Bulletin of High Institute of Public Health
Vol. 29 No. 1 [1999]

" Pollution Abatement of Glue Industries Wastewater "

A. Hossam EL-Din Hassan* and M. Hassan Ramadan*

Abstract: There are more than ten glue works in Egypt; five of them are in Alexandria. The process of extracting fat and glue from animal bones generally is accompanied with many environmental impacts. This study assesses the generated wastewater of glue industry. Solid wastes generated from glue works ranged between 234 and 400 tons/year. The components of the solid wastes are trash, dirt, and contaminated fat. The final wastewater of the plants are discharged either by a vacuum truck to unknown places, to the sewer system, or to water course that empties into a wetland area. No treatment of the plant's wastewater is provided, except one plant uses a set of underground tanks as an oil trap. The raw bones washing wastewater stream is high in Biochemical Oxygen Demand [BOD] [mean 4,560 mg/l], Chemical Oxygen Demand [COD] [mean 14,960 mg/l], total dissolved solids [TDS] [mean 4,160 mg/l], total suspended solids [TSS] [mean 1,438 mg/l], and oil and grease [O&G] [mean 434 mg/l]. The high values of the organic content are attributed to loss of fat and glue due to the effect of hot water. The low value of O&G in wastewater in some plants using heptane indicates the good performance of fat extraction process. Also the results of wastewater analyses from the fat/water separation process are extremely high in BOD [mean 12,320 mg/l], COD [mean 34,520mg/l], TDS [mean 41,810 mg/l], TSS [mean 7,451 mg/l], O&G [mean 1,047 mg/l], and sulfates [mean 29,260 mg/l]. These wastewater discharges are major contributors to the final effluent high values for organic material and solids. It is clear from the results of washing floor contaminated with kerosene that this wastewater is high in BOD [mean 14,470 mg/l] and COD [mean 30,670 mg/l]. This wastewater as well is one of the major contributors to the final effluent high values for organic material. Wastewater of heptane/water separation tanks showed that it contained relatively high levels of BOD [mean 490 mg/l] and COD [mean 768 mg/l], although it is low compared with the results of other plants using hot water for extracting fats. The analysis of wastewater sample from the evaporator/concentrator tanks showed that it had an elevated level of total dissolved solids [2,696 mg/l], ammonia nitrogen [120 mg/l], BOD [400 mg/l], and COD [1,640 mg/l].The final wastewater was high in BOD [mean 13,680 mg/l], COD [mean 30,200 mg/l], TDS [mean 8590 mg/l], TSS [mean 11,900 mg/l], and O&G [mean 4,170 mg/l]. Samples of the plant's wastewater show that the plants effluent does not meet the requirements of the laws.The studied wastewater for different plants showed a high level of organic compounds that are amenable to biological treatment. In the absence of toxic effects, biological treatment plants are capable of reducing BOD and total suspended solids by more than 90%. Pollution prevention opportunities which could reduce the size and operating cost of the treatment plant for this kind of works will be illustrated.

* Environ. Health Dept., High Institute of Public Health, Alexandria University.

INTRODUCTION

Bones constitute a major waste product in the newly erected slaughterhouses in the major cities of Egypt, where 2 million animals are slaughtered every year.[1] Egypt slaughtered 29.5 million poultry in 1987. This should yield 1769 tons of legs which could be made use in production of gelatin, glue and fat.[2] Dried bones is composed approx. of 50% calcium phosphate, 10%calcium carbonate, 25% collagen, and 5-10% bone fat, and the remainder is made up mainly of mucopolysaccharides, calcium fluoride, magnesium phosphate, sodium salts, and heavy metals such as iron and manganese.[3]

Gelatin is a polymer of amino acids being prepared from collagen, the principal intercellular constituent of the white connective tissues of animal skins and bones, by alkaline or acid hydrolysis followed by extraction with hot water.[4] Methods of gelatin pretreatment processing, depending on the source or type of raw material, include: acid-pretreatment, alkali -pre-treatment, and direct extraction with high pressure steam.[5,6] According to Egyptian pharmacopia, gelatin is the protein obtained by heating the collagenous tissues of animals such as skin, tendons, ligaments, and bones, with water, evaporating the aqueous extract and drying the residue in air.[7]

Animal glue is a protein derived from the simple hydrolysis of collagen.[8] Animal glues are popular variety of protein glues, prepared from the bones of dead animals, waste of slaughter house and hide scraps from leather industry.[9] They are dry, hard, odorless materials ranging in color from amber to brown. They are soluble only in water, and insoluble in oils, waxes, organic solvents and absolute alcohol's, but may be emulsified in water-oil, or oil-water systems under proper conditions. They are used in wood working, gummed tape, coated abrasives, textiles, paper, match industry and uranium mining.[8] A good glue should not attract moisture, and should be capable of absorbing six to seven times its own weight of water without liquefying.

