR Karachi Laboratories Complex. Method used is described below:

PREPARATION OF TEST SOIL: Soil sample is dried to about 3% moisture, ground in a hammer mill through a 0.125 inch screen, and sieved to separate the fraction which will pass a 60-mesh sieve. This procedure is repeated until approximately 75% of the soil has been reduced to 60-mesh.

SOIL TREATMENT: A 100-gram portion of pulverized soil is placed in a 4-inch, flat-bottomed preparation dish, which is tapped on the table top to pad and level the soil. To the soil is added in one portion 30 ml. of distilled water containing the appropriate amount of the polymer to be tested and the dish is tilted gently back and forth until all of the soil surface has been wetted and all the large bubbles covering unwetted soil have been recovered.

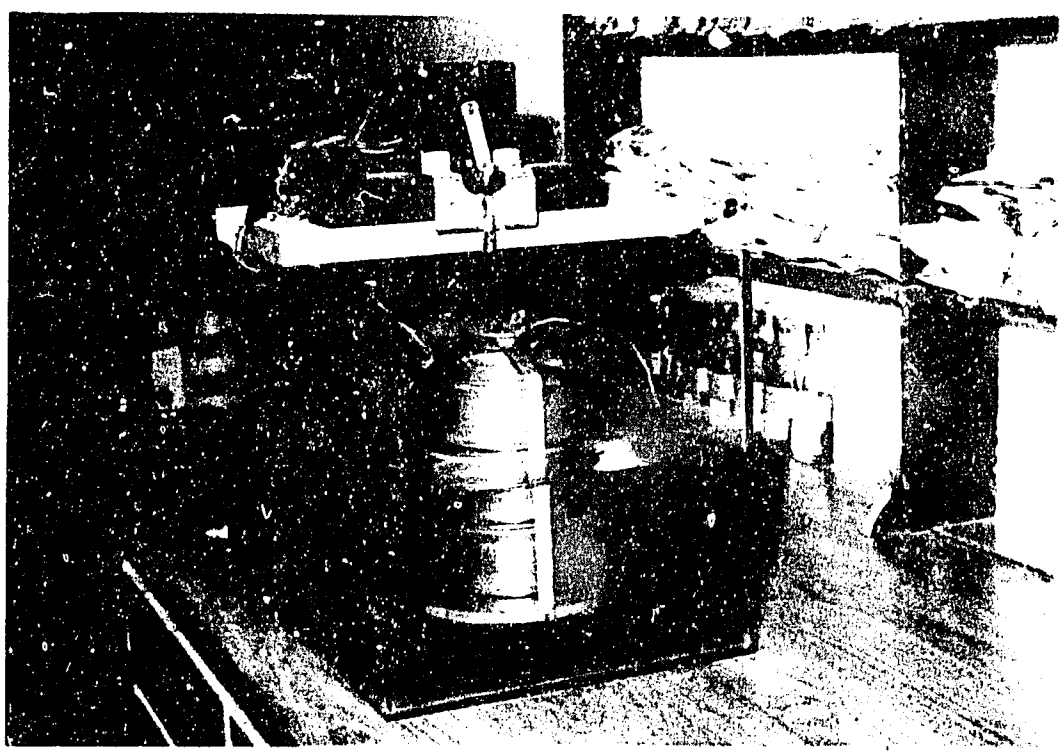
Dishes containing the moist, treated soil are stacked together to prevent evaporation and allowed to stand 2 hours. If any of the soil has not been wetted at the end of this period, the soil is sliced gently with a spatula to distribute the dry soil and allow it to become wetted. The soil should

not be mixed unnecessarily, as some polymer treatments are sensitive to the amount of mixing given the moist soil. All of the soil is transferred by means of a stainless steel spatula, 1.25 inches in width, to an 8-inch sieve with 4-mm openings and pressed with the spatula through a small area of the sieve to form crumbs. It is important that each sample be pushed through approximately the same sized area, as this controls the compaction of the crumbs. The crumbs are placed in a 6-inch Petri dish and dried for 2 days at 25° C and at a relative humidity of 40 to 50%.

WET-SIEVING: A 40-gram sample of dried crumbs is wet-sieved by a modification of the Yoder method. The apparatus is a device for raising and lowering any number of sets of sieves in water, and a variety of designs have been used.

Three sieves are used, with openings of 0.84, 0.42, and 0.25mm, stacked in order of decreasing size from the top. The weighed soil crumbs are placed on the top sieve and the water level is allowed to rise in the tank until the soil begins to wet from below. The water level is then held constant until the crumbs are completely wetted by capillarity. The final water level is such that the top screen is at the surface of the water when the sieves are at the top of the cycle. The sieves are set in motion and are raised and lowered through a distance of 1.5 inches at a rate of 30 cycles per minute for 30 minutes. The sieves are allowed to drain and are dried in a circulating air oven at 110° C. The dry aggregates are removed from each sieve and weighed. The results are usually expressed as the aggregation value, which is the percentage of the soil retained as aggregates larger than 0.25 mm.

$$\text{Aggregation value} = \frac{\text{total weight (grams) recovered}}{40} \times 100$$



SOIL AGGREGATES STABILITY TESTING APPARATUS, FABRICATED BY PCSIR

Set-up for Determining the Textural Class of Soil

This set-up is based on a particle size analysis of the soil sample by hydrometer method. The textural class is determined by estimating the percentage of sand, silt and clay in the sample. A brief description of the experimental procedure is as follows:

"The soil sample is treated with hydrogen peroxide in order to remove the organic matter present in the sample; then it is soaked overnight in sodium pyrophosphate (dispersive agent). The soil mixture is then dispersed in a blender for a few minutes, and it is transferred in a measuring cylinder to which distilled water is added to bring contents to 1 litre mark. The contents of the cylinder is homogenised by repeatedly inverting the cylinder. The density readings are taken first after 40 seconds and then after 2 hours by using a soil hydrometer (ASTM 15H). These readings are used to calculate the percentage of sand, silt and clay and the textural class is then determined using Textural Triangle".

Maximum Water Holding Capacity of Soil

It is the amount of water retained by soil at saturation; it is also indicative of soil structure. A brief description of the experimental procedure is as follows:

'A known quantity of soil is placed in a specially designed box, having perforated bottom. The perforations of the bottom are covered with a filter paper cut to its size. The filter paper is clipped by a spring ring. The box is then placed in a petri-dish on a glass triangle and water is poured into petri-dish so that atleast half the height of the box remains immersed under water and left overnight. The box is removed and placed on the blotting paper to strain out the excess water. The weight of the box and saturated soil is taken, then the soil is dried in an oven for 8-10 hrs. and reweighed. Water retained by the soil is determined and the percentage of water holding capacity is calculated. Necessary correction for the weight of water absorbed by filter paper is also incorporated in the calculations'.

Relative Hydraulic Conductivity

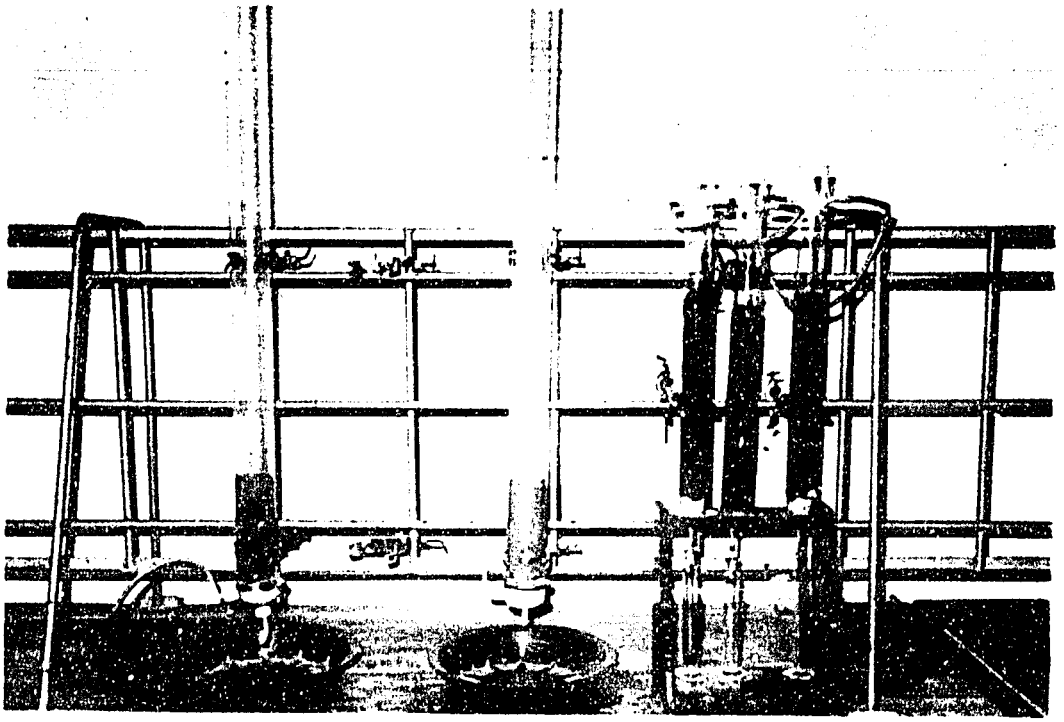
Two methods were used:

(1) A series of plastic tubes with funnel-shaped bottoms are filled with soil under test to maintain 1/2 meter column and the solution containing soil conditioner allowed to penetrate and kept overnight for 'curing'. It is followed by the addition of fixed amount of water (about 30% by weight of soil) and allowed to drain; volume of water collected at the bottom at the end of each hour is replenished by tap water. System takes about 24 hours to attain stabilization, when the water drains at constant rate. Ratio of these rates to that of control is calculated as relative hydraulic conductivity.

(2) Soil is treated with the conditioner and dried in air to constant weight. It is then packed in the column and from thereon the procedure is the same as described in (1).

Electrical Conductivity

This property was determined on a 1:1 soil-water extract by Soil Conductivity Meter, Type MC-4, Electronic Switch Gear, London.



APPARATUS FOR DETERMINING OF HYDRAULIC CONDUCTIVITY OF SOILS

Soil Kit

It was made in the Laboratory for determining pH, potassium, phosphorus, nitrate nitrogen, ammonia nitrogen, chloride and sulphate.

Chemical Analysis

All the determinations for soluble and exchangeable cations and anions, electrical conductivity, pH, cation exchange capacity etc.were carried out according to the methods given in USDA Handbook 60.

