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WORLD ENVIRONMENT CENTER

ENVIRONMENTAL ASSESSMENT

OF

LEVE TANNERY

GABROVO, BULGARIA

SEPTEMBER 25 TO OCTOBER 2, 1993

By: Dr. Thomas C. Thorstensen

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File

DISCLAIMER

The opinions expressed herein are the professional opinions of the author and do not represent the official position of the Government of the United States or the World Environment Center.

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I. EXECUTIVE SUMMARY

This report is the result of a one week trip to the tannery in Gabrovo, Bulgaria. The coordination of the visit was done by Dr. Christian Spassov. Dr. Spassov arranged for the accommodations and the translator support needed for the project. The technical and management personnel of the tannery and the local officials were cooperative and it is believed that the observations and conclusions in this report are as accurate as was possible in the limited time assigned to this project.

The tannery LEVE is a large consolidated company consisting of five "workshops." These include:

1. A large chrome leather tannery
2. A vegetable leather tannery
3. A leather lubricants factory
4. An animal glue factory
5. A leather goods manufacturing factory.

Of these workshops the large chrome leather tannery was investigated in detail. The vegetable leather tannery was under limited production for chrome leather and no vegetable leather was being produced. The leather lubricants factory, the animal glue factory and the leather goods factories are non-polluting.

The tannery has a production capacity of 70 metric tons of hides per day. The water used in production in this factory is 45 l per Kg of hides processed. The tannery can process either cattle hides or pigskins. The tannery was modernized in 1983-1985. The equipment installed at that time was "state-of-the-art" and is in excellent producing condition. Present production is limited by the availability of hides and general economic conditions.

In order to evaluate the pollution load and the best practical treatment system for this tannery, the data of the EPA 440/1-79/016, surveying the United States leather industries was used. The tannery management agreed with this approach and found the data to be in agreement with their experience. The available data on this tannery was from grab samples. The tannery operated on a batch basis in most of its polluting processes so grab samples are inconclusive.

Tannery wastes are high in suspended solids and biochemical oxygen demand, animal fats and process chemicals. The process chemicals include sulfides, calcium hydroxide, acids, salt, chromium and specialty chemicals. In consideration of the high BOD and the limited land area available the secondary treatment of these wastes at the tannery is impractical and not cost effective. The tannery is now building the needed holding tank and pumping system to discharge pre-retreated wastes into the municipal treatment system.

The municipal treatment system is large and has ample capacity to take the proposed industrial

wastes. The pre-treatment requirements are, for the most part, reasonable. There is provision for the payment of a surcharge, by an industrial discharger for excess discharging. In the case of the tannery pretreatment for the removal of sulfides and chromium, along with primary treatment, should result in a waste water discharge to the municipal system that will not cause problems of incompatibility or overload.

The present tannery treatment system is in poor condition due to corrosion of some pipes and general deterioration from use. When in good condition and run on a well balanced operating plan, the environmental impact of the tannery on the community should be minimal.

At present both the sulfide and chromium are being precipitated and can be removed in the primary treatment in the sludge. This is a satisfactory solution. The chromium is non-toxic trivalent chromium and is acceptable for land application. The sulfides are also in an insoluble form. The pretreatment of tannery wastes by primary settling is very effective due to the co-precipitation of the wastes by interaction. Proper timing of the mixing is important. The alkaline wastes (high in BOD and SS) should be accumulated and treated for sulfide by oxidation or precipitation. The acid wastes are variable in concentration and flow. Automatic balancing of the flows through pH control is recommended.

The treatment of the sulfide by air oxidation is well established in the industry. This system could be used in this tannery very effectively with present equipment.

The chrome tanning process fixes about 70% of the chromium introduced. There are simple and effective methods of recovering the spent solutions and reusing the chromium. This system could be employed in this tannery but will require some modification of the floor drains, some pumping and storage tanks. The savings in materials make this an attractive method of decreasing the chromium discharge.

The regulations presently in force for the discharge of industrial waste into the municipal treatment system call for a limit on the concentration of chlorides. The tanning of leather involves the use of salt cured hides and also some salt in the chrome tanning process. This salt is standard industry practice and cannot be avoided by the tannery. The salt discharged has no deleterious effect on the municipal treatment system. It is impossible for the tannery to meet this regulation and there is, in my opinion, no technical reason for its need. It is strongly recommended that the regulation be eliminated from the requirements as applied to the tannery.

