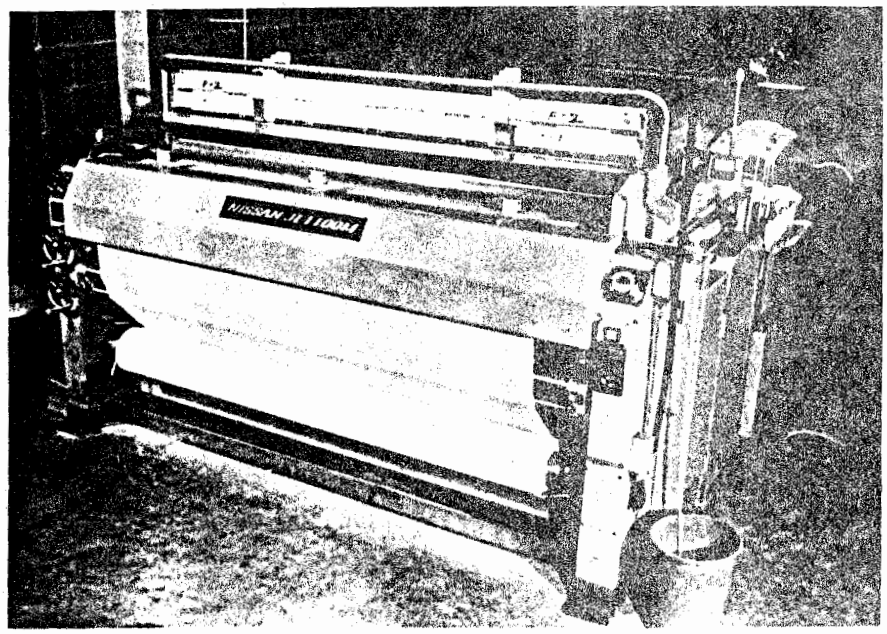
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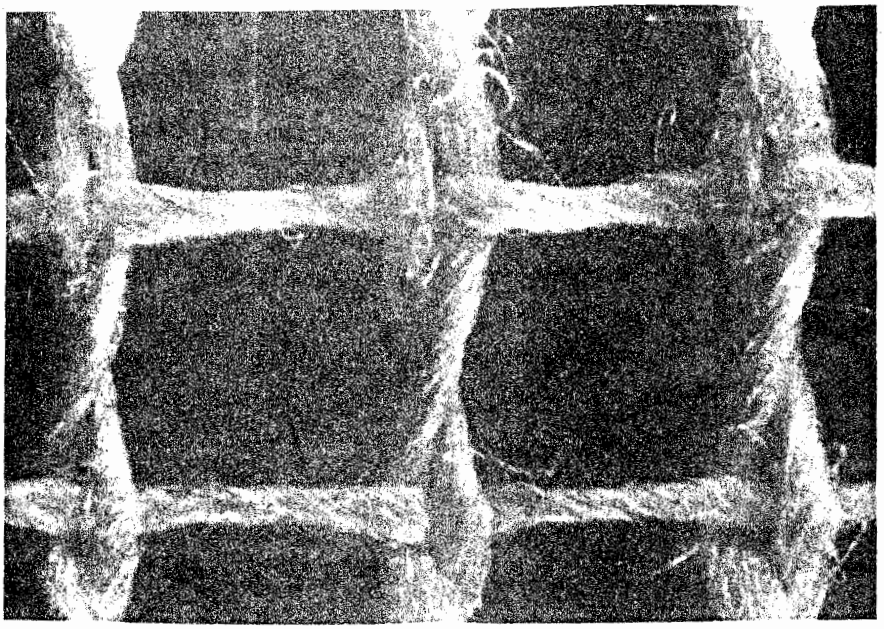

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ASSESSMENT OF LAND TREATMENT TECHNOLOGY FOR TEXTILE MILL INDUSTRY

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ABSTRACT

The textile mill industry consisting of six subcategories of manufacturing must continually review the options for meeting state and federal environmental regulations. Land treatment is becoming a method of choice for an increasing number of mills. This report examines land treatment on a first-cut basis. Average plant sizes for each six subcategories are used along with representative waste and soil characteristics. These results do not represent design criteria because of the highly critical need to test the waste and site to be used, before specifying or permitting of such systems. Instead the results of this report should be used to compare the land treatment alternative to conventional processes. Although not included specifically, land treatment can meet the highest levels of waste treatment (RCRA, BAT, etc) when correctly designed, thus comparison against other alternatives should include the advanced wastewater treatment requirements for meeting present and future regulations.