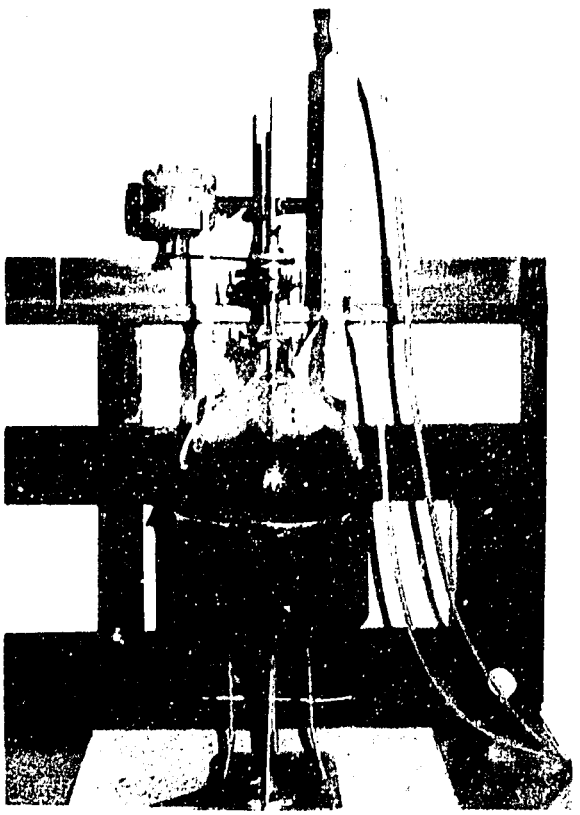
VI - HYDROLYZED POLYACRYLONITRILE (HPAN): PRODUCT DEVELOPMENT

This category of soil conditioners was selected for in-depth and intensive investigations for the following reasons:

1. Raw material for its manufacture was available as a by- product of the indigenous textile industry, based on imported acrylonitrile fibre – more than 500 tons currently available at a very economic price.
2. Plenty of information on the application aspects of HPAN was available in published literature.
3. To get a product with high solid content and manageable viscosity when starting with acrylonitrile monomer has been reported to be difficult. To overcome this it had been proposed to copolymerise acrylonitrile with some acrylic monomer; fortunately the polymer waste is already a copolymer of acrylonitrile with about 8-9% methyl acrylate. This was an added advantage.

Hence this by-product held out a real promise for an economically viable and effective product. Preliminary examination and investigations undertaken showed that alkaline hydrolysis would be more practical from the technological aspect. A systematic study of the alkaline hydrolysis was therefore undertaken.

Hydrolysis reaction was carried out in a 1-litre, 3-necked flask heated on a temperature-controlled water bath, equipped with thermometer, stirring arrangement and a reflux condenser. The following data was collected during the study:



1-LITRE REACTION FLASK, WITH STIRRING ARRANGEMENT

Basic Chemistry

The rate of hydrolysis was determined by nitrogen estimation. Total nitrogen was determined by Kjeldahl's method, while the nitrogen in the CN group was estimated by using IR-Spectroscopy. The nitrile group in the polymer exhibits symmetric valency vibrations of a characteristic frequency and appears in the spectrum as an absorption band at 2245 cm^{-1}. A calibration curve was obtained by plotting optical density vs nitrogen content in the polyacrylonitrile and polyacrylic acid.

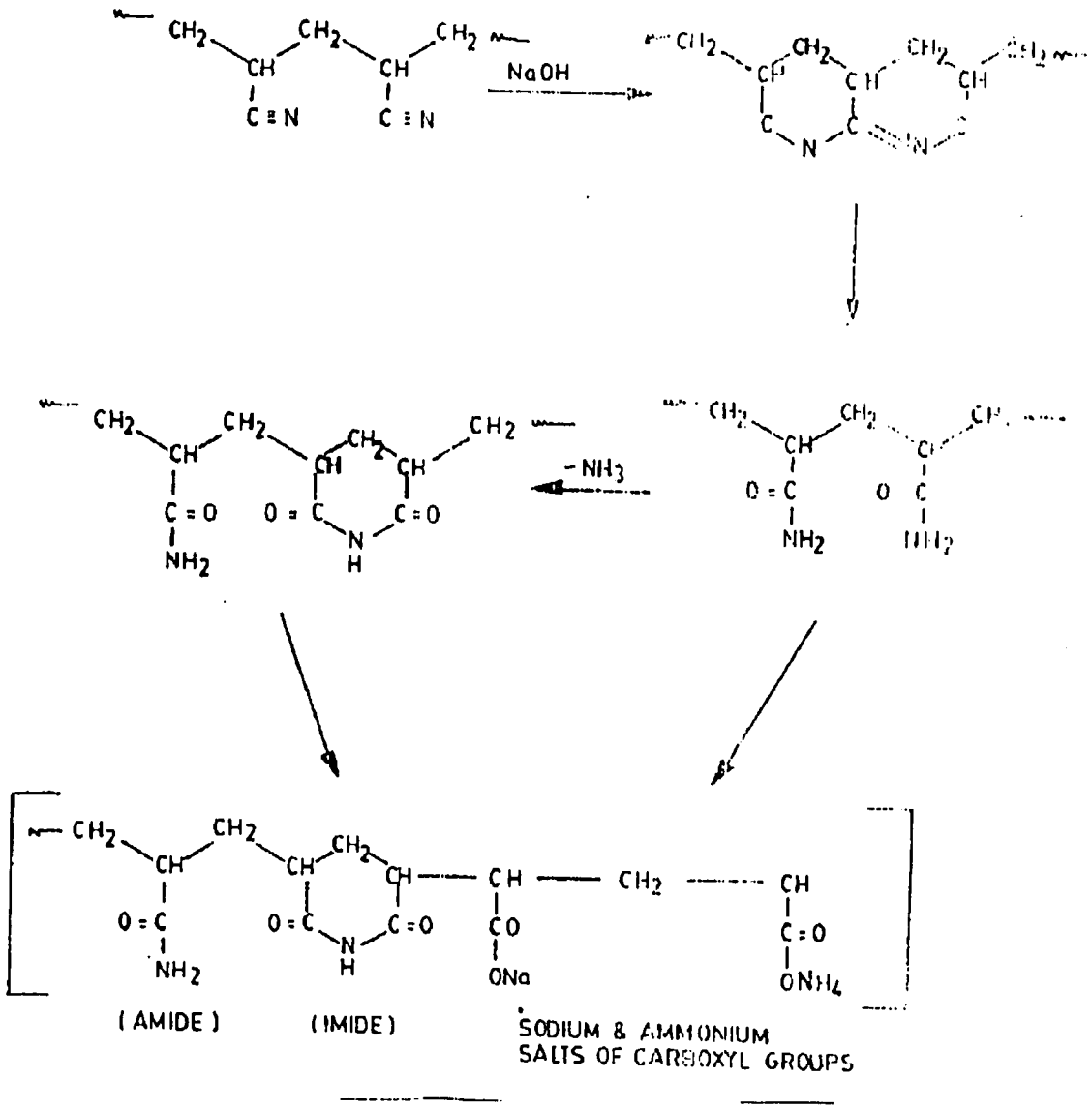


Fig. 4. Probable reaction mechanism during hydrolysis of acrylic fibre

The water soluble acrylic polymers were found to possess mostly amide and carboxyl groups; ammonia escapes as gas. The difference in nitrogen content by both methods shows that rate of hydrolysis is fast in the beginning and then stabilizes to imide-amide groups. The CN group cyclises before being hydrolyzed. The most probable reaction is depicted in Fig.4. One of the project associates involved in the basic studies is working for his Ph.D. programme with Karachi University.

Determination of Desirable Fibre/Caustic Soda Ratio

This ratio has an important influence on the nature and the characteristics of the hydrolyzed product. Three ratios 1:1,1:0.8 and 1:0.6 were chosen on the basis of exploratory research. Reaction was carried out at 95° C.

As the hydrolysis progresses, soluble solids continue to increase and then levels off after about 3 hours. Solid content in case of 1:0.8 reached 18.3% and in case of 1:1, it reached 20.3% after 3 hours.

After 3 hours, mass is still too viscous; continuing to heat for further 3 hours gave significant reduction in viscosity, which is a very desirable quality for the end product.

Agitation during the reaction has a strong influence on the rate of hydrolysis; this became obvious as capacity of the reactor was increased form 1-litre to 3-litre and it became necessary to convert available attritor (5 litre capacity) with a geared motor reactor in order to produce larger quantities.

During the progress of the reaction, the mass goes through a highly viscous stage – its management depends on the agitation mechanism and the quantity of caustic soda.

The end products have a small amount of free alkali, which can be used on soils where Na content may not be important. However, the free alkali is neutralized for producing neutral products. Following products were prepared for comparative purposes:

PRODUCT REFERENCE NO.	FIBRE/CAUSTIC RATIO	NATURE
PANA - 8F	1:1	Alkaline
PANA -11F	1:0.8	"
PANA -15F	1:0.6	"
HPAN - I	1:1	Neutral
HPAN -II	1:0.6	"

Influence of Temperature on Degree of Hydrolysis

This study was carried out on fibre/caustic soda ratio of 1:1 at 90,95 and 100° C; caustic soda being used as 10% aqueous solution. Samples were drawn after fixed intervals and examined for:

1. Free alkali by titration with standard hydrochloric acid;
2. A portion of the sample was adjusted to pH 6.5; suspended impurities removed by filtration and the filtrate acidified to pH 2.5-3.0 to precipitate the polymer. The pasty mass

obtained was washed with ethanol and dried in vacuum at 50°C. Its nitrogen content was estimated by Kjeldahl Method.

The nitrogen content is reduced from 24 to 7% in 30 minutes with elimination of ammonia and thereafter nitrogen reduction is very slow with 4-4.5% of nitrogen being retained in the final product. The free alkali reduction is almost linear.

Results of the degree of hydrolysis are shown in Fig.5. Characteristics of the polymer with reference to its aggregation value vs degree of hydrolysis was also carried out and the results are shown in Fig.6. It will be seen that the reaction should not be allowed to go beyond 65% degree of hydrolysis.

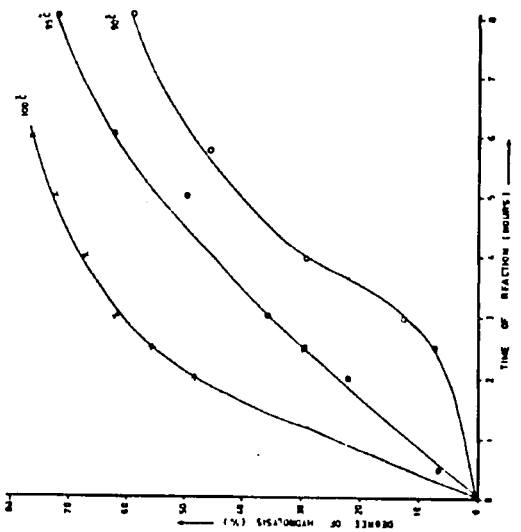


Fig. 5. Effect of reaction period on degree of hydrolysis of acrylic fibre at 90, 95 and 100°C; Fibre-caustic ratio-1:1

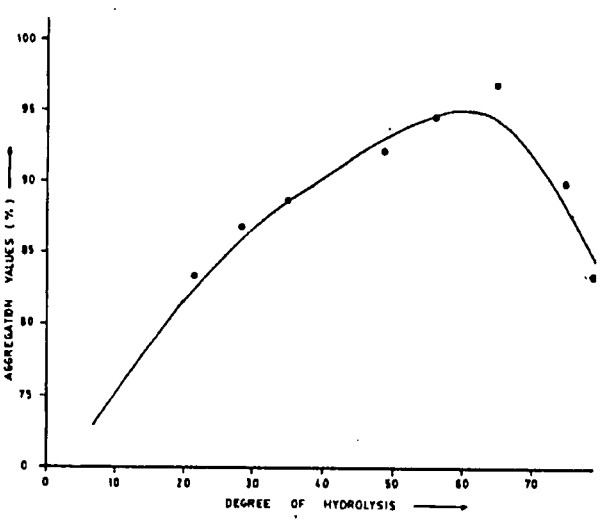


Fig. 6. Effect of degree of hydrolysis of acrylic fibre on aggregation value; Fibre-caustic ratio-1:1, [Malir soil 1, 0.1% application]

Soil Aggregation Characteristics of Soil Conditioners

Comparative evaluation of PANA-8F,-11F,-15F and HPAN-1 for soil aggregation and the distribution of water stable aggregates of varying sizes at different concentrations has been carried out and the results are presented in Table 2. Characteristics of the soils used in these investigations are shown in Table 3.