There was a meeting in Gabrovo with the mayor and other concerned officials. This included enforcement officials from both the local and regional environmental offices. At this meeting the results of this investigation and those of Mr. Hanson on the textile industries of Gabrovo were heard. The meeting was attended by about twenty persons from the regulatory agencies and the concerned industries along with the city officials. The technical reports were well received by all parties and a spirit of cooperation for the solving of the environmental issues was stated by all concerned.

II. INTRODUCTION

This report covers the visit of Dr. Thomas C. Thorstensen to Gabrovo, Bulgaria under the sponsorship of WEC/AID. The visit was to inspect and evaluate the pollution controls for the tannery Leve in Gabrovo. The visit was of one week duration September 25, 1993 to October 2, 1993. Dr. Thorstensen is the president of TSG Inc. a professional technical consulting firm.

III. WASTE MINIMIZATION TECHNIQUES

The waste minimization techniques used in the leather industry are based on the conservation of water, and the recycling of the chromium chemicals. The waste load generated by the industry is primarily from the hides and some of the chemicals used in the process. The wastes can be greatly decreased by primary treatment through mixing of the waste streams and controlled co-precipitation. In this case pretreatment of the waste waters before discharge into the municipal sewer system is the only practical solution to the problem. The techniques are well established and have been described in a book I have written on the subject. Copies of this book were given to the tannery and to the regional regulating agency.

IV. FINDINGS

Technical Comments of the tannery LEVE

The LEVE tannery consists of five "shops" located in the town of Gabrovo. These are 1) the main tannery for chrome tanned leather, 2) the tannery for vegetable tanning, 3) the leather goods factory, 4) the leather lubricants factory, and 5) the glue factory.

Of these shops the main chrome tannery and the sole leather tannery are the only sources of significant pollution. The chrome leather tannery is by far the largest unit and was the focus of the study conducted in Gabrovo. The sole leather tannery was operating in a limited basis making chrome tanned leather. The sole leather tannery had no pretreatment system but had plans for the construction of a primary treatment system. These plans were reviewed and will be reported on in this report.

The chrome tannery was operating at the time of the visit, at less than capacity due to the limited availability of hides. The production was steady and there was no difficulty in observing all of the operations. The management was cooperative and, I believe, were both frank and truthful in the discussions of their technical problems.

The tannery is large with a capacity for the production of chrome tanned cattle hides and pigskins of 70 metric tons per day. At the time of the visit production was cattle hides. Although no pigskins were in the tannery, at the time, the anticipated pollution load from pigskin production was considered from my observations made previously, under my WEC study of pigskin tanneries in Hungary.

There was data available from previous studies of the tannery effluent. These studies appeared to be taken from grab samples taken at different times of the day and during varying production conditions. Considering the question of the reliability of the sampling, and the language problem, I used the United States Environmental Protection Agency studies of the tanning industry (EPA 440/ 1-79 / 016) as a basis of calculatING the pollution load generated at full capacity.

The EPA data was taken on a large number of tanneries in the United States. This data was broken down to tanneries of specific type depending on the type of leather being made and the processes being used. The data used is given on the basis of the weight of hides being processed.

In the tanning industry the majority of the pollution comes from the hides. This results in very high Suspended Solids, Biological Oxygen Demand and high Chemical Oxygen Demand. In addition, there are present chromium, sulfides, lime, and salts from the processing. The EPA data is an excellent method of estimating the pollution load of any tannery. This method has proven to be accurate, in my experience, for tanneries of different

size and production method variations worldwide. The EPA data was reviewed with the technical director and the environmental officer of the tannery and they agreed that the approach taken was valid and preferred.

The EPA data for tanneries in the "Hair Pulp Cr Tan, Retan, Wet Finish" is given in Table I.

The Leve tannery has a maximum production capacity of 70 tons of salted hides per day. The water use is reported at 45 l/Kg of hides processed. The total water use is therefore 70000 x 45 l/day or 3150 cubic Meters/day. The total pollution load for the tannery, at maximum production, calculated from the EPA averages, will be as given in Table II. This data is based on complete mixing of the wastes. In practice the total amount of wastes will be as listed. The concentrations will not be steady but will vary considerably as various batch processes are dumped.

Production Methods Used at the Leve Tannery:

The Leve tannery was completely modernized in the mid eighties. The machinery purchased was state-of-the-art, at that time, and is typical of modern tanneries in Europe and the United States.