Little information concerning animal bone fat is available in the literature except for some studies on the composition

and fatty acids content of bone fat.[10,11] Residual bone is meant the residue remaining after separation of gelatin, fat, and glue from bones. It is ground to various degrees of finesses depending upon the assigned purpose, e.g., for poultry feed.

There are more than ten such glue works in Egypt; five of them are in Alexandria. The extraction of fat and glue from animal bones is accompanied with many environmental impacts. This study assesses glue wastewater which is expected to impact the media receiving it.

AIM OF THE STUDY

The objective of this study was to assist glue industry in the Greater Alexandria area, in reducing its impact on the environment. The emphasis was placed upon wastewater.

MATERIAL AND METHODS

Five glue works in Alexandria have been surveyed. Wastewater samples from the different locations in each plant have been collected and analyzed according to the Standard Methods for the Examination of Water and Wastewater[12] for comparison with the law regulating limits for the discharge of wastewater. Solid wastes have been environmentally evaluated as well.

Process Description

The following is a general description of the processes used at the different glue works [figure 1]. It can be stated that almost all the plants are using the same production processes. Some of the plants use live steam in extracting fats while other use heptane. One of the existing glue works is cooling the droplets of glue onto cold rotating metal cylinders which are chilled by water, three plants form the droplets of glue by immersion into a cold kerosene bath, while the last one introduces the beads into a five stage dryer with controlled temperature and humidity.

The Major Processes Steps Include:

1- Weighing, storage, and manual sorting of bones. Mechanically crushing sorted bones to smaller pieces to facilitate glue

and fat extraction, then washing by cold water and hot water

2- Steam or heptane is introduced to extract fat.

3- Fat is mixed with sulfuric acid and salt. Mixture is boiled, then water is allowed to separate by gravity. The fat is packed.

4-Steam is introduced to extract glue. When a dilute solution of 15% glue in water is formed, it is pumped to the glue production process.

5- Two types of glue are produced. "Liquid" glue and "Pearl" glue, [small beads of solid glue].The treated dilute glue is concentrated to approximately 50%.

6- Phenol and hydrogen peroxide are added to the concentrated glue to preserve and bleach the glue, respectively and then packed.

7- Bead Forming: Concentrated, hot, viscous, glue solution is passed through sieves to form droplets of glue which then cooled, dried and packed.

8- After extracting fat and glue, the bone residue is impure solid calcium phosphate, is milling , packing, and selling .

RESULTS AND DISCUSSION

According to the survey which has been carried out in Alexandria in the five glue works [given names A,B,C,D, and E], it has been found that :

The plants extract fat and glue from animal bones of carcasses of dead animals, and the remaining bone structure is impure calcium phosphate. Fat is sold for use as a basic soap making ingredient. The glue in liquid or pearl form is used as an adhesive agent. Calcium Phosphate is sold in three different categories : as animal feed ingredient, a fertilizer ingredient, and as a component in porcelain manufacturing.

Environmental Assessment

a] Wastewater discharges, and solid waste discards, are generated at all the glue works studied. The generated solid waste ranged between 234 and 400 tons/year. The sources of solid wastes in the plants are the trash that is separated from the raw bones; the dirt that is separated from the finely ground raw bone; and tha contaminated fat that floats

Table 1: Physico-chemical characteristics of wastewater samples from the different locations in Glue Werks located in Alexandria, 1999