TABLE 2. SOIL AGGREGATION/WET SIEVE STABILITY TEST DATA: DISTRIBUTION OF WATER STABLE AGGREGATE SIZE AT VARIOUS CONCENTRATIONS

Polymer No	Soil No.	0.1 % Application >0.84 mm	0.42-0.84 mm	0.25-0.42 mm	Aggregation Value	0.05 % Application >0.84 mm	0.42-0.84 mm	0.25-0.42 mm	Aggregation Value	0.02 % Application >0.84 mm	0.42-0.84 mm	0.2 0.42 mm	Aggregation Value
	%	%	%	%	%	%	%	%		%	%	%	%
PANA - 8F	M-1	87.0	4.0	1.6	92.6	25.9	37.7	13.9	77.5				
PANA -15F	M-1	89.7	2.9	1.0	93.6	71.4	12.5	4.7	88.6	1.5	25.7	26.4	53.6
HPAN - I	M-1	48.7	20.7	6.2	75.6								
PANA -11 F	M-2	92.0	3.7	1.4	97.1	46.9	33.9	7.0	87.8				
PANA -15F	M-2	94.6	0.6	0.3	95.5	90.7	3.8	1.2	95.7	2.2	42.7	25.0	69.9
PANA - 8F	M-2	89.2	6.4	1.4	97.0	17.0	51.2	9.8	78.0				
PANA -15F	K	6.8	23.1	11.1	41.0								
PANA - 8F	K	10.5	21.5	11.1	43.1								
HPAN - I	K	8.2	16.3	13.2	37.7	2.0	13.5	14.5	30.0				
PANA -8F	H	92.2	1.9	1.0	95.1	18.3	33.4	12.0	63.7				

CONTROL DATA FOR UNTREATED SOILS

Soil Source	Soil No	> 0.84 mm	0.42-0.84 mm	0.25-0.42 mm	Aggregation Value, %
Malir	M-1	14.5	8.8	8.5	31.8
Malir	M-2	13.8	11.2	11.5	36.5
PCSIR (Karachi)	K	9.2	7.2	8.4	24.8

TABLE 3. PHYSICO-CHEMICAL PROPERTIES OF SOILS

Soil Property	Malir 1	Malir 2	PCSIR Karachi	Hub
Texture				
Sand %	77.4	77.4	54.8	90.0
Silt %	13.6	9.1	33.9	4.0
Clay %	9.0	13.5	11.3	6.0
Texture Class	Loamy Sand		Sandy Loam	Sand
Air-dried moisture, %	0.81		0.20	0.68
pH (1:1 H_2O)	8.2	8.4	7.4	8.1
Electrical Conductivity mmhos	0.45		1.5	0.40
Organic matter, %	1.23		1.7	0.35
Total Soluble Salts, %	0.05		0.08	0.04
Sodium Absorption ratio	2.44		3.25	1.54

Continue

Continuation

Potassium Absorption ratio	0.11	0.36	0.40
Cation exchange capacity, meq/100g	8.26	11.88	5.39
Exchangeable sodium, %	2.25	3.38	0.99
Exchangeable potassium, %	4.58	6.89	7.20
Soluble cations and anions, meq/L			
Sodium	3.49	13.48	2.09
Potassium	0.15	1.54	0.54
Calcium	2.24	27.68	2.88
Magnesium	1.84	8.48	0.80
Carbonate	Nil	Nil	0.83
Bicarbonate	3.33	4.16	2.91
Chloride	1.40	5.63	1.41
Sulphate	0.52	2.6	0.52
Ammonium Acetate Extractable Cations, meq/L			
Sodium	6.52	21.74	4.96
Potassium	2.56	9.23	5.08
Calcium	58.40	116.00	59.20
Magnesium	37.40	37.4	11.04
Manganese (ppm)	1.56	7.6	1.33
Zinc (ppm)	0.23	0.33	0.51
Exchangeable Cations, meq/L			
Sodium	3.30	8.26	2.87
Potassium	2.41	7.69	4.54
Calcium	56.16	88.32	56.32
Magnesium	35.56	21.92	10.20
Nitrate nitrogen, ppm	2.0	2.5	5.0
Ammonia nitrogen, ppm	5.0	6.0	5.0
Phosphorus, ppm	100.0	90.0	37.5

Tests Carried Out At NIAB

The following tests on PANA-8F and HPAN-1 were carried out at the Department of Soil Science of the NIAB (Nuclear Institute for Agriculture and Biology), Faisalabad:

(a) - Measurement of relative hydraulic conductivity;
(b) - Moisture retention at field capacity.

The data collected is presented in Tables 4,5 and 6.

TABLE 4. EFFECT OF CONDITIONERS ON RELATIVE HYDRAULIC CONDUCTIVITY (RHCs) OF THE SOILS

Date	Time	Obsd. after hrs.	High Saline Soil			Low Saline Soil		
			Control ml	PANA-8 ml	HPAN-1 ml	Control ml	PANA-8 ml	HPAN-1
			1	2	3	4	5	6
27-3-90	3.10(PM)	Zero	-	-	-	-	-	-
"	4.10 "	1	1.0	0.5	7.5	9	8	45.0
"	5.10 "	2	1.5	0.25	9.0	0.5	5.0	35.0
"	6.10 "	3	2.25	0.25	7.0	3.25	3.75	28.0

Continue

Continuation

"	7.10	"	4	2.5	0.25	7.5	2.5	4.0	30.0
"	8.10	"	5	2.25	Nil	19.0	3.25	3.75	24.0
"	9.10	"	6	2.7	Nil	7.5	3.7	5.5	23.0
"	10.10	"	7	6.5	0.3	7.3	7.2	6.0	15.0
"	11.10	"	8	7.5	0.2	8.0	2.2	2.5	4.0
28-3-90	9.00(AM)		18	66/10=6.6	-	63/10=6.3	20/10=2	23/10=2.3	96/10=9.6
"	10.00	"	19	7.0	-	7.0	2.5	2.75	11.0
"	11.00	"	20	6.5	-	4.5	2.25	2.5	8.0
"	12.00	"	21	7.5	-	7.5	2.25	2.75	10.0
"	13.00	"	22	6.0	-	5.5	2.0	2.0	7.5
"	14.00	"	23	6.5	-	6.5	2.2	2.2	8.25
"	15.00	"	24	6.0	-	5.75	2.0	2.0	7.5
"	16.00	"	25	6.25	-	6.25	2.0	2.0	7.5
"	17.00	"	26	5.75	-	5.6	2.0	2.0	7.0
29-3-90	9.00			86.4/16=5.4	-	89.6/16=5.6	32/16=2.0	31/16=2.0	112/16=7.0
	Average			6.0	-	6.0	2.0	2.0	7.5
	R H Cs			3.0		3.0	1.0	1.0	3.75

Table 5. Moisture Retention at Field Capacity

	Wt. of dish	Dish + (Soil+H_2O)	Dish +Soil After heating	Wt. of H_2O	Wt.of dry Soil	Moisture %
Low Saline Soil						
Control	44.89	82.83	73.6	9.23	28.33	32.6
HPAN-I	37.16	78.16	67.7	10.46	29.85	35.0
PANA-8F	43.65	96 51	83.3	13.21	39.65	33.3
High Saline Sodic Soil						
Control	47.91	101.31	88.20	13.11	40.29	32.53
HPAN - I	42.66	74.73	66.60	8.13	23.94	33.9
PANA - 8F	44.57	106.10	92.10	14.1	46.53	30.3

Table 6. Aqueous 0.1% HPAN Application on Soil in Lysimeter

Treatment	Relative HCs	% Moisture Retention at Field Capacity
Low Saline Soil		
Control	1.0	32.6
HPAN - 1	3.75	35.0
PANA - 8F	1.0	33.3
High Saline Sodic		
Control	1.0	32.53
HPAN - I	3.0	33.9
PANA - 8F	0	30.3

Soils used had the following characteristics:

	Electrical Conductivity, ds cm^{-1}	pH	Texture
Low Saline Soil	2.4	8.1	Loam
High Saline Sodic	13.2	9.8	Silty Clay Loam

Further tests were carried out at PCSIR using Malir and PCSIR soils with the facilities set up at this unit. Second method described in Chapter V for hydraulic conductivity was used for the study. The soils under test were passed through 12-mesh and treated with HPAN-I equivalent to 25, 50, 100 & 300 Kg/ha. The treated samples were air dried and tested as described earlier. Results are presented in Table 7.

TABLE 7. RELATIVE HYDRAULIC CONDUCTIVITY AND WATER RETENTION AT FIELD CAPACITY

Dosage (Kg/ha)	25	50	100	300	Control
PCSIR SOIL					
Relative hydraulic Conductivity	1.1	2.05	3.1	7.8	1.0
Water retention at field capacity, %	32.5	33.6	33.8	33.9	31.5
MALIR SOIL - 2					
Relative hydraulic Conductivity	1.03	1.17	1.3	2.08	1.0
Water retention, at field Capacity, %	30.9	30.8	31.2	32.6	31.3

Reactors

Design of the reactor is a very important factor for preparing Soil Conditioners on a commercial scale. Preliminary studies were carried out in 1-litre flask; when experimentation was scaled to 3-litre flask, importance of agitation was realised. Hence an attritor with a geared motor (available with PCSIR) was converted into a reaction vessel of 5-litre capacity. This unit also contained ceramic balls, which made possible to increase the intensity of agitation. A steam generator (30 psi) was fabricated for heating the reactor. A 30-litre reactor has also been fabricated. The reactor that has been designed can be used for producing other category of soil conditioners. During the second phase of the project it is planned to make a 400-litre capacity reactor, when residual problems, if any, will be solved.