In addition to the evaluation of land treatment as an option for the textile mill industry, a fundamental design procedure is presented for land treatment design. This procedure demonstrates the detailed levels of soil and waste analyses required to design any land application system. Successful long term performance and adherence to soil, food-chain, groundwater nondegradation constraints depend on utilizing an in-depth design procedure. Results of this study have demonstrated the differences attributable to soils, the waste parameters which are critical in design, the potential savings associated with in-plant source control.

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CONCLUSIONS

1) Waste characterization for subcategories of textile mills, relative to important land treatment parameters, are reasonably well known. A major, serious gap continues to be the lack of data on specific organic compounds present; therefore, the analyses and conclusions of this report will have to be modified as these become available.

2) The soil types and land conditions used in these analyses were selected as representative case studies. In actual field situations near textile mills, the variations in assimilative capacity could be substantial; although the design principles used in this report would remain valid. This variation is due to actual soil and field conditions hence a detailed field testing program is essential.

3) In each textile mill subcategory the LLC was calculated along with the required area for land treatment of the entire raw waste produced, Table 15. No single constituent controlled all the textile mill segments.

4) Typically the textile mill utilizing a sandy loam site versus a clay loam site would require greater land area (between 2 and 7 times the size). However both soil types are quite feasible for land treatment.

5) Pretreatment or in-plant alteration will be a requirement for wool scouring (neutralization), wool dyeing and finishing (neutralization), yarn/stock dyeing and finishing (neutralization), and knit fabrics dyeing and finishing (sodium imbalance).

6) From an investment perspective, the wool scouring with dyeing and finishing, and woven fabric dyeing and finishing require the greatest expenditure for land treatment. At the other extreme knit fabric dyeing and finishing involves the lowest investment costs.

7) Savings of up to 700% can be achieved in those textile mill categories needing the largest investment by eliminating the land limiting constituents (Sr, As, SO_4, depending on segment). In-plant substitution or process modification would be needed for these changes.

8) Relative to 1983 industry pollution standards, textile mills which can utilize land treatment will enjoy considerable economic advantage (investment and operational).

RECOMMENDATIONS

1. Further waste characterization is needed to document parameters critical to land treatment. Some of the constituents controlling land area did not appear to be a logical component in the textile processes hence verification is necessary.

2. In-plant source control programs should begin to evaluate the presence and justification of the chemical constituents found to dictate the needed land treatment area (LLCs). These programs can establish removal or substitution techniques to reduce the LLC(s) and hence required investment and operational cost for land treatment.

3. Specific investigations of the major organic species present in the waste from each textile mill subcategory should be undertaken. Also to be included are any organic compounds of strong environmental concern. This class of waste constituents is a major remaining design segment which should be addressed for a complete land treatment system.

4. Textile mill managers and environmental personnel should examine carefully the use of land treatment. Specific site and waste evaluations for either complete waste or sludges must be undertaken. Sites of 1-2 miles from the industrial plant for liquids or 12-30 miles for sludges can be economically utilized thus increasing the range of possible land treatment systems.

5. As energy costs increase, more attention to the less energy - and less technology - intensive land treatment option should be given.

ACKNOWLEDGMENTS

The authors wish to record the steady, fundamental support of the Water Resources Research Institute, Neil S. Grigg and James M. Stewart. The Department of Biological and Agricultural Engineering has continuously furthered this research as an expanding program concerning the environment. Dr. F. J. Hassler, Department Head and Dr. F. J. Humenik, Associate Head Incharge for Extension, have been particularly responsible for the success of this project. Valuable colleague input was received from Dr. Philip W. Westerman.

Laboratory efforts, where utilized, were effectively undertaken by Ms. June Preston and Ms. Dorothy DeBruyne.

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OBJECTIVES AND OVERALL APPROACH

Within the framework or evaluation of industrial waste management alternatives, land treatment can serve an important role. An increasing number of plant managers and corporate environmental personnel are considering the substantial alternative of land treatment for industrial waste as an approach toward the goal of zero discharge. Therefore this report is focused on the potential use of land treatment for the textile mill point source category as one of many possible industrial categories considered under a present research program.