Location		Washing			Fat/water Separation			Kerosen			Heptane			Before Treatmen	Condens. from vac. m/c	Final Effluent		
Parameters	Unit	A,B,C, D,E			A,B,C,E			B,C,D			B,E			E	E	A,B,C,D,E		
		MIN.	Max.	Mean	MIN.	Max.	Mean	MIN.	Max.	Mean	MIN.	Max.	Mean			MIN.	Max.	Mean
Temp.	C	24	50		36	56		22	42		44	44		43	39	22	60	
pH	units	6.2	6.9		1	4.2		6	6.7		8.6	9.5		1.4	8.6	2.8	10	
O&G	mg/l	30	1176	434	147	2650	1047	16	135	62				140	75	4.8	20600	4170
BOD	mg/l	410	19000	4560	5600	19000	12320	1600	25000	14470	400	580	490	1000	400	210	51000	13680
COD	mg/l	1200	38400	14960	11040	66000	34520	2000	46000	30670	736	800	768	3240	1640	400	116000	30200
TDS	mg/l	312	11550	4160	14296	63070	41810	734	25480	21179				10759	2696	290	19660	8590
TSS	mg/l	334	3560	1438	3785	17150	7450	98	21180	10130				653	173	553	52210	11900
Settleable Solida																		
at 1 hours	mg/l	0.3	12	4.6	0.5	5.5	3.4	0.4	4	2				0.1	nil	0.1	1	0.36
NH_3	mg/l	0.88	120	53.2	7.2	600	367	9.24	18	11.4				120	120	0.8	600	240
BO_2	mg/l	0.01	1.44	0.42	0.01	0.01	0.01	0.01	0.72	0.34				0.01	0.01	0.01	0.8	0.29
NO_3	mg/l	0.05	2.5	0.92	0.05	0.05	0.05	0.05	0.05	0.05					0.6	0.05	5	1.27
SO_4	mg/l				800	92000	29260							8000	32.5	290	13000	3620
PO_4	mg/l	8	35	23	25	2320	618	0.2	50	17.5				176	0.6	1.7	350	91
Cr	mg/l													0.053	0.003	0.01	0.45	0.02
Cd	mg/l													0.004	0.9004	ND	0.002	0.001
Cu	mg/l													0.098	0.008	0.01	0.209	0.081
Ni	mg/l													0.016	0.003	0	0.045	0.018
Pb	mg/l													0.064	0.004	0.03	0.239	0.083
Zn	mg/l													0.572	0.528	0.55	0.863	0.463

NB: 1] A, B, C, D, and E are different glue plants 2] Plant E is the only plant treating its waste

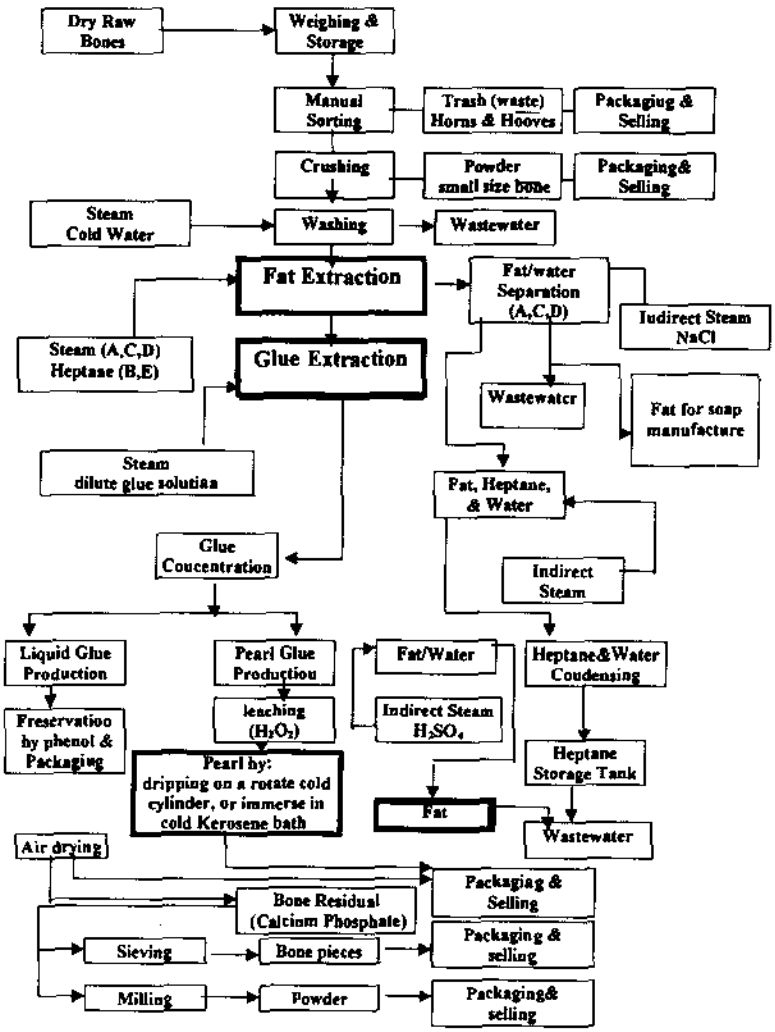

Figure 1: Schematic diagram of glue manufacturing process

on the surface of the process wastewater.