Soaking and Unhairing: The salted hides are opened from bundles and placed on pallets. The hides are then loaded into drums of about 10 tons (hides) capacity and wet with cold water. The hides are washed with water to remove the surface dirt and the salt from the curing of the hides. The solutions are drained and the unhairing is done by the addition of sulfide salts and lime (Ca OH2). The chemical action of the lime and sulfides result in the destruction of the hair. The hair sludge is washed out and the hides further treated with lime.

The combined wetting, washing and hair destruction process results in the generation of large quantities of suspended solids, BOD, animal fats, salt and residual sulfides and lime. The combined wastes from these processes has been calculated and is given in Table II.

Chrome Tanning: After unhairing, the limed hides are in a swollen condition. At this point the hides are "split" to the desired thickness for the leather being made. (Some of the hides are being processed into "Wet Blue". This production will be discussed later.) The grain limed hides and the splits are separated and the limed hides are moved, by conveyer to the chrome tanning drums. The chrome tanning drums are similar to the soaking/unhairing drums. The weight of each hide is measured on the conveyer and the weight of the batch is automatically controlled. The control system was developed by the technical director and very innovative.

In the chrome tanning, the limed hides are washed then delimed with ammonium sulfate and proprietary chemicals. Following this, salt and acids are added to remove the remaining lime and bring the acidity to the desired level for chrome tanning. The chrome tanning is done with trivalent chromium salts. These salts are non toxic and are nearly insoluble at near neutral pHs. The chrome tanning results in two types of wastes. Early in the process the washing and deliming the wastes contain some suspended solids and BOD. There are also some sulfide and ammonium salts present. The pH is slightly alkaline. Later, at the end of the chrome tanning, the spent tanning solution will contain salt, spent chromium tanning materials, some animal fats, and have a pH of about 3.5 to 4.0. The approximate composition of these two wastes is given in table III.

Wet Blue Production: The tannery is, at this time, processing some hides into "Wet Blue." Wet Blue refers to leather that is chrome tanned and is to be processed through the subsequent stages at another factory. The economics of the industry are such that Wet Blue is now a major item in international commerce. The wet blue leather, after chrome tanning will be wrung, to remove excess water, palleted and shipped. From a pollution control standpoint the wet blue production is identical with the other leather production except that the subsequent processes are not done.

Coloring and Fatliquoring: The chrome tanned leather is sorted for quality and different leathers may be made as best suited form the individual hides. In the coloring and fatliquoring, the chrome tanned leather is treated with various proprietary chemicals, dyes, and leather oils to make the desired leather. A wide variety of leathers may be made from the chrome tanned leather, depending on the coloring and fatliquoring processes used. The wastes from this treatment result in large volumes of water of low suspended solids and low BOD. The COD at this point will be considerably higher than the BOD of these solutions. The waste waters are relatively dilute and are mildly acidic.

Subsequent Operations: The subsequent operations are drying, mechanical softening, and surface dressing. These finishing operations result in very little waste water. There will be some discharge of VOCs into the air but with the application of modern emulsified finishes this discharge is minimal.

Due to the limited time for this investigation, priority was given to the discharge of liquid wastes and the pretreatment of those wastes for discharge into the municipal treatment system.

The requirements for discharge into the municipal system and for direct discharge are given in Table IV.

From a comparison of the requirements and of the total wastes generated it is obvious that the treatment of the tannery wastes is a matter of great importance. The suspended solids and the BOD are at levels almost ten times that of the normal municipal sanitary wastes. To treat the wastes to a level to meet the requirements for direct discharge into the river would require an extensive secondary treatment system to decrease the BOD. To do this would

require a large land area and a very large investment in the treatment system. Through the pretreatment of the tannery wastes the pollution load can be greatly reduced and the resulting wastes be acceptable to the municipal treatment plant.

Since pretreatment is the only practical solution to the problem in this case, a visit was made to the municipal treatment system to determine its capability of receiving the pre-retreated tannery wastes. The municipal system was found to be a large primary and secondary system with sufficient capacity to receive the treated tannery wastes. At present the municipal system is in need of control instrumentation for flow, dissolved oxygen and pH to increase efficiency. However, the capacity of the system is more than adequate. I understand that Mr. Hanson, the other WEC volunteer in Gabrovo at the time of my visit plans to address the problems of the municipal plant in his report.

The Present Leve Tannery Treatment System:

The present treatment system consists of the following:

1. The acid and alkaline waste streams are screened with bar screens and the separate streams are pumped to the mixing tanks.