There are two specific objectives of the research and evaluation presented in this report,

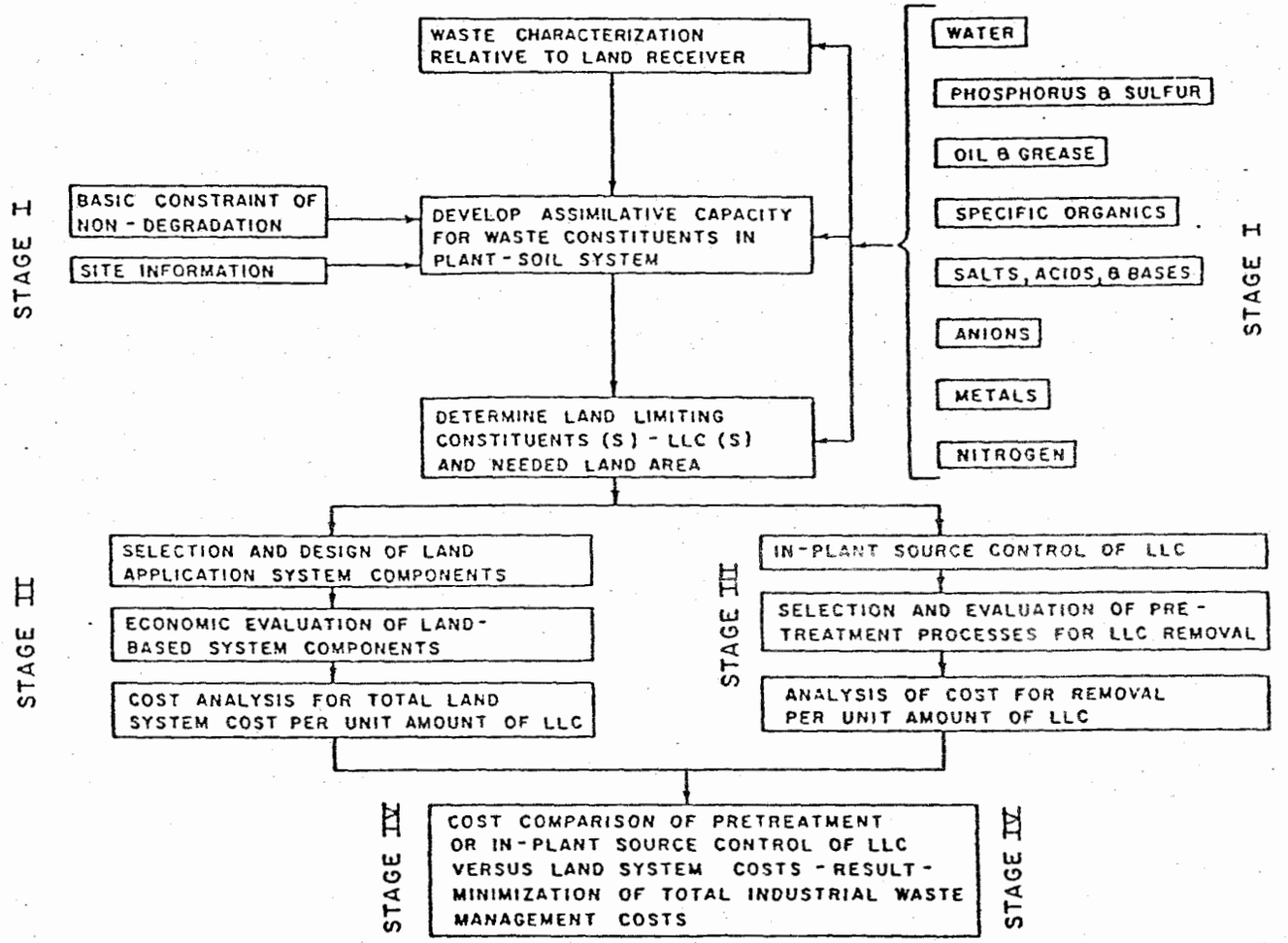
1) to establish a general estimation of the use of land treatment technology for each of the subcategories within the textile mill classification. This should be considered only as a first order approximation since waste parameter evaluation and site characterizations are specified only as representative of typical conditions.

2) to further demonstrate the utilization of a complete design procedure or methodology for land treatment of the entire waste stream from each of the various subcategories of the textile mill industrial classification.