Concluding Observations

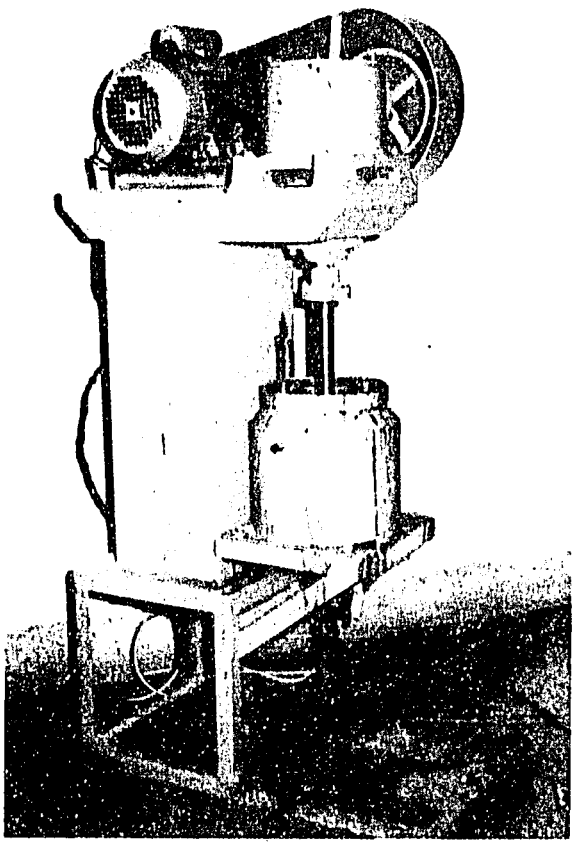
Our target for the final product was that we should get upto 30% solid content, a reasonable viscosity and be capable of almost indefinite dilution. Our investigations had established the following important facts:

- Total solids increased as the quantity of alkali was increased; it also increased with the increase in reaction time;
- More intensive the agitation during the viscous stage,better was the solubility of the end product.
- Lower the quantity of alkali, better were the aggregation properties;

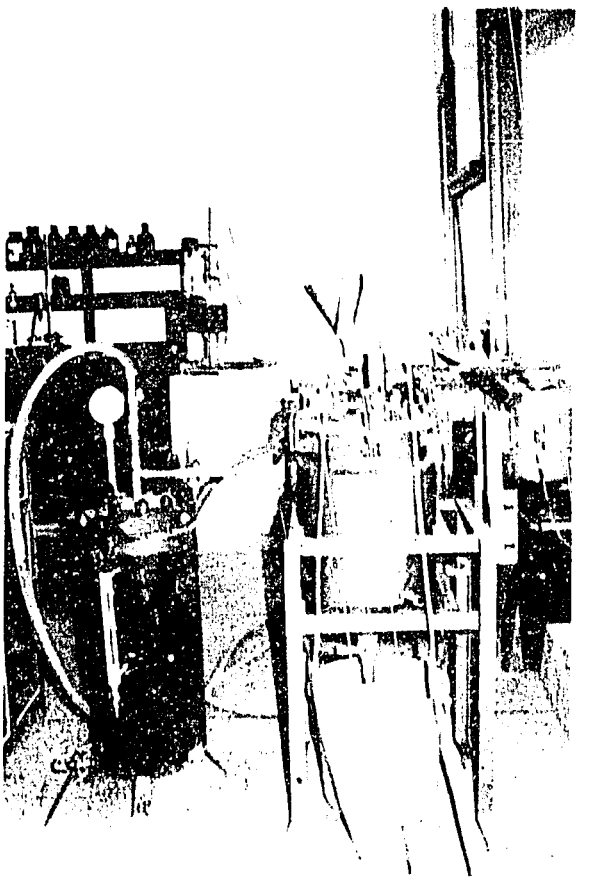
- With increased reaction time, free alkalinity kept on reducing and solid content kept increasing.
- Proper balance of preparative conditions had to be achieved to get the desired product. Two products were finally developed.

PANA 8 - F was prepared with fibre - NaOH ratio of 1:1, at 95°C with a reaction time of about 8 hours. It has a free alkalinity of about 2.5% and a pH: 11.8.

HPAN - I was another product prepared from PANA – 8F by neutralization; pH of the final product was 7.5.



5-LITRE REACTION VESSEL SET-UP USING AVAILABLE ATTRITOR WITH PCSIR



30-LITRE REACTOR WITH STEAM GENERATOR

VII-POLYACRYLAMIDE (PAM) SOIL CONDITIONER: PRODUCT DEVELOPMENT

Polyacrylamides are versatile synthetic polymers, readily water soluble over a broad range of conditions. They can be engineered to fit a large number of uses such as in paper industry, mining and mineral processing industries, the sugar industry, sewage treatment industry and several other industries, where separation of solids and liquids are desired.

Different ionic characters can be introduced into the molecule, with the result that nonionic, anionic, cationic and even amphoteric polyacrylamides can be produced. Anionic polymers have been introduced in recent years specifically for soil conditioning.

Acrylamide monomer, which is the main raw material is obtained from acrylonitrile monomer and is available as a dry crystalline powder.

Polyacrylamide is prepared by the polymerization of the monomer in aqueous medium, using different catalysts. It was not possible to get hold of the monomer and so the work was conducted with 2 kg of the monomer available with PCSIR. Since a cheaper indigenous alternative had been discovered as a by-product of the local industry and since HPAN and PAM are both anionic and more or less interchangeable, therefore stress was placed on HPAN.

With the limited quantity of the monomer available, research work undertaken showed that polymerization process does not present any special difficulty. Reaction is carried out in water, at a concentration of 25% monomer using ammonium persulphate and sodium thiosulphate. Full preparative parameters could not be worked out but it is felt that if ever a need arose for preparing anionic PAM, there would be no difficulty.

It was also found that partial hydrolysis of the polymer would improve the soil conditioning properties.

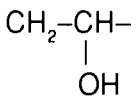
Economics of production has been worked out and the results are reported in the relevant chapter.

VIII - POLYVINYL ALCOHOL (PVOH) SOIL CONDITIONER: PRODUCT DEVELOPMENT

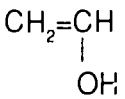
Basic Chemistry

The key to remarkable properties of PVOH lies in its chemistry, for it is a polymer of a monomer, which does not exist in a free state.

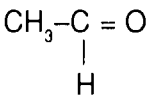
The single 'vinyl alcohol' radical would be



but this particular combination does not choose to make itself into a stable monomer by joining up the two loose bonds, so:

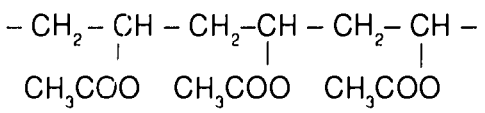


but insists on appearing in the isomeric form:

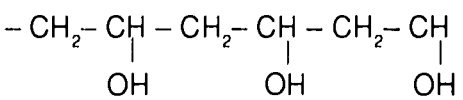


which is acetaldehyde, quite a different matter.

So to make this polymeric curiosity one has to start with a polymer which already has a long chain of linked vinyl radicals, (polyvinyl acetate is the usual one),



and replace all or most of the acetate groups with hydroxyl groups:



Significant Characteristics

Two important factors, which control the characteristics of PVOH are:

1. Molecular weight of the acetate from which it is derived: this can range between 20000 and 300,000. Alcohols prepared from low molecular weight acetates are more easily soluble in water. As the molecular weight increases, its water solubility decreases and finally a stage is reached when a certain portion of the acetate has to be left unhydrolysed to retain its water solubility. Another important property which depends on this factor is the viscosity; lower the molecular weight, higher the viscosity.
2. Degree of hydrolysis: The product remains insoluble in water upto 40% level of hydrolysis; thereafter the solubility in water is directly proportional to the extent of hydrolysis. Over 99% conversion can be achieved.

Criteria For Product Development

Commercially available polyvinyl alcohols have the following range of properties:

Molecular weight	15,000-200,000
Hydrolysis (mole %)	71-99.5
Viscosity, (cps)	3 - 68 (4% solution in water)
pH	5 - 7

Based on the available literature, the parameters which would suit application of PVOH as soil conditioner would be following:

- Molecular weight, in the range of 65000-75000.
- Viscosity of a 30% solution to be such that the final product does not pose handling problems.
- It should have good binding property and stability on storage.

Different categories of Polyvinyl alcohols are prepared commercially for the following applications:

- Adhesives and Binders.
- Textile Warp Sizing.
- Textile finishing.
- Paper Sizing and Coating.
- Miscellaneous.

Polyvinyl alcohols under the trade name of 'GOHSENOL' manufactured by the Nippon Synthetic Chemical Industry Co., Ltd. Osaka, Japan, are being imported in the country. Examination of the literature of its products showed that PVOH of G-Type was likely to fulfil the requirements of soil conditioner.

Initially the solubility and viscosity of the 7 grades of G-Type of PVOH were studied. GH-17 fulfilled all the requirements; its characteristics are as follows:

Hydrolysis (mole %)	:	86.5-89
Viscosity (cps)	:	27-33
pH	:	5-7

Preparation of Soil Conditioner

Water (2-litres) is poured in the reactor (5-litre capacity) and temperature raised to about 65 °C. PVOH (800g) is added gradually, while stirring continuously and maintaining the same temperature. This takes about one hour. The material is then allowed to cool, while maintaining agitation.

The product requires addition of minor quantities of the following:

1. Viscosity control agent, 0.5%
2. Anti-rusting additives, 0.1%
3. Mold preventing agent, 0.05%

Final product had 30% solid content and a pH of 6.5.

Soil Aggregation Characteristics of PVOH

Soil aggregation characteristics of PVOH and the distribution of water stable aggregates of varying sizes at different concentrations was studied. Results are given in Table 8. Data for mean weight diameter is given in Table 9.

TABLE 8. EFFECT OF PVOH (GH -17) ON AGGREGATION PROPERTIES / DISTRIBUTION OF WATER STABLE AGGREGATE SIZE AT VARIOUS CONCENTRATIONS

Proportion of Aggregates		2.38-4.76 mm	1.68-2.38 mm	0.84 -1.68 mm	0.42-0.84 mm	0.25-0.42 mm	Aggregation value
Dosage, % (dry weight bases)	Soil						
0.1	M-1	5.8	13.2	11.9	29.5	11.4	71.8
"	M 2	63.7	9.5	3.3	4.7	2.1	83.3
"	PCSIR	12.2	6.3	8.0	26.3	14.2	67.0
"	HUB	78.7	2.0	7.3	0.5	0.5	90.0
0.05	M-1	-	4.0	3.4	29.2	21.9	58.5
"	M-2	40.0	15.8	8.9	6.7	5.0	76.4
"	PCSIR	3.2	3.0	-	21.9	19.1	47.2
"	HUB	58.5	5.5	12.0	7.0	3.7	86.7
0.01	M-1	-	-	-	7.5	20.0	27.5
"	M-2	-	-	3.6	20.4	16.7	40.7
"	PCSIR	-	-	-	6.0	11.9	17.9
"	HUB	2.5	4.5	17.5	20.5	12.0	57.0

TABLE 9. EFFECT OF PVOH (GH - 17) ON MEAN WEIGHT DIAMETER

	Mean weight Diameter, mm		
Application	0.1 %	0.05%	.01 %
Soil M - 1	0.88	0.43	0.20
Soil M - 2	2.55	1.94	0.30
Soil PCSIR	0.92	0.32	0.19
Soil HUB	3.30	2.42	0.51

IX - EXPLORATORY FIELD EVALUATION OF SOIL CONDITIONERS

Performance of soil conditioners have been evaluated with the small quantity of the conditioners that could be produced in the laboratory. Findings of some of the experiments carried out are recorded below:

1. For germination studies, experiment was laid out in randomized complete block design with three replications. Experiments were conducted in earthen pots; each pot was filled with 8 kg soil. Concentrations studied were 0.1 and 0.05% of the conditioners by weight of soil. 100 seeds were planted; data is tabulated in Table 10.