b] Received bones are contaminated with plastic, wood, iron, household items, and other forms of trash. This trash is removed and discarded on a nearby land.

c] During the processing of grinding and crushing raw bones, wastewater that is laden with fat is discharged to sewers. The fat accumulates in the wastewater holding tank and is removed periodically away by truck to unknown place. Discarded solid wastes can leach compounds into the soils and ultimately may reach the groundwater. Part of the processed wastewater of plant D is discharged to a watercourse that empties into a wetlands area. The combined wastewater of plant E is discharged to a set of underground structure as oil traps and then to the sewerage system. No treatment of the plant's wastewater is provided.

d] The major sources of process wastewater are washing of raw bones, and dewatering of extracted fat. Plant E has more two sources of wastewater which are : removal of water from heptane and the wastewater extracted from the glue by the vacuum concentrators. The results of the analysis are presented in Table [I].

It is clear from Table [1] that the wastewater stream generated from bone washing is high in BOD, which ranges between 3800 to 19000 mg/l with exception of plant A, [plant A, 410 mg/l], COD ranges between 6400 to 38400 mg/l [plant A, 1200 mg/l], total dissolved solids [TDS] ranges between 2699 to f1550 [plant A, 312 mg/l], total suspended solids [TSS] ranges between 1053 and 3570 mg/l [plants A&E, 343 and 334 mg/l], phosphorous ranges between 15 and 35 mg/l, [plant A, 8 mg/l], and O&G ranges between 30 and 1176 mg/l. The high values of the organic content represented as O&G, BOD, and COD are attributed to loss of fat and glue due to the effect of hot water. The low oil and grease values which appeared in some plants using heptane in extracting fats indicate that the fat extraction process using heptane is efficient, and no much fat remains in the bones when they are washed. The high values of TDS and TSS are attributed to the dirt and foreign materials which are adhered to the delivered bones.

The low results of most of the parameters in plant A, although it is using hot water in extraction, are attributed to that the plant washes the bone several times, thus diluting the waste generated.

e] The analysis of wastewater generated from the gravity separation tanks following the sulfuric acid addition shows that this wastewater is extremely high in BOD [range, 5600-19000 mg/l], COD[range, 11040-66000 mg/l], total dissolved solids [TDS] [range, 18296-63070 mg/l], total suspended solids [TSS] [range, 3785-17150 mg/l], oil and grease [range, 147-2650 mg/l], and sulfates [range, 800-92000 mg/l]. These discharge wastewater are the major contributors to the final effluent high values for organic material and solids.

The high values of O&G, BOD, and COD indicate that significant quantities of organic material, probably mostly fat, are discharged to the sewer system. Ammonia [range, 300-600 mg/l while plant A is 7.2] and phosphate [range, 25-2320 mg/l], are also high indicating organic substance[s] in the wastewater. The TDS value is high indicating significant quantities of salts, partly sulfate from the sulfuric acid addition.

f] When the liquid glue is processed in cold kerosene to form beads as in case of plants B, C & D, some of the kerosene leaks onto the floor and flows to the drain. It is clear from results that this wastewater was high in BOD [range, 1600-25000 mg/l] and COD [range, 2000-46000 mg/l].This kind of wastewater discharges is one of major contributors to the final effluent high values for organic material in these plants.

g] Samples were taken while discharging the wastewater from plants B and E. Heptane is used in fat extraction. Heptane is recovered in two condensers and is stored in two tanks. Periodically, water is removed from the bottom of these tanks. It is clear from the results that this waste stream contained relatively high levels of BOD [range, 400-580 mg/l] and COD [range, 736-800 mg/l]. Although it is low compared with the results of other plants using hot water for extracting fats, some heptane and/or other organic material are lost in this waste stream.

h] Wastewater was collected from plant E. Water is removed from the glue by a three stage vacuum evaporator/concentrator. It is evident from the results that this wastewater had an elevated level of total dissolved solids [2696 mg/l], ammonia nitrogen [120 mg/l], BOD [400 mg/l], and COD [1640 mg/l]. A condensing stream acts to dilute the total industrial wastewater discharge. This wastewater stream is not highly contaminated, so it may be reuse, as a pre- washing of raw bones.

i] A sample of the final wastewater from all the plants was taken for analysis. This wastewater was high in BOD [range, 1400-51000 mg/l while plant A is 210 mg/l], COD [range, 3520-116000 mg/l while plant A is 400], TDS [range, 5231-19660 mg/l while plant A is 290 mg/l], TSS [range, 553-52210 mg/l], and oil and grease [range, 25-20600 mg/l while plant A is 4.8 mg/l].

j] Table [1] contains also the heavy metals analysis of the samples collected. It is clear from the results that heavy metals contents are meeting the requirements mentioned in laws governing discharge of wastewater.

Samples of the plants' wastewater show that the plants effluents do not meet all of the requirements of the law, except heavy metals. All the studied plant's wastewater showed a high level of organic compounds that are amenable to biological treatment. In the absence of toxic effects, biological treatment plants are capable of reducing BOD and total suspended solids by greater than 90 percent. Furthermore, implementing additional pollution prevention measures will reduce the size and operating cost of a treatment plant.

Pollution Prevention Opportunities and Assessment Include:

1. Utilize better quality raw bones to reduce the amount of solid waste generated.
2. Recover fat from process wastes to reduce the organic loads and the wastewater quantity
3. Use better method to concentrate thin glue solution to improve process waste quality.
4. Use cold surface technology for pearl glue

formation to reduce kerosene content in wastewater, and eliminate the worker exposure to kerosene vapors

5. Using new degreasing process to reduce air pollution due to solvents and wastewater becomes free of fat.
6. Collect the bone-dust during grinding and packing to reduce air pollution.
7. Use organic solvent for extract fat to reduce quantity of fat discharged to sewers.
8. Stop using phenol as a toxic compound in liquid glue.
9. If options highlighted above are all implemented, the estimated annual savings will range from LE 680,000 to 1.43 million per each plant. The capital cost is estimated to range from LE 255,000 to LE 1.39 million per each. Hence, a simple payback period would be 5 up to 12 months per each plant.

REFERENCES

1. Abo-tour SMI. Recovery and evaluation of gelatin, fat and glue fbones of slaughtered animals.1988;M.Sc.thesis Food Science & Technology Dept., Fac. of Agriculture, Alex. Univ.
2. Tawfik MS. Studies of utilization of some by-products of poultry slaughter-houses. M.Sc.thesis Food Science &Technology Dept., Fac. of Agriculture, Alex. Univ.
3. Libby FW, Horney GA. Radiocarbon dating of bone and shell from their organic components. Science 1964; 140; pp: 999-1001.
4. Charley H, Wiley J. Gelatin. In: Food Science. New York: Academic press, Inc., 1970; pp. 413-417.
5. Dulage R, Rosenbaum LJ. Gelatin. In: Industrial cold adhesives. London: Limited, 1964; pp. 23-25.
6. Grand RJA, Stainsby G. The action of cold alkali on bone collagen. J. of the Science of Food and Agriculture, 1975; 26 [3] : 295-302.
7. Anon. Gelatin. In: The english text of the Egyptian Pharmacopia. Cairo: Ministry of Health, 1984; pp. 442-443.
8. Hubbard JR. Animal glues. In: Handbook of adhesives. New York: Skeist. I., Van Nostrand Reinhold Company, 1977; pp. 139-151.
9. Jain PC, Jain M. Engineering Chemistry [Chemistry of engineering materials]. New Delhi, Dhanpat Rai & Sons., 1988; p. 637.
10. Miller GJ, Frey MR, Kunsman JE, Field RA. Bevine bone marrow lipids". J. Food Science, 1982; 47: 657.
11. Shmidt AA, Yusupova IU. Composition of aliphatic acids of fats obtained from various kinds of bones. Maslozhirovaya Promyshlennost, 1986; No. 13[34]: 12.
12. American Public Health Association, American Water Works Association, Water Pollution Federation. Standard Methods for the Examination of Water and Wastewater. Washington, DC: 1992, 18th Ed.