The presentation of material in this report will utilize the stage I portion, Figure 1, of an overall pretreatment-land application methodology. Each major subcategory of textile mills will be separated as necessary. A complete description of the overall design procedures and required data base can be found in Overcash and Pal (1979). Basically, each subcategory has been delineated with as complete as possible a chemical characterization for those parameters important when the plant-soil system (as opposed to an aquatic system) is the ultimate receiver. One major gap continues to be the lack of data on specific organic compounds which may be of concern because of the presence in substantial quantity or because of probable environmental impact. Available pertinent data on waste characterization involve 25-30 constituents for the analysis used in this report.

While waste characterization is important, the second major stage I input, site-specific data, is equally or more critical in achieving successful design and long term performance. It is obvious that without a specific land treatment site, the detailed plant, soil, and groundwater data cannot be determined. That is, considerable variation in land area requirements, for a given waste stream, occurs when there is a variety of site conditions used in design calculations. These site conditions are typical of probable land treatment sites. Because of the wide variations due to site characteristics, this report utilizes two common soil characteristics as a preliminary evaluation tool. These are i) a sandy loam and ii) a clay loam soil. The reader should not infer that these represent extremes and that all other actual site conditions would

DESIGN METHODOLOGY FOR INDUSTRIAL WASTE PRETREATMENT - LAND APPLICATION SYSTEM



be between these two soils. The two soils selected simply represent significantly different soil textures for the purpose of demonstrating the importance of actual land treatment site data. As described in following sections, specific site data are used to establish the plant-soil assimilative capacity for each constituent in the waste.

With the available waste characteristics (kg/yr) in each textile mill subcategory and the two representative sets of land treatment site assimilative capacities (kg/ha/yr), the land limiting constituent was determined. That is, a balance between waste generation and plant-soil assimilative capacity is made on a constituent-by-constituent basis. This balance or ratio equals the land area needed for each parameter, with the largest area requirement being the land limiting constituent(s) (LLC). A LLC analysis defines i) the parameters which are critical in determining land area requirements and ii) the actual land treatment area needed for each representative industrial situation covered in this report on the textile mill industry.

SUMMARY OF LAND TREATMENT DESIGN METHODOLOGY

The determination of land treatment technology for a textile mill waste follows certain well-established principles and techniques. These are sufficiently flexible to be adapted to all types of industrial waste and therefore are common to all land treatment designs. A brief review of these principles will be included here and the reader may consult more detailed texts for further information (Overcash and Pal, 1979).

A single basic constraint is utilized throughout the industrial land treatment design. This constraint is as follows,

> *the industrial waste, when considered on a constituent-by-constituent basis, will only be applied to the plant-soil system at rates or over limited time spans that no land is irreversibly removed from some other potential societal usage (agriculture, development, forestation, etc).*

Such a constraint is basically one for nondegradation of the plant-soil system and represents a fairly strong design objective. Where substantial data to meet this constraint are unavailable, the use of land treatment should be accompanied with sufficient monitoring to guage progress relative to this constraint. Approaching industrial land treatment with this constraint or philosophy appears to 1) reflect most accurately the thrust of all environmental regulations and 2) improve the probability that the design criteria used will provide long-term reliable land treatment performance.

The primary nondegradation design constraint regarding the long term effect or assimilative capacity of the soil-plant system is translated into land application rates by one or more of three calculational procedures. That is, from experience with determining the assimilative capacity of many industrial waste constituents, the methods for calculations are of three broad types,

1) those compounds which degrade or require uptake for assimilation in the plant-soil system e.g. oils or organics

2) those compounds which are relatively immobile and nondegradive and thus are permitted to accumulate in soils to predetermined critical levels, e.g. heavy metals

3) those compounds which are mobile and nondegradative and therefore must be assimilated over land areas such that receiving waters are not altered to a degree which would require further drinking water treatment e.g. anionic species.

Results of these calculations for the assimilative capacity at a specific plant-soil system site are usually expressed as the mass of a constituent in the waste which is assimilated per unit land area per unit time (kg/ha/yr) or as the concentration in the soil (ppm or percent of soil weight). Thus with the basic design constraint and one or more of the individual calculational tools, the assimilative capacity for each constituent in the waste can be determined. This procedure is repeated in this report for each separate subcategory within the textile mill point source category.