2. A rectangular concrete tank of 730 Cubic Meters capacity. This tank has baffles for controlled flow of the wastes and it is also equipped with an air sparing system. This apparently was designed as a secondary treatment component. At present the air blower is in operating condition but the piping for the air is corroded and of little use. At present this tank is being used as an equalization tank to control the flow to the mixing and settling tanks.

3. A circular mixing tank 8 M in diameter is used to mix the wastes and is a point of addition of Iron Sulfate as a coagulant.

4. A circular primary settling tank 12.5 M in diameter settles the coagulated wastes and the clarified water is discharged to the river.

5. A sludge screw lift moves the sludge to the sludge thickener.

6. The sludge thickener is a 12.5 M diameter settling basin. The overflow from this settler flows to the river for discharge.

7. The thickened sludge is pumped to the filter house where coagulants are added and the sludge dewatered by a moving belt filter press.

At the present time the system is not operating well. The filter press is broken down and cannot be put into operation until critical parts are obtained.

There is corrosion in the pipes throughout the system resulting in leaks and inefficient

operation. There is an accumulation of sludge in the clarifier and in the sludge thickener resulting in some anaerobic activity.

A sump is under construction to pump the clarified wastes to the municipal sewer system. There is also a pipe in place for this purpose. When this construction is complete and the filter press is in operation the impact of the tannery on the environment should be greatly decreased.

Requirements for Discharge to the Municipal System:

The requirements for the discharge to the municipal system are given in Table V. These requirements must be met by the tannery if extra charges for the treatment of the tannery wastes are to be avoided. In addition, there are some requirements that must be met in order to assure the protection of the municipal sewer system and the health of the community. We shall consider these requirements and their significance individually.

Suspended Solids: The suspended solids generated in the tanning industry are about ten times the concentration found in domestic wastes. In the case of the Leve tannery the concentration, without treatment, is estimated at 2200 mg/l. Tannery wastes when combined interact with the result that the suspended solids can be removed to the extent of 60 to 75 percent. Although the tannery pretreatment system may at times not achieve this efficiency, the municipal system is large enough to process the excess without damage to the operation of the system if there are temporary excesses in the suspended solids discharged from the tannery pretreatment system.

Biochemical Oxygen Demand: The primary treatment of the tannery wastes in the tannery pretreatment system can result in a decrease of the BOD by about 80% under ideal conditions. The resulting level of BOD may, at times , place the tannery in a surcharge category for the treatment of the BOD. This cannot always be avoided. The excess BOD can easily be handled by the municipal treatment system.

Chemical Oxygen Demand: In domestic sewage the COD is normally higher than the BOD by a factor of about 2. In tannery wastes, the COD will exceed the BOD by more than twice.

With primary pretreatment the ratio of the COD to the BOD will be even higher. I would recommend that the COD not be considered as a requirement for the discharge of retreated tannery wastes.

Sulfide: Sulfide in sewers can be dangerous as a toxic substance. The requirement of the limitation on the presence of sulfide in the retreated tannery waste is reasonable and should be enforced. The present reduction of the sulfide concentration is by precipitation with iron. This is a good system that effectively will remove the sulfide with the sludge filter cake.

An alternate method that may be useful in this case is the oxidation of the sulfide with air using

a manganese salt as a catalyst. In the present pretreatment system, if the alkaline wastes were placed in the former secondary treatment tank with the manganese catalyst and aerated, the sulfides could be removed. This would also decrease the iron needed in the coagulation. The method is described in my book Fundamentals of the Treatment of Tannery Wastes. I have left copies of this book both with the tannery and with the regional authorities.

Chromium: The chromium used in the tanning industry is trivalent. This form of chromium is not toxic and has very little solubility when in soil. The presence of chromium in tannery sludges has no adverse effect on drinking water supplies. The chromium may have an adverse effect on the operation of the secondary treatment system of the municipal treatment facility. For this reason the requirement limiting the concentration of chromium in the retreated tannery wastes should be met. With the pretreatment system in proper operation the chromium removal should be satisfactory.

There has been a general acceptance of recycling of spent chrome tanning solutions by the industry. The recycling can result in a savings to the tannery of about 20-20% in the amount of chromium required. The system, if applied to this tannery would require modification of the drainage system from the chrome tanning area and the installation of additional tanks and piping. These additional costs are made up by the savings in the tanning materials. This system is described, in my book mentioned above.