TABLE 10. % GERMINATION OF CROPS

	0.1%			0.05%		
Crop	HPAN-1	PVOH	Control	HPAN-1	PVOH	Control
Tomato	93.0	91.3	91.6	90.3	89.3	88.7
Linseed	96.0	95.0	94.7	94.3	93.0	92.3
Okra	85.3	82.7	84.3			

These results do show that HPAN-1 is better than PVOH and there is an overall improvement in germination. Since germination under control is high, results are not particularly significant to demonstrate germination enhancement effect. Literature, however, shows that in soils where germination is around 40-45% under normal conditions, HPAN can increase it by 40-70%.

2. Second experiment was conducted at PCSIR Complex,Karachi, in randomized complete block design with 2 replications. The plot size was kept at 2.4 x 2.4 meter. Before incorporating the polymer, soil samples at a depth of 6" were taken to determine the physical characteristics of soil. Four crops, Raddish (Raphanus sativus L.) Turnip (Brassica rapa L.) Sugarbeet (Beta vulgaris) and wheat (Triticum aestivum Miller)were selected for the experiment.

Two methods of sowing were adopted ; in one, the polymer was added to the soil, seed bed was prepared and the seeds were planted in rows immediately followed by irrigation. In the other, normal sowing method was adopted i.e. the soil was thoroughly worked up, polymer was incorporated and a light irrigation was given. When the soil came into condition, it was pulverized, levelled and then seeds were sown. In the first method, where seedbed was irrigated immediately after sowing, the purpose was to create unfavourable condition for germination by forming a hard crust on top, so as to make it difficult for the plants to come out and determine the adverse effect on germination. Sowing was done in rows in the first week of December, 1989. Uniform distance between plants was maintained and 1100 ml of HPAN was added to each plot.Yields of crops obtained by the two methods are shown in Table 11.

TABLE 11. CROP YIELD & GERMINATION ENHANCEMENT DITH DIFFERENT TREATMENTS

Crop	Normal Sowing		Flooding
	Yield	Germination	Yield
Turnip	+ 37%	+7.5%	+ 23%
Sugar beet	0	+7.5%	- 4%
Wheat	+ 16%	+3.8%	- 4%

A GENERAL VIEW OF EXPLORATORY FIELD STUDY AT PCSIR LABS, KARACHI

TURNIP CULTIVATION (CONTROL)

TURNIP CULTIVATION (HPAN TREATED); 37% INCREASE IN YIELD

3. Third experiment was carried out at HUB, about 30 miles from Karachi. Onion and okra were selected as test crops. HPAN and PVOH were tested singly and in combination. Design was randomized complete block with three replications. Two methods used for incorporation of soil conditioners in the soil included: application of polymer at water source, while in the other, polymer was applied only in rows where the seed was planted. Plot size was 5′ x 5′ and basal dressings of N,P and K were given.

Only the okra crop progress could be pursued, since onion crop suffered due to lack of attention during disturbances in the city. Significant results are as follows:

a) Yield was higher when the conditoner was sprinkled in rows (20 - 30%) than when ′fed at water source (10-15%); this is perfectly understandable, because the former received higher dosage of the conditioner;

b) Crop yield was higher, by 25-30% with a dosage of 30kg/acre (dry basis) in case of HPAN and 20-25% with PVOH;

c) Highest yield of + 55% was obtained when a blend of equal parts of HPAN and PVOH was used @ 60kg/acre.

Even though planning of these experiments was by no means entirely satisfactory, yet the following broad significant conclusions can be drawn:

- Higher increase in the yield in case of certain crops like turnip and okra cannot be attributed to enhanced germination. This must be due to other beneficial effects of improvement in soil structure and the resulting improved environment;
- Enhancement effect in germination could not be demonstrated from the data, however, germination was noticeably faster and so was the growth of the plant making possible early harvesting by almost two weeks.

A more systematic work is planned for November 1990-February 1991 as shown below.Sufficient HPAN and other requirements are available for going through with this program even though the First phase ended September 1990.

A GENERAL VIEW OF EXPLORATORY FIELD STUDY AT HUB FARM (PRIVATE)

OKRA CULTIVATION (CONTROL)

OKRA CULTIVATION (HPAN/BAND TREATMENT)

OKRA CULTIVATION (HPAN ADDED AT SOURCE OF WATER)

OKRA CULTIVATION (HPAN+PVOH ADDED AT SOURCE); OVER 40% INCREASE OF YIELD

PROPOSED PLAN OF WORK FOR TESTING EFFICACY OF HPAN ON FOUR WINTER VEGETABLES DURING NOVEMBER - JANUARY 1990-1991 AT EXPERIMENTAL FIELD OF PCSIR LABORATORIES.

DESIGN	RANDOMIZED COMPLETE BLOCK
METHODS OF APPLICATION	TWO: 1. AT SOURCE 2. IN ROWS
REPLICATIONS	4
MATERIAL: HPAN-1	30 Kg/ACRE
SIZE OF PLOT	6' x 4'
PARAMETERS TO BE STUDIED	1. GERMINATION % AGE 2. GROWTH RATE 3. YIELD
SOWING TIME	IST. WEEK OF NOVEMBER 1990
HARVESTING	JANUARY 1991
TEST CROPS	1. TURNIP 2. RADDISH 3. SUGARBEET 4. CAULIFLOWER

RANDOMIZED COMPLETE BLOCK DESIGN

TURNIP

SOURCE	CONTROL	ROWS	SOURCE
ROWS	SOURCE	CONTROL	ROWS
CONTROL	ROWS	SOURCE	CONTROL

RADISH

SOURCE	CONTROL	ROWS	SOURCE
ROWS	SOURCE	CONTROL	ROWS
CONTROL	ROWS	SOURCE	CONTROL

SUGARBEET

SOURCE	CONTROL	ROWS	SOURCE
ROWS	SOURCE	CONTROL	ROWS
CONTROL	ROWS	SOURCE	CONTROL

CAULI FLOWER

SOURCE	CONTROL	ROWS	SOURCE
ROWS	SOURCE	CONTROL	ROWS
CONTROL	ROWS	SOURCE	CONTROL

X. PREFEASIBILITY STUDIES: MANUFACTURE OF SOIL CONDITIONERS

A. HYDROLYZED POLYACRYLONITRILE (HPAN) (BASED ON INDUSTRIAL BY-PRODUCT)

Soil conditioner is defined as, 'any synthetic organic chemical substance or chemically modified natural substance which is represented as having a primary function of forming and/or stabilizing soil aggregates to which it is applied and thereby improving the resistance of such soil to the slaking action of water, increasing its water and air permeability, improving the resistance of surface crusting, improving its ease of cultivation and/or otherwise favourably modifying its structural or physical properties'.

By the turn of the 1950s, it had been generally accepted that water-soluble polymers of high molecular weight had the potential of being effective soil conditioners. Polymeric soil conditioners introduced in the early 1950s were unsuccessful due to a number of factors, more important being the high cost and unsatisfactory application methods. Interest revived during the late 1960s, renewed emphasis being to achieve the desired results with much lower concentrations of the polymers and through surface treatment. Commercial products have made their appearance since the mid-80s and are being promoted for improved seedling emergence and healthier vegetable crops.

Work done on a variety of polymers and modified natural gums has been reviewed; however, polymers of practical interest appear to be confined to polyacrylamides, hydrolyzed polyacrylonitrile (HPAN) and polyvinyl alcohol though the primary competition is between the first two. Acrylamides have made commercial appearance, not because they are necessarily better, but they can be produced on the existing plants for polyacrylamides as an additional product. On the other hand, HPAN would require a new plant, which means that market for polymeric conditioners would have to grow substantially before a commercial unit can be set up.

PCRWR/USAID funded research project which has been pursued at the PCSIR Karachi Laboratories Complex since 1988 has resulted in the development of a few soil conditioners; of these the most important is the HPAN category based on by-product of polyacrylonitrile fibre industry. A 30-kg mini-pilot unit has also been set up for obtaining data for plant design and making the product available for evaluation purposes.

The objective of this pre-feasibility study is to estimate the economics of producing HPAN Soil Conditioner in commercial quantities. Since the existing market of the soil conditioner is nil and the information is desired primarily to identify potential profitable outlets/applications, the study is designed to be interim in nature, in which several assumptions and simplifications have been made in the interest of time. Effort has been to maintain an accuracy of ± 20%.

Plant Capacity

Economics have been estimated for two capacities - 1000 kg/day and 2000 kg/day in order to have some idea of the advantage of scale of production.

Process Plant

The entire plant can be fabricated in the country; Jacketted reaction vessel has been so designed that it can also be used for the preparation of the polyacrylonitrile from the imported

acrylonitrile. Capital equipment requirements are listed in Table12. Flow sheet is given at the end of this chapter.

TABLE 12. EQUIPMENT REQUIREMENTS

1. **JACKETTED AGITATED REACTION KETTLES:**	200 gallon capacity of type 304 stainless steel with double motion agitator, outer agitator scrapping the kettle wall; 2- piece cover with vapor outlet duct; 4" bottom outlet with quick opening valve. Carbon steel jacket rated at 90 psi, 2 HP agitator drive. Cost of One Unit: Rs. 4,50,000
2. **BOILER:**	900 SB & 150 psi steam pressure. Cost including gas fired equipment, connections and accessories: Rs.3,50,000.
3. **STORAGE TANKS:**	4 small - for chemicals involved in the reaction and 2 tanks of 500 gallon capacity for collecting finished product. Cost: Rs. 1,50,000.
4. **FILLING UNIT (MANUAL) :**	Rs.70,000
5. **TRANSFER PUMP :**	Rs. 40,000. 2 reaction kettles are proposed for 1200kg/ day capacity; for doubling production one 400 gallon reactor can be added at a subsequent stage.

Raw Material

Main ingredient of the product is the acrylic fibre, which contains 85% polyacrylonitrile. Acrylic fibres are the third largest volume synthetic fibres after polyesters and nylon. Their use is in knitted apparel (sweaters, sportswear, hosiery) and home furnishings (blankets, carpets) and make up 20% of the world production of synthetic fibres. World production is little over 2 million tons; 5% of this production results in waste/low-priced by-product. This has been found to be a very satisfactory raw material for HPAN Soil Conditioner.

Present consumption of polyacrylonitrile fibre in Pakistan is 10,000 tons, yielding over 500 tons of the by-product; survey carried out by the Project team showed that it was available @ Rs.14-16/kg. Huge quantities of the by-product should also be available on the World Market.

Polyacrylonitrile fabric rags can also be used for this industry; on the basis of interview with about a dozen hawkers, it was revealed that such rags could be collected for Rs. 10-12/kg.

Capital Expenditure

Total investment for a 1200 kg/day capacity unit is estimated at Rs.4.0 million and for a 2500 kg/ day unit at Rs.5.5 million. It has been proposed that debit/equity ratio will be 50:50. (Table 13).