INDUSTRY DEFINITION

The textile mill industry utilizes natural fibers (wool and cotton) as well as synthetic fibers (rayon, cellulose acetate, nylon, polyolefins, etc) as raw materials. Textile mills can be categorized into various segments based on i) the form and composition of raw materials (Jones, 1973), ii) processes employed in the manufacture of product(s) and byproduct(s) (Development Document, 1974), or iii) waste generation rate and location (Abrams, 1976). The subcategorization included in this report is essentially that established by the Environmental Protection Agency (Development Document, 1974 and Rawlings, 1978). These are: (1) Scouring and Wool Top Manufacture, (2) Wool Fabric Dyeing and Finish, (3) Woven Fabric Dyeing and Finish, (4) Knit Fabric Dyeing and Finish, (5) Carpet Dyeing and Finish, and (6) Yarn and Stock Dyeing and Finish. A brief description of these segments of the textile mill industry follows:

1) Scouring and Wool Top manufacturing facilities in the United States are principally located in Massachusetts, Texas, Rhode Island, and South Carolina. There is no such facility in North Carolina (Table 1). Wool scouring is accomplished by processes including sorting, blending, slashing, desuinting, washing, drying, and top making. Wastes are generated at almost every step as shown in Figure 2. Sources of waste constituents are dirt and dust on the natural fiber, grease and oils plus vegetable matter on the natural fiber, wasted wool, fly, sweeps, chemicals and detergents used in various processes, and non-reusable process water. Total estimated production rate of wool top by the 17 plants in U.S. is 69 million kg/year.