Chloride: The present regulations require a limitation on the concentration of chloride discharged into the system. This requirement cannot be met by any tannery regardless of the pretreatment system used. The hides entering the tannery are salt cured and as such contain about 10% salt by weight. Thus there are 100 Kg of salt per ton of hides. When diluted by the process water the salt is dissolved in 45 Cubic meters of solution. Since the salt is 60% chloride the concentration of chloride will be about 1300-1400-mgl. This calculation does not include the salt that is used in the chrome tanning.

Obviously the requirement cannot be met. I would suggest that the requirement be waived for the tanning industry or dropped entirely. I know of no technical for the need of the requirement in this municipal system.

Extractable Materials: Although the tanning wastes without treatment may contain extractable materials they are primarily animal fats. These are biodegradable and can be easily treated at the municipal treatment plant. The pretreatment at the tannery, when properly operating, should remove the animal fats sufficiently to meet the requirement as listed.

V. CONCLUSIONS AND RECOMMENDATIONS

The recycling of the chromium tanning solutions will result both in a decrease of the chromium discharged and will also be a cost saving for the tannery. This system is highly recommended.

The initial holding tanks (formerly secondary treatment tank) can be used both for sulfide oxidification and waste equalization. The conversion of these tanks to these purposes can be done with only slight modifications in equipment and procedures. This system is recommended.

For best operation of the pretreatment plant the balance of the acid and alkaline wastes must be kept. At no time should the pH of the system be allowed to drop below 7,0. Under acid conditions there can be a release of toxic hydrogen sulfide or the solubilization of the precipitated chromium. The balance of the mixing of the two streams should be maintained by automatic pH control. In the system at Leve tannery I would recommend that the rate of flow from the large holding tank of alkaline wastes be controlled to neutralize the system to the desired pH as the acid wastes come from the tannery. Some acid neutralization of the excess of alkaline wastes will be needed to achieve the desired balance at all times.

The balance of the pH of the system by automatic/recording pH equipment will greatly increase the efficiency of the system. This moderate cost modification is recommended.

The connection to the municipal sewer system is essential and its completion should be your highest priority.

The requirements for the pre-treated wastes discharged to the sewer system must be modified to eliminate the chloride concentration regulation. It is impossible for any tannery to meet the limit of chloride.

COD to BOD ratio of tannery wastes are higher than with domestic sewage. Either parameter will give a measure of pretreatment efficiency. COD is a faster analysis that can be done with good accuracy by trained technicians. I would recommend that surcharges, if any, are to be used for BOD or COD, based on COD at levels attainable with proper pretreatment of the tannery wastes.

All decisions of regulation and enforcement of the pretreatment systems should be made based on technical agreement between the industry and the municipal treatment plant engineers.

VI. COST AND PAYBACK INFORMATION

In this case the cost savings of the chromium recycling has been found to payback the costs of the recycling equipment in about one year. This payback rate will vary depending on the local costs of construction and chemical costs. Since this was a preliminary short investigation, no accurate estimate of costs and payback can be made.

VII. IMPLEMENTATION PLAN AND SCHEDULE

The tannery is, at present, constructing the connector to the municipal sewer system. This work and the repairs on the present system is being delayed for lack of parts and the general slow economy of the industry. The costs of the work suggested and the work planned is relatively small for an industry of this size, however, the funds are limited and the work will probably proceed slowly.

TABLE I

ENVIRONMENTAL PROTECTION AGENCY LOAD AND PERMIT DATA

CATEGORY 1: Hair Pulp, Cr Tan, Retan, Wet Finish

Parameter	**mgl/**	**Kg/1000 Kg**
Flow - M^3/day 45l/Kg	4.6 gal/lb	38.41/Kg
BOD - Biochemical Oxygen Demand	1620 mgl	62.3 Kg
TSS - Total Suspended Solids	2610 mgl	92.3 Kg
COD - Chemical Oxygen Demand	4640 mgl	178 Kg
O&G - Extractable Fats & Oils	400 mgl	15.4 Kg
Total Cr - Total Chromium	75 mgl	2.9 Kg
Sulfide	64 mgl	2.5 Kg
TKN - Total Keldjhal Nitrogen	330 mgl	12.6 Kg
NH^3 - Ammonia	104 mgl	4.0 Kg
Phenol	1 mgl	.04
pH	6-9	