TABLE13. CAPITAL EXPENDITURES

capacity: kg/day	1200	2500
1. Process equipment (local)	11 00 000	17 00 000
2. Erection of equipment, foundation, supports,piping etc. (30% of equipment cost)	3 30 000	5 10 000
3. Engineering/preproduction expenses.	1 70 000	2 60 000
4. Contingencies	1 60 000	2 50 000
BUILDINGS:		
5. Factory/administration 4500 sq. ft.	9 00 000	10 00 000
6. Store godowns, 2500 sq.ft.	3 80 000	4 50 000
TOTAL FIXED CAPITAL		
Sum of items 1 to 6)	30 40 000	41 70 000
WORKING CAPITAL	9 60 000	13 30 000
TOTAL INVESTMENT	40 00 000	55 00 000
FINANCIAL STRUCTURE:		
Equity Investment	20 00 000	27 50 000
loan	20 00 000	27 50 000
	40 00 000	55 00 000
Debit/Equity Ratio: 50:50		

MANUFACTURING COST

Cost of manufacturing and selling HPAN Soil Conditioner on 1000 kg/day scale works out to Rs. 12.76/kg and on the larger unit to Rs. 10.95/kg. (Table 14).

TABLE 14. COST SHEET

PRODUCTION: 300,000 / 600,000 KG PER YEAR; 300 DAYS ANNUAL OPERATION

Capacity	1000 kg/day		2000 kg/day	
	Cost/day	Cost/kg	Cost/day	Cost/kg
I- FACTORY MANUFACTURING COST:				
A - Direct Production Costs:				
1. Raw Materials:				
Fibre waste, 320 kg per 1000 kg @ Rs.15/kg	4800		9600	
Chemicals	400		800	
TOTAL RAW MATERIALS	5200	5.20	10400	5.20
2. Packaging Materials	1500	1.50	3000	1.50
3. Direct Labour	650	0.65	800	0.40
4. Indirect Labour	1200	1.20	1400	0.70

Continued

Continue from pre page

5. Maintenance/repairs	150	0.15	200	0.10
6. Utilities	400	0.40	500	0.25
DIRECT PRODUCTION COST	9100	9.10	16300	8.15
B - Fixed Charges:				
Insurance	100		130	
Depreciation	750		1000	
Interest on loan	666		917	
Total Fixed Charges.	1516	1.52	2047	1.02
TOTAL FACTORY MANUFACT-URING COST	10616	10.62	18347	9.17
II - GENERAL EXPENSES				
Administrative cost	657	0.66	1129	0.56
Interest on working capital	330	0.33	430	0.22
TOTAL GENERAL EXPENSES	987	0.99	1559	0.78
III - COST OF PRODUCTION	11603	11.60	19906	9.95
IV - SELLING COST 10%	1160	1.16	1991	1.00
V - COST TO MAKE & SELL	12763	12.76	21897	10.95

PROFITABILITY

This has been worked out for three prices: Rs. 14/-, Rs. 15/- and Rs. 16/- per kg. Profitability is good. Selling price could be fixed between Rs. 15 & 16/kg.

TABLE 15. OPERATION ANALYSIS

Annual Production (Kg)	300,000			600,000		
Selling Price Rs.	14	15	16	14	15	16
Sales returns (x1000) Rs.	4200	4500	4800	8400	9000	9600
Peoduction Cost (x1000) Rs.	3828	3828	3828	6570	6570	6570
Cross Annual Profit (x1000) Rs.	372	672	972	1830	2430	3030
Earning on total invesment %	9.3	16.8	24.3	33	33.1	55.1
Earning on Equity %	18.6	33.6	48.6	66	88.2	110.2

TABLE 16. SUMMARY

Yearly Production,Kg	3,00,000	6,00,000
24 hours daily production,Kg	1,000	2,000
Fixed Capital Rs	30,40,000	41,70,000
Working Capital Rs	9,60,000	13,30,000
TOTAL CAPITAL Rs	40,00,000	55,00,000
Equity Investment Rs	20,00,000	27,50,000
Factory cost Per day	10,616	18,347
Per Kg	10.62	9.17

Continued

Continue from pre page

Cost to make Per Day	11,603	19,906
Per Kg	11.60	9.95
Cost to make & sell Per day	12,763	21,897
Per Kg	12.76	10.95
Earning on Equity Investment %		
- Sales price Rs. 14/kg	18.6	66
- Sales price Rs. 15/kg	33.6	88.2
- Sales price Rs. 16/kg	48.6	110.2
Earning on Total Capital, %		
- Selling price Rs. 14/kg	9.3	33
- Selling price Rs. 15/kg	16.8	44.1
- Selling price Rs. 16/kg	24.3	55.1

B - MANUFACTURE OF POLYACRYLAMIDE (PAM), HPAN & PVOH (BASED ON IMPORTED MONOMERS)

Plant Capacity

Manufacture of PAM and PVOH soil conditioners can be undertaken on a small to medium scale with a locally designed and fabricated machinery. Plant cost for PAM would be about the same as HPAN (based on indigenous by-product) and PVOH would cost about 10-15% less. Working capital would be higher on account of higher prices. Actually both of these conditioners could be made on the plant discussed for HPAN in the previous chapter.

Manufacture of HPAN based on imported acrylonitrile monomer would require higher capital costs, and part of the equipment will need to be imported for converting polymer of polyacrylonitrile into a form suitable for the hydrolysis step. Capital costs would be 50-60% higher and a larger unit would probably offer improved economics. There are no other known applications of HPAN and setting up a unit should be considered, when sufficient demand has been generated.

95% of the raw materials needed for the manufacture of these conditioners would need to be imported. Acrylamide monomer needed for PAM is available @ $ 1.20/kg; landed cost, assuming no customs duty works out around Rs. 34/kg.

PVOH polymer costs around $ 2.50/kg; custom duty on this item is Rs. 30/kg. and landed cost works out @ Rs. 100/kg.

Acrylonitrile monomer costs around $ 0.80/kg; landed cost works out to be around Rs. 24/kg.

Comparative analysis of the costs of manufacture of these conditioners on the basis of 1000 kg/day production has been carried out and the results are presented in Tables 17 to 18.

TABLE 17. CAPITAL EXPENDITURE: (Rs.X1000)

CAPACITY: 1000 KG/DAY	PAN	PVOH	HPAN
1. Plant Cost	1600	1200	3000
2. Building	1300	1300	1600
3. Total Fixed Capital (1 + 2)	2900	2500	4600

Continued

Continue from pre page

4. Working Capital	1600	2000	2000
5. Total Investment (3 + 4)	4500	4500	6600
6. FINANCIAL STRUCTURE:			
Equity	2250	2250	3300
Loan	2250	2250	3300

TABLE 18. COST SHEET : PRODUCT 300,000 KG/YEAR

1- FACTORY MANUFACTURING COST			
A- Direct Production Costs: Daily basis			
Raw Materials 320 kg	10880	32000	7680
Packaging materials	1500	1500	1500
Direct Labour	700	600	1100
Indirect Labour	1200	1200	1500
Maintenance/Repairs	150	150	350
Utilities	400	300	900
DIRECT PRODUCTION COST	14830	35750	13030
B- FIXED CHARGES:			
Insurance	100	100	160
Depreciation	720	540	1380
Interest on Loan	750	750	1100
FACTORY MANUFACTURING COST	16400	37140	15670
II- GENERAL EXPENSES			
Administrative	700	700	800
Interest on working capital	530	650	650
TOTAL GENERAL EXPENSES:	1230	1100	1450
III- COST OF PRODUCTION (I + II)	17630	38300	17120
IV- Selling Cost	1160	1160	1160
V - Cost to Make and Sell	18790	39460	18280
" " " /kg	18.79	39.46	18.28

TABLE 19. OPERATIONAL ANALYSIS

Annual Production		300, 000 kg.	(Rs.)
	PAM	PVOH	HPAN
Selling price kg	22/-	43	22/-
Sales Return x 1000	6600	12900	6600
Product cost x 1000	5637	11838	5484
Gross Annual Profit x 1000	963	1062	1116
Earning on Equality, %	42.8	47.2	33.8%
Annual Foreign Exchange Requirement $	1,20,000	2,25,000	80,000

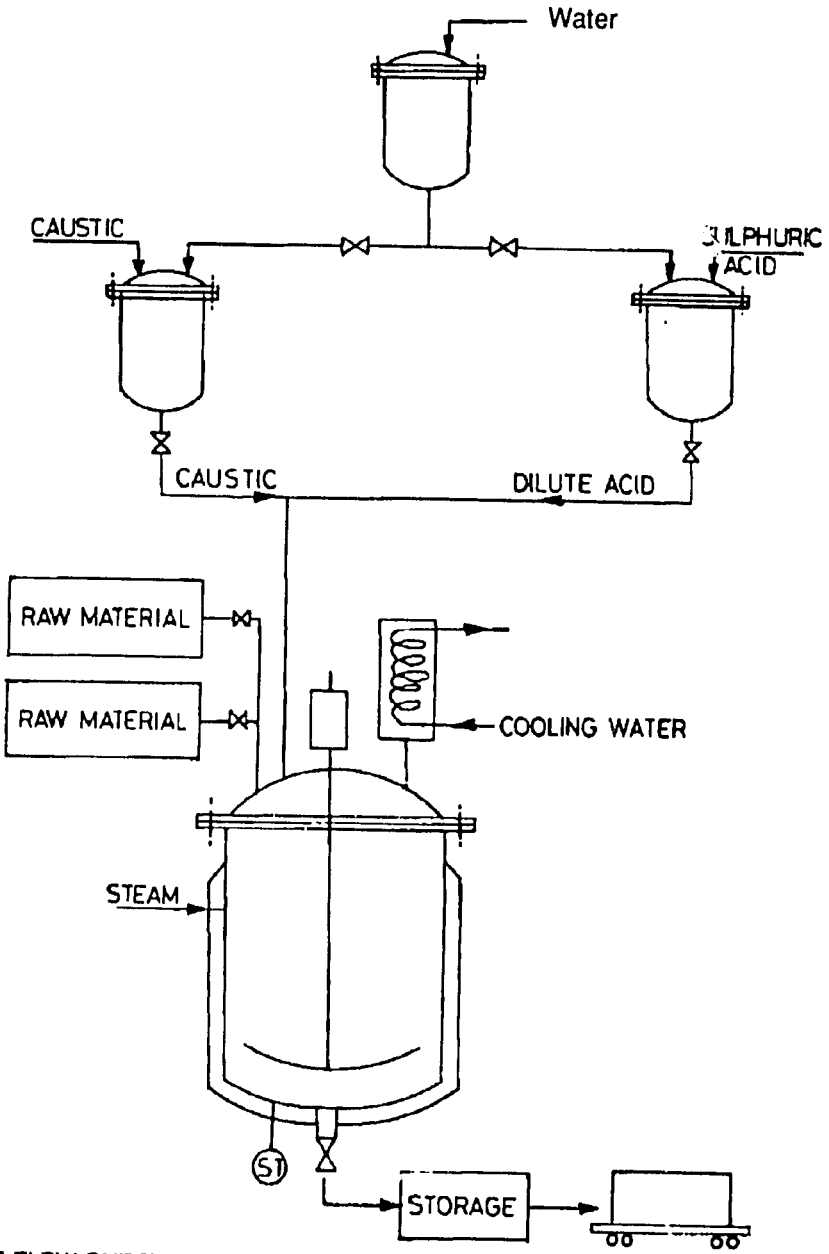


Fig 7.FLOW SHEET FOR THE PRODUCTION OF HYDROLYSED POLYACRYLONITRILE(HPAN)

Concluding Remarks

HPAN based on industrial by-product is the most promising product and can be sold at a price (Rs.15.0 per kg) which could make its application economical in a number of situations. Its indigenous manufacture will not involve any foreign exchange ependiture.