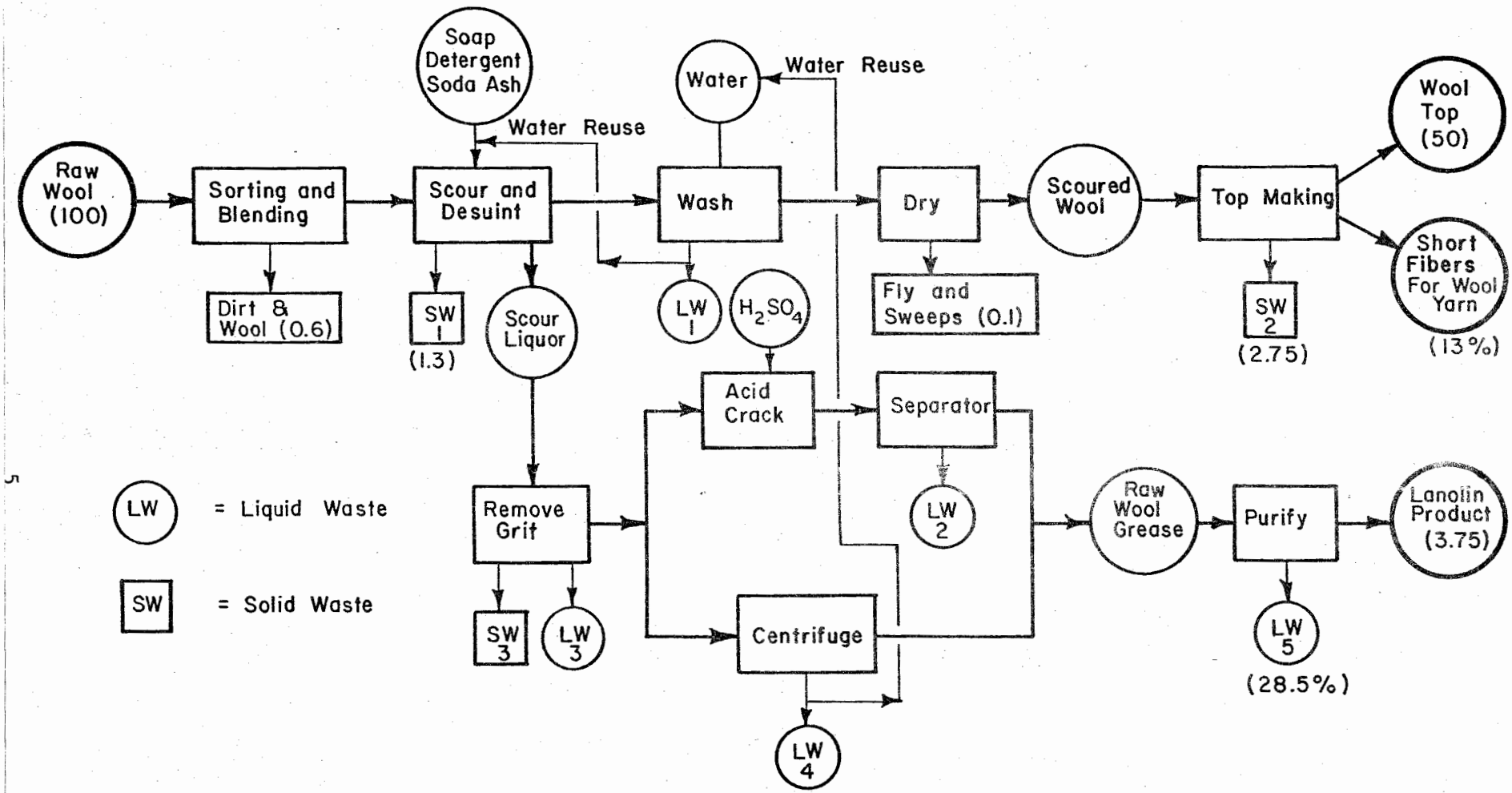


Figure 2. Scouring and wool top manufacturing processes.

Table 1. Segmentation of Textile Industry based on raw material, products manufactured, and process operations.

Category	Mills in North Carolina	Mills in U.S.	Rate of Waste Generation, kg dry waste/1000 kg product
wool top manufacture	0	17	1445
wool dyeing and finish	9	112	160
woven fabric dyeing & finish	104	651	100
knit fabric dyeing & finish	326	738	78
carpet dyeing & finish	6	144	40
yarn/stock dyeing & finish	85	345	21

2) Wool Fabric Dyeing and Finish: This segment of the textile mill industry is principally located in Massachusetts, New Jersey, New York, Pennsylvania, North Carolina, Maine, Georgia, South Carolina, Connecticut, and Oregon. Wool top is the raw material for these mills. Mill processes include bleaching, rinsing, dyeing, washing, spinning, fulling, carbonizing, warping, sizing, and special finishing. These various steps are outlined in Figure 3. Liquid or solid waste results from each step in different amounts depending on the kind and amount of process chemicals, detergents and water used. The total estimated production rate of finished wool fabric in 112 U.S. mills is 309 million kg per year.

3) Woven Fabric Dyeing and Finish. This segment of the textile industry is primarily situated in North Carolina, New Jersey, Massachusetts, Georgia, South Carolina, Pennsylvania, Rhode Island, Virginia, Tennessee, Alabama, California, and Connecticut. North Carolina alone represents 17% of the United States total. Woven greige goods are the raw material for these mills where desizing, scouring, washing, mercerizing, bleaching, dyeing or printing, and finishing are performed for the production of woven fabric. Liquid wastes generated during various operations (Figure 4) include components such as water, enzymes, sulfuric acid, scouring or slashing agents, caustic soda, hydrogen peroxide, dyes, finishing agents, other process chemicals, detergents, and human wastes from employees. The total estimated production rate of woven fabric is about 1.80 billion kg per year in 651 mills (Table 1).

4) Knit Fabric Dyeing and Finish. North Carolina is the leading state in knit fabric manufacture utilizing knit griege goods as the raw material. Other states that have attracted the knit fabric producing mills are Pennsylvania, New Jersey, Tennessee, Georgia, South Carolina, Virginia, Massachusetts, California,

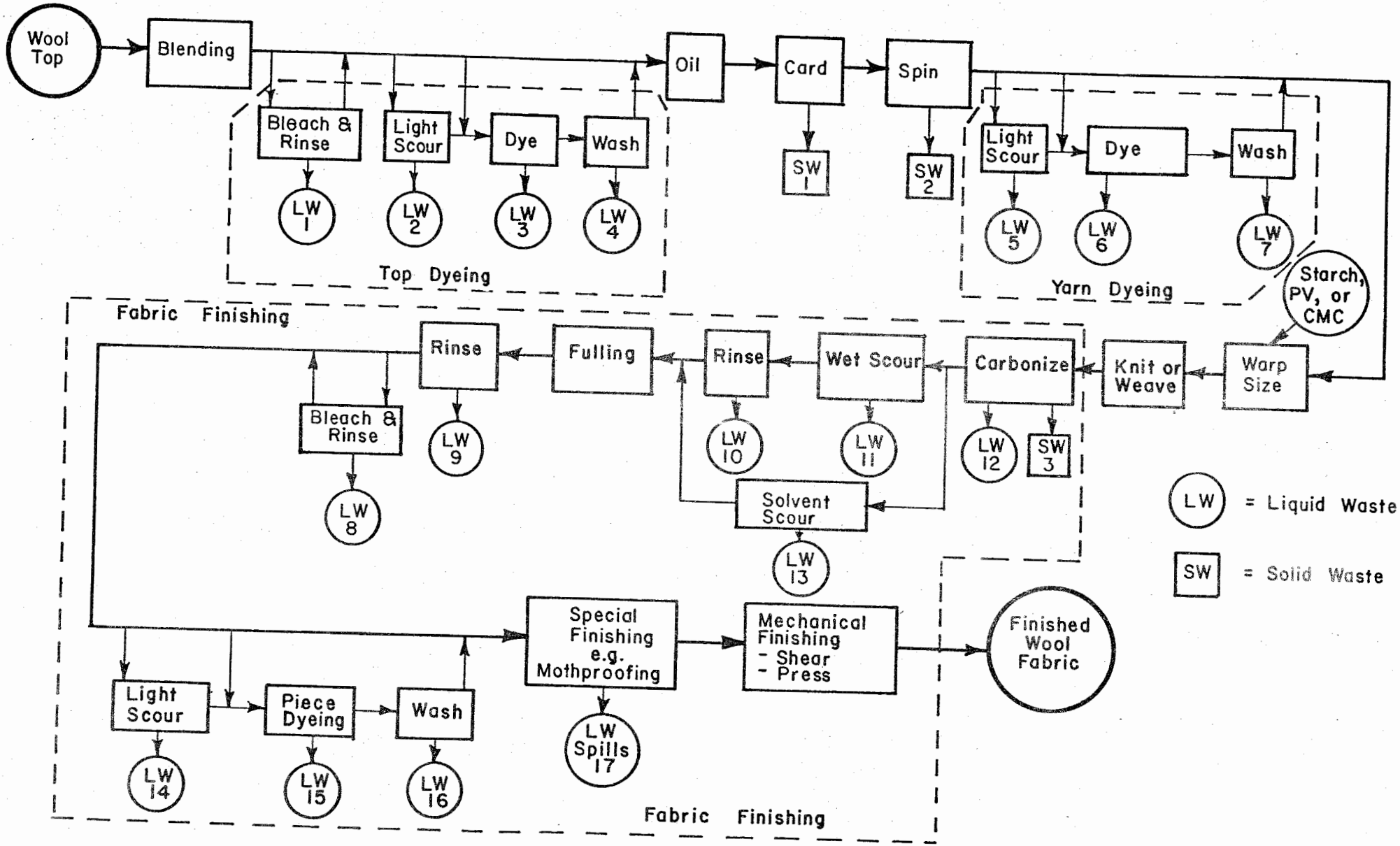


Figure 3. Wool fabric dyeing and finishing processes.