TABLE II

CALCULATED WASTE LOAD PER DAY @ 90 TON/DAY PRODUCTION

Parameter	Kg/Day	mgl
Flow - M^3/day 45 l/Kg	3150	
BOD - Biochemical Oxygen Demand	4361	1264
TSS - Total Suspended Solids	6461	1873
COD - Chemical Oxygen Demand	12460	3612
O&G - Extractable Fats & Oils	1078	312
Total Cr - Total Chromium	203	58
Sulfide	175	51
TKN - Total Keldjhal Nitrogen	882	256
NH^3 - Ammonia	280	81
Phenol	2.8	.8
pH	6-9	

TABLE III

Requirements for Industrial Discharge Into the Gabrovo Municipal Sewer System

Parameter	
Maximum Temperature	40° C
pH	6.5 - 9.0
Chloride	400
Sulfates	400
BOD - Biochemical Oxygen Demand	600
COD - Chemical Oxygen Demand	1000
Petroleum Hydrocarbons	15
Extractable Oils	75
NH^3 - Ammonia	15
Chromium +6	.3
Chromium + 3	2.5

VIII. APPENDICES

A. Business Cards

B. Cirriculum Vitae of Thomas Thorstensen

APPENDIX A

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PRESIDENT: TSG, Inc. (Technical Support Group)

EDUCATION: University of Minnesota, B.S., Chemical Engineering
U.S. Naval Academy, Officers Training
Lehigh University, M.S., Chemistry
Lehigh University, PhD, Chemistry
Reg. Professional Engineer, Massachusetts & New Hampshire

FELLOW: American Institute of Chemists

MEMBER: American Leather Chemists Association (ALCA) President 1974 - 1976
International Union of Leather Trades Chemists
Alsop Award for Outstanding Research
ASTM
ACS

FORMERLY: President of Thorstensen Laboratory, Inc.

LISTED: Who's Who
American Men of Science

PUBLICATIONS: Approximately 30
Author, book: Practical Leather Technology; 4th ed.
Author, book: Fundamentals of Pollution Control for the Leather Industry

PATENTS: Approximately 12

TECHNICAL ADVISOR:

Department of State, AID
UNIDO
World Bank
Department of Defense, Spec. Reviews

As Advisor, trips have been made to Europe, Asia, Yugoslavia, India, Japan, Afghanistan, Malaysia, Columbia, South America, Philippine Islands, Egypt, Hungary and Domestically.

Research and testing in Thorstensen Laboratory included fibers, plastics, paper, and leather and included the effluent from these types of industries, materials use, industrial feasibility and chemical engineering.

SPECIAL PROJECTS:

1960 - 1962 Lowell Technological Institute, visiting professor. This was an industry-sponsored chair financed entirely by volunteer contributions from leather companies and other interested companies.

1962 During the summer of 1962, the U.S. Department of State requested a technical tour of **Yugoslavia**.

1964 Early in 1964 - Trip to **India** in a technical capacity for the United Nations to aid the Central Leather Research Institute in Madras with its leather research program.

1965 At the request of the **Malaysian** government, we conducted a feasibility study on the establishment of a series of leather factories in Malaysia.

1967 Requested by an industrial client in **Japan** to visit Japan and establish new processes for a tannery. On this basis, a new factory was built and is now operating successfully.

1968 Toured **Afghanistan** for the U.S. Department of State to advise them on the direction of the USAID program in the field of sheepskin utilization and Karakul skin preservation.

1969 Published a book, "Practical Leather Technology". Van Nostrand Reinhold Publishing Co. N.Y., now Krieger Publishing Co., Melbourne, Florida.

1969 - 1970 Staff designed entire layout for USAID project in Afghanistan for laboratories, cure houses, and office.

Trained Peace Corps workers for work in **Afghanistan** conducted at this laboratory.

1980 Conducted a development project on Utilization of hides for food in Haiti.

1985 Advised the Government of Columbia on pollution control of approximately 50 small tanneries.

RECENT SPECIAL PROJECTS:

1989 As an advisor to the World Bank, studied the proposed and under construction, combined treatment systems for five tanneries in **India**. Information was given to the Indian Government and engineers.

1990 For the World Environmental Center and USAID, advised in **Egypt** large tannery on by-product use. (Gelatin and Glue Plant)

1991 Under World Environmental Center/USAID project in **Philippine Islands** to study tannery pollution control and a glue factory.

1991 Under World Environmental Center/USAID visited **Hungarian** tanneries on pollution problems. Three large tanneries.

1993 Under World Environmental Center/USAID visited **Bulgaria**. One combined large tannery and glue factory.

ADDITIONALLY:

We have been contacted to design and supervise glue factories in Turkey and Russia. These were to be our most recent work including the implementation of the completed factories. Names and companies are available.