The second promising soil conditioner is PAM, selling price of which works out at Rs.22/kg. This could increase to Rs.30/kg if custom duty has to be paid on the imported raw material.Manufacture of HPAN based on imported PAN monomer is possible at the same price as PAM, but there are technical problems still needed to be solved.

HPAN and PAM are interchangeable in 90% of the applications. PVOH is expensive (Rs. 43 kg) and can only be considered for very specialised purposes.

XI - SCOPE OF APPLICATION OF SOIL CONDITIONERS IN PAKISTAN

Broad functions of polymeric soil conditioners are:

- Stabilization of soil aggregates and seed-bed condition or prevention of crusting until seeds are germinated and sprouted.
- Increase of pore space in soil, soil permeability, water infiltration and drainage.
- Improvement in working property of the soil; soil dries faster after rain or irrigation facilitating its working.
- Decreased water run-off.
- Improved percolation of soil and removal of encrusted salt from the surface.

In view of the functions elucidated, there is a wide and varied scope of application of polymeric products in agriculture. Commercial usage is still in its infancy because of higher cost of these products and lack of sufficient proven application data.Extensive field studies are currently in progress and it is expected that the consumption of these polymers will become significant by the turn of the century.

Soil conditioners based on the by-product of the indigenous industry developed during the investigations of the Phase-I of this Project offer a new and promising line of products. Based on current costs (selling price works out to Rs. 15/kg) their application in Pakistan is examined. This exercise is aimed at identifying areas, where intensive application studies are warranted.

A - Enhancing Agricultural Productivity

Vegetables

Anionic Polymers are currently used for stabiiizing seed-bed condition or preventing crusting until seeds are germinated and sprouted. These conditioners have been found to be most effective for vegetable crops, especially onion, lettuce, brassica and sugar beets. This is mainly attributed to faster and better germination and emergence of seedlings. Highest yields have been reported under situations where plant emergence was the limiting factor.

Another important observation is that the root system of crops are more extensive following application of the conditioner and hence greater benefit is to be expected for root crops. In addition, many cases of increase in crop productivity have been reported. This is attributed to the fact that improved structure of the soil enables increased utilization of plant nutrients and provides optimum growing conditions leading to healthier, more uniform crops, increased yields and earlier harvesting.

Soil conditioner has to be applied to a well prepared seed-bed as soon as possible after drilling. Where possible, product may be applied by conventional sprayers over the drill lines. This is more economical in terms of product usage and in addition capping between the drill lines may result in reduced weed emergence.

Where only good emergence of seeds is desired, quantity of the soil conditioners required may vary from 5 to 15 kg/ha (dry basis); in other cases where greater range of benefits is desirable, this can vary from 20 to 60 kg/ha (dry basis). The effect of soil conditioners persists for 2-4 years.

An attempt has been made to make an assessment of additional financial gains which the growers could get with the application of soil conditioners; assumptions made for undertaking this exercise include:-

1. Literature reports increase of seed emergence upto the levels of 58% and increase in yields of upto 70% (Carrots); it is assumed that average increase would be 25%.
2. Quantity of soil conditioner to be used at the maximum level; this means 200 kg of Polymer (30% solids) per hectare at price of Rs. 15/kg, which has been worked out for indigenous HPAN.

Costs of production of selected vegetables have been worked out with the co-operation of a few plant agronomists associated with some of the leading multinational companies in the field of fertilisers and the data is given in Table 20.

TABLE 20. CURRENT ECONOMICS OF GROWING VEGETABLES

	Okra	Turnip	Cauliflower	Beets	Potato	Garlic	Onion
1. Cost/ha.							
Land preparation	2400	2400	2400	2400	2400	2400	2400
Seeds	300	1200	2500	1200	9000	3700	2400
Manure + Fertilizer	2500	2500	2500	2500	10000	2500	2500
Pesticides	2500	1200	2500	1200	2500	1200	1200
Interculture	7000	1200	2500	1200	7000	2500	1200
Irrigation	1200	-	2400	-	2400	-	-
Miscellaneous	1200	1000	2500	1000	2500	2500	1200
Total Cost	17100	9500	17300	9500	35800	14800	10900
2. Yield (kg)	7000	15000	12000	10000	18000	7000	12000
Gross Sale Proceeds	28000	22500	36000	20000	54000	38500	18000
4. Net Income	10900	13000	18700	11500	18200	23700	6000

Additional income to be obtained due to increased productivity by application of soil conditioner is given in Table 21. Also worked out is the minimum increase in productivity needed for each crop to attain break-even point i.e. when the revenue from enhanced production equals cost of soil conditioner.

TABLE 21. LIKELY FINANCIAL BENEFIT FROM USING SOIL CONDITIONER

	Okra	Turnip	Cauliflower	Beets	Potato	Garlic	Onion
Current Cost	17100	9500	17300	9500	35800	14800	10900
Soil Conditioner	3000	3000	3000	3000	3000	3000	3000
Total Cost:	20100	12500	20300	12500	38800	17800	13900
Expected yield	8750	18500	15000	12500	22500	7850	15000
Expected Sale Proceeds	35000	28075	45000	25000	67500	48125	22500
Net Income	14900	15575	24700	12500	28700	30325	8600
Increase in Current income	4000	2575	6000	1000	10500	6625	2600
Productivity Increase needed for break-even point, %	10.7	13.3	8.3	16.5	5.0	7.3	18.0

B - Cash Crops

Two of the cash crops, namely sugarcane and cotton, which are important for country's economy are examined.

Sugarcane: Total area under cultivation is about 800,000 hectares; average yield is 37-38 tons/ha; progressive growers have been able to increase the yield to 50 tons and innovative growers upto 80 tons (PARC Survey).

Sugarcane's root system is the secret of optimum cane growth. The individual roots, with its thousands of root hairs need an environment conducive to normal activities and growth. Good germination is necessary for a satisfactory stand. Optimum germination and early shoot vigour result when both internal and external factors are optimal. These requirements of the crop which have been identified for improved productivity show that HPAN may be able to make a useful contribution.

Production costs/acre of a progressive farmer has been worked out to Rs. 4650 (Seed- 900; Fertilizer - 750; Labour, 30 mandays - 600; Tractor - 700; Earthing up - 100; Transport - 600; Harvesting - 600; Miscellaneous - 400 = 4650). This works out to Rs. 11,450 per hectare.

Average yield: 40 tons/hectare, gross receipt amounts to Rs. 16,000/- giving a net income of Rs. 4,500/. Being a low priced crop, using 200 kg HPAN, break-even point works out at 20%; even at 25% increase in productivity, additional income to the grower would be Rs.1000/-. This means we would need to get greater productivity for lesser quantity of HPAN to provide better incentive to the grower. In any case, this can make a significant contribution to the overall production of sugarcane in the country.

Cotton:

1. Cotton is the most important commerciai crop of Pakistan and its yield per unit area is, therefore, of great concern to the Government and the people of the country.
2. Despite all efforts made in the past, cotton production displayed an erratic trend for more than 15 years upto 1987, (Table 22).
3. Progressive steps taken in recent years by the Federal and Provincial Governments coupled with efforts of growers, Pakistan Central Cotton Committee and all other public and private agencies engaged in cotton production have resulted in improved production since 1983.
4. Improvement has resulted from timely supply of necessary inputs, better cotton varieties, improved agronomic practices, greater emphasis on integrated pest management, pest survey and forecasting, massive education and training programme for the farmers, and price incentives.
5. For cotton to grow well, the quality of soil is very important. It should be deep, porous and well-aerated with good water-holding capacity. The subsoil should permit adequate extension to the roots. Anionic PAM has been tested on furrow irrigated cotton by adding the product to the water; good results are reported with 32 kg/ha (dry basis). This means 100 kg of indigenous HPAN could be productive. Present productivity of 530 kg/ha could possibly be increased to around 650 kg.

Table 22. Area, Annual Production & Yield of Cotton

Year	Area X 1000 ha	Production X 1000 bales.	Yield Kg/ha
1970-71	1733	3050	314
1972-73	2010	3947	350
1974-75	2031	3567	314
1977-78	1843	3233	312
1980-81	2108	4201	339
1981-82	2215	4398	338
1983-84	2218	2955	225
1985-86	2262	6800	511
1986-87	–	–	531

C - Reduction in Losses of Irrigation Water From Runoff and Excessive Evaporation

Pakistan has limited water resources and hence the need for conservation is vital for the economy of the country. Many irrigated soils in the country have a characteristic low hydraulic conductivity, which results in substantial economic consequences, such as water loss from runoff of tail water, increase in irrigaion time causing ponding in parts of the field followed by erosion, increase of diseases and physiological problems in crcps and adds to the production costs.

Studies reported during the 1980s indicate that polymer applied in solution in small amounts to soil surfaces in controlled amounts should make it possible to enhance soil permeability to that level where it will result in irrigation or rainfall penetration to avoid runoff and to achieve needed percolation. Additional advantage is that the evaporation from soil can be decreased by upto 60% with 0.1% polymer applied to the upper soil layer. A new precision in water use is theoretically possible, and associated benefits in addition to water saving are (1) possibility of greater crop productivity, (2) less erosion and (3) prevention of soil crusting.

What are the levels of soil conditioners that would be needed for soil improvement? This will depend on the effects desired to be introduced. It has been suggested that the concentrations of the polymer in the irrigation water for various purposes should be as follows:

- 0.0005-0.001% with any and all irrigation to follow up effects achieved below or to enhance water penetration if there were no previous treatments.
- 0.002-0.005% with 5-10 cm of irrigation to increase water penetration and to leach salts.
- 0.002-0.01% with 0.5-2.5 cm of irrigation to enhance water penetration, prevent crusting and decrease erosion.
- 0.005-0.1% with 2-5 cm of irrigation for massive soil improvement.

How these concentrations relate to quantity of the polymer used is shown in Table 23.

TABLE 23. RATIONAL PROGRAM OF SUPPLYING SOIL CONDITIONER IN IRRIGATION WATERS.

Polymer in Irrigation Water %	IRRIGATION, cm				
	0.5	1.3	2.5	5.0	10
	Polymers / ha (full coverage)				
0.0005	0.33	0.66	1.25	2.5	5.0
0.001	0.7	1.3	2.50	5.0	10.0
0.002	1.3	2.6	5.0	10.0	20.0
0.01	7	13	25	59	100
0.05	5	65	125	250	500
0.1	70	130	250	500	1000

Application rates can vary from a minimum of 10 kg to 500 kg/ha. (dry basis). Translated in terms of finance, cost can range from Rs.500 to 22000. It is certainly worth investigating areas of application where soil conditioners can be applied economically.