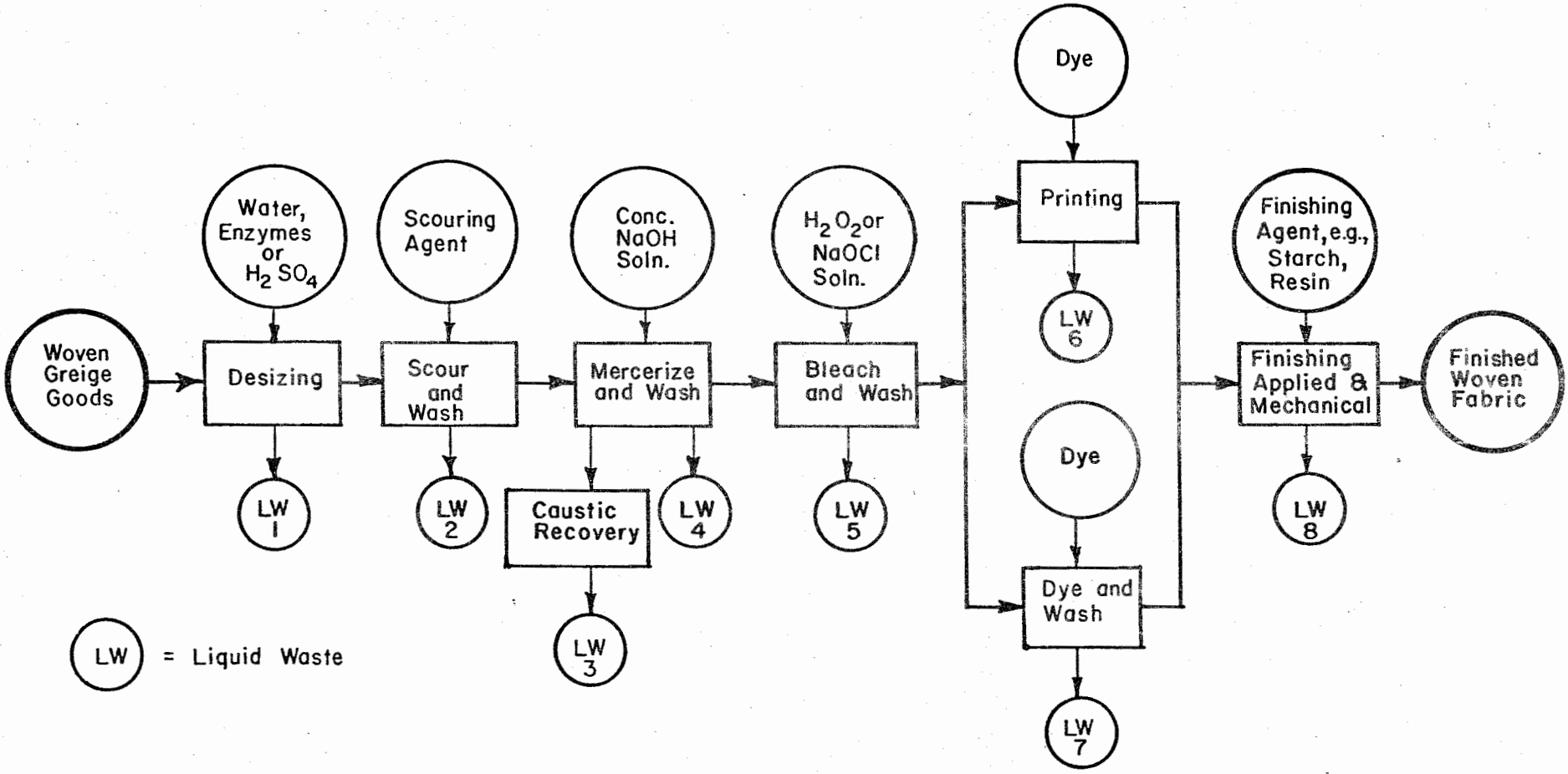


Figure 4. Woven fabric dyeing and finishing processes.

Rhode Island, and Wisconsin. Various processes (Figure 5) which these mills carry out are kier scouring, bleaching, washing, dyeing, drying, printing, wet pad finishing, and dry finishing. The waste sources are the lost raw material, process water, detergents, and chemicals. Total production rate of finished knit goods is estimated close to 770 million kg per year by 738 mills in the U.S.

5) Carpet Dyeing and Finish: These operations are carried out largely in Georgia, California, North Carolina, South Carolina, Pennsylvania, Tennessee, and New York. An important raw material for this segment of the textile industry is yarn which undergoes tufting, piece dyeing or printing, drying, latex backing or foaming, and finishing operations. Liquid and solid wastes generated during different processes are shown in Figure 6. Total annual production rate of finished carpet by 144 mills in the U.S. is projected nearly 679 million kg per year.

6) Yarn and Stock Dyeing and Finish. North Carolina is again a leading state in this segment of the textile industry, followed by Georgia, Pennsylvania, New Jersey, Rhode Island, Massachusetts, South Carolina, Texas, Alabama, California, and Illinois. Various processes that generate wastes during stock and yarn dyeing and finishing operations are mercerizing, bleaching, washing, dyeing, and finishing (Figure 7). The major raw materials used for finished yarn or stock manufacture are cotton or cotton blend yarn or stock and synthetic fiber yarn. The liquid wastes originate from process chemicals, detergents, and water. The annual production rate of finished yarn or stock is 8.3 billion kg per year from 345 mills in the U.S.

WASTE GENERATION RATE AND CHARACTERIZATION

An average size textile mill was used as the design basis in each segment of the industry. The total waste flow from such average size plants are shown in Table 2. Water is used in large amounts compared to other process chemicals in all segments of the textile mill industry. Waste characterization of average size plants was accomplished by use of available information from various sources (Rawlings, 1978; Versar, Inc., Springfield, Virginia, 1976; Jones, 1973; EPA Development Document, 1974). A variety of important parameters needed for land treatment design were selected, as well as other constituents of secondary interest. The mass generation of each waste constituent was obtained using total waste volume. The waste generation rate from various sources are presented in Tables 3, 4, 5, 6, 7, and 8. The overall design process requires evaluations on an individual parameter basis. Such an approach is required to i) safely as well as satisfactorily assimilate each waste parameter in the soil-plant system, ii) make decisions