D - Reclamation of Saline & Sodic Clay Soils

Soil salinity/sodicity is a serious problem of irrigated agriculture causing low crop production. Out of the 14 million ha. of irrigated land, about 40% is salt affected. 80% of the salt affected soils of the Punjab and 60% of Pakistan are saline-sodic in nature. Technologies available for reclaiming of the salt affected soils include physical methods, agronomic measures and chemical treatment.

Gypsum is by far the most commonly used amendment for sodic soil reclamation. It dissolves to provide, firstly, a level of electrolyte in the soil solution, which maintains sufficient permeability to allow water entry into and through the soil profile, and at the same time, provides calcium for exchange with sodium. The increased leaching of soluble salts, resulting from the extra profile drainage after gypsum application has been well documented.

Amount of gypsum required can vary from 2.5 upto 15 tons/ha depending on the condition and nature of the soil. Its success depends on availability of ample quantities of good quality water followed by effective and well developed drainage system. The sufficient watering ensures leaching of salts and solubilisation of applied gypsum for exchange and replacement reaction. Upto one acre feet of water is needed for one ton of gypsum applied. Since the infiltration rate and hydraulic conductivity of sodic soils are often very low, it involves considerable time requirement for reclamation.

Reduction of water and the time factor are two areas, which have received considerable attention. Addition of organic matter in the form of green manuring or farmyard manure has been suggested for enhancing soil permeability. Soils and Water Use Laboratory, Dokki in Egypt has evaluated on laboratory scale importance of using PAM in combination with gypsum. Greater efficiency with decreased consumption of gypsum is certainly possible but the method needs to be evaluated in the fields.

Current results with gypsum has by no means been a success story. While 40% growers have been satisfied, others have found it uneconomic or even a total failure in about 25% of the cases.

There are three options for introducing polymeric soil conditioner, (1) spray soil conditioner before application of gypsum, (2) introduce it in water which is used for flooding after gypsum application, and (3) premix it with gypsum and produce a dry product. This is an area worth exploring, with conditioner applications in the range of 20-50 kg/ha (dry basis) costing between Rs.1000 and Rs. 2,500.

E - Moisture Conservation in Barani Areas

Rainfed (barani) lands constitute 24% of the cultivated area, but yield only 10% of Pakistan's agricultural production. Increasing productivity in these areas is being tackled by a number of organisations in the field of agriculture. Amongst the several factors which are responsible for low productivity, lack of moisture conservation is an important factor in which application of soil conditioners could posssibly have a role to play. Methods currently in use for moisture conservation include:

- Fallowing land.
- Planting in a ridge and furrow configuration.
- Intercropping, which consists of alternating crops from row to row.

Wheat is the most important crop grown in barani areas followed by rape, mustard and groundnut.

About one-third of the wheat crop is grown under rainfed conditions every year, but the yield is extremely low. Most important limiting factor for wheat production in these areas is he availability of moisture in the soil at the seeding time. So technology is needed to conserve moisture in the soil when rains are received

In most of the areas, rains are received during monsoon season and sowing period usually remains dry. Therefore the farmer has to depend on monsoon rains for wheat planting. From germination onward, all the growth stages need sufficient soil moisture for a good crop.

Most of the rain water goes waste by surface runoff due to unlevelled fields with low absorption capacity of the soil. If the rainwater can be conserved in the soil so that sufficient water is available not only for wheat germination but also for the growth of the crop. Moisture conservation should start with the onset of monsoon.

Crop residues, manure applications, or mulches are used to improve the rate at which water will enter the soil in bare fields; and in new plantings when young plants provide little cover. These surface treatments also reduce evaporation from the soil surface. These very functions can be performed by polymers and their effectiveness needs to be evaluated under field conditions. Economics of wheat production has been worked out in Table 24.

TABLE 24. ECONOMICS OF WHEAT PRODUCTION PER HECTARE

MATERIAL COSTS	Seeds, 100 kg	240
	Fertilizers	750
	Pesticides	500
	Water	125
LABOR COST	Ploughing & sowing	700
	Interculture	250
	Fertilizer, Pest-icide application	250
	Harvesting in Kind	500
	TOTAL COST	3315
Wheat yield, 2500 kg		
Gross receipts		6000
Net Income		2685
Soil conditioner, 100 kg		1500
	TOTAL COST	4815
Income receipt from 3110 kg		7464
Net Income		2649

Desired results will have to be obtained by lesser consumption of the conditioner.

F - Field Drainage

Excess water can be drained away from land either in open surface ditches or through tile underdrains. Each method has its advantages and disadvantages, but the tile drainage is a more permanent and effective method.

Tile drainage involves digging a trench and laying short lengths of clay pipe end to end and then filling the trench. Unstable sandy soils and clay soils can cause problems; on sand, the pipes

silt and on clay they can become blocked. Standard solution is to backfill the trench above the newly laid pipeline with gravel. Transportation could be expensive and, therefore, soil stabilisation which can ensure maintenance of high permeability after its return to the trench offers a feasible alternative. Anionic polymers are successfully being used for this purpose.

Efficiency of HPAN-1 will have to be tested under field conditions. Concentrations of polymer to be applied can be worked out in the laboratory for the specific soil. Method of application will also need to be standardized.

Use of polymer is most likely to be effective for newly established drainage systems.

XII IDENTIFICATION OF ORGANIZATIONS FOR COLLABORTION DURING PHASE II

During the Phase II of this Project, a pilot facility is planned to be set up at PCSIR Karachi Complex so that larger quantities of Polymer soil conditioners can be produced for field testing. This would have a capacity of 300 litres, which can make 200 litres of the finished product.

Enhancing agricultural production of vegetables and cash crops will be accorded top priority, because of its importance and greater chances of success stories. Other areas which are going to be explored have been identified in the previous chapter.
Organisations/individuals identified for the program are listed below:

Enhancing Agricultural Productivity

AGRICULTURAL RESEARCH INSTITUTE, Peshawer, with research stations at D.I. Khan and Mardan (Sugarcane and sugar beets)

AGRICULTURE RESEARCH INSTITUTE, Quetta. 96 acres of land available for experimental purposes.

PUNJAB AGRICULTURAL RESEARCH INSTITUTE, Faisalabad, has 10 research institutes and over 40 research substations. Collaboration will be sought with vegetable and Sugarcane research institutes.

UNIVERSITY OF AGRICULTURE, Faisalabad. Collaboration with Faculty of Agriculture and Directorate of Research.

RATTANABAD SOCIAL AND AGRICULTURAL EXTENSION CENTRE, Tharparkar. Collaboration between PCSIR and this organisation already exists.

PRIVATE FARMERS identified so far: Mushtaq Ahmad of Umair Farms at HUB and Super Highway; Khamisoo Khan, Union Committee Deh Dozan, Ali Gabol Goth, university Raod; Baluch, Malir Farms. Many more can be attracted when sufficient quantities of soil conditioner can be produced.

PAKISTAN CENTRAL COTTON COMMITTEE, Karachi. 700 acres for experimental purposes at two of their research stations at Multan & Sakrand.

SIND SUGAR RESEARCH INSTITUTE; for sugarcane cultivation.

For Other Programs

DRAINAGE AND RECLAMATION RESEARCH INSTITUTE, Hyderabad. Collaboration in application to salinity control, land reclamation and drainage.

DIRECTORATE OF LAND RECLAMATION, Lahore, has 9 experimental stations in districts of Gujranwalla, Faisalabad, Mianwali, Jhang and Muzafargarh.

DIRECTORATE OF SOIL CONSERVATION, Rawalpindi; collaboration in erosion reduction aspects and enhancing agricultural productivity in rainfed areas.

WATER AND POWER DEVELOPMENT AUTHORITY (WAPDA), Lahore.

NATIONAL AGRICULTURAL RESEARCH CENTRE, Islamabad, provides land facilities for crop under rainfed conditions.

APPENDIX

Bio-Data of Professional Manpower Associated With The Project

1. Mr. M. ASLAM, Principal Investigator. Chairman (Retired) PCSIR and currently Technology & Industrial Consultant.

   Academic Record: M. Sc. (Bombay University, 1946), B.E. Chemical (S.CALIF. 1951), Dipl. Plastic Technology (West Coast, 1951), FRIC (London, 1965), FPAS (1973), Fellow of Pakistan Inst. Chem. Engrs., (1969) Member (Prof.) Institute of Food Technology, Chicago (1987). Gold Medal for Technology from Pakistan Academy of Sciences (1973). TQA from Government of Pakistan (1969).

2. Dr. S.S.H. RIZVI, Co-Principal Investigator. Director General, PCSIR Karachi Laboratories Complex.

   Academic Record: M.Sc. (Dacca University, 1953), Ph.D. (Manchester, 1962).

3. Dr. ASHHAD MEHDI, Co-Principal Investigator. Head of the Plastics & Polymer Research Centre.

   Academic Record: M.Sc. (Aligarh, 1951), Ph.D.(London, 1964). Gold Medal for Technology from Pakistan Academy of Sciences (1987).

4. Mr. SALIM AKHTAR, PSO, Plastics & Polymers Research Centre, PCSIR Karachi Laboratories Complex.

   Academic Record: M.Sc. (Karachi, 1966), Post Graduate Diploma from Tech. Univ. Trondheim (Norway), 1976.

5. Mr. SHAKEEL AHMAD, employed full-time for the project. Academic Record: M.Sc. (Karachi Unversity 1987).

6. Mr. DABIR AHMAD, PSO, Applied Physics Computer and Instrumentation Centre, PCSIR Karachi Laboratories Complex. Academic Record: M.Sc. (Karachi University, 1961), Post- Graduate Diploma Uppsala (Swden 1971).

7) Mr.AHMAD SAGHIR, SSO, Applied Physics Computer and Instrumentation Centre PCSIR Karachi Laboratories Complex. Academic Record: M.Sc. (Karachi University, 1968).

8. Dr. S. SHAHID HUSSAIN, Advisor for field studies, Chief Scientific Officer, General Services Division, PCSIR Karachi Laboratories Complex.

   Academic Record: M.Sc. (Aligarh, 1955), Ph.D., Botany (W.Ontario, 1963).

9. Mr. NASIR RAZA KHAN, SSO, PCSIR Karachi Laboratories Complex.

   Academic Record: M.Sc. AGRIC (Tandojam, 1965).

10. Dr. A.H.K. YOUSUFZAI, Advisor for Ph.D. Program. Academic Record: M.Sc. (Sindh, 1960), Ph.D. (Glasgow 1965).

Publications And Reports

1. M.Aslam, 'Polymers as soil conditioners and sealing agents' Part-1: State-of-Art-Study and their potential applications in Pakistan. Pakistan Academy of Sciences, Islamabad. Monograph, 66 pp. (1990).
2. Rizvi, S.S.H., Dabir Ahmad & Ahmad Saghir, 'Methodology for laboratory evaluation of synthetic soil conditioners - a review'. Project Report, (March 1989).
3. M. Aslam, S. Ashhad Mehdi and Salim Akhtar, 'Research and Technology development plan for polymers suitable for soil conditioning and sealing'. Project Report, (March 1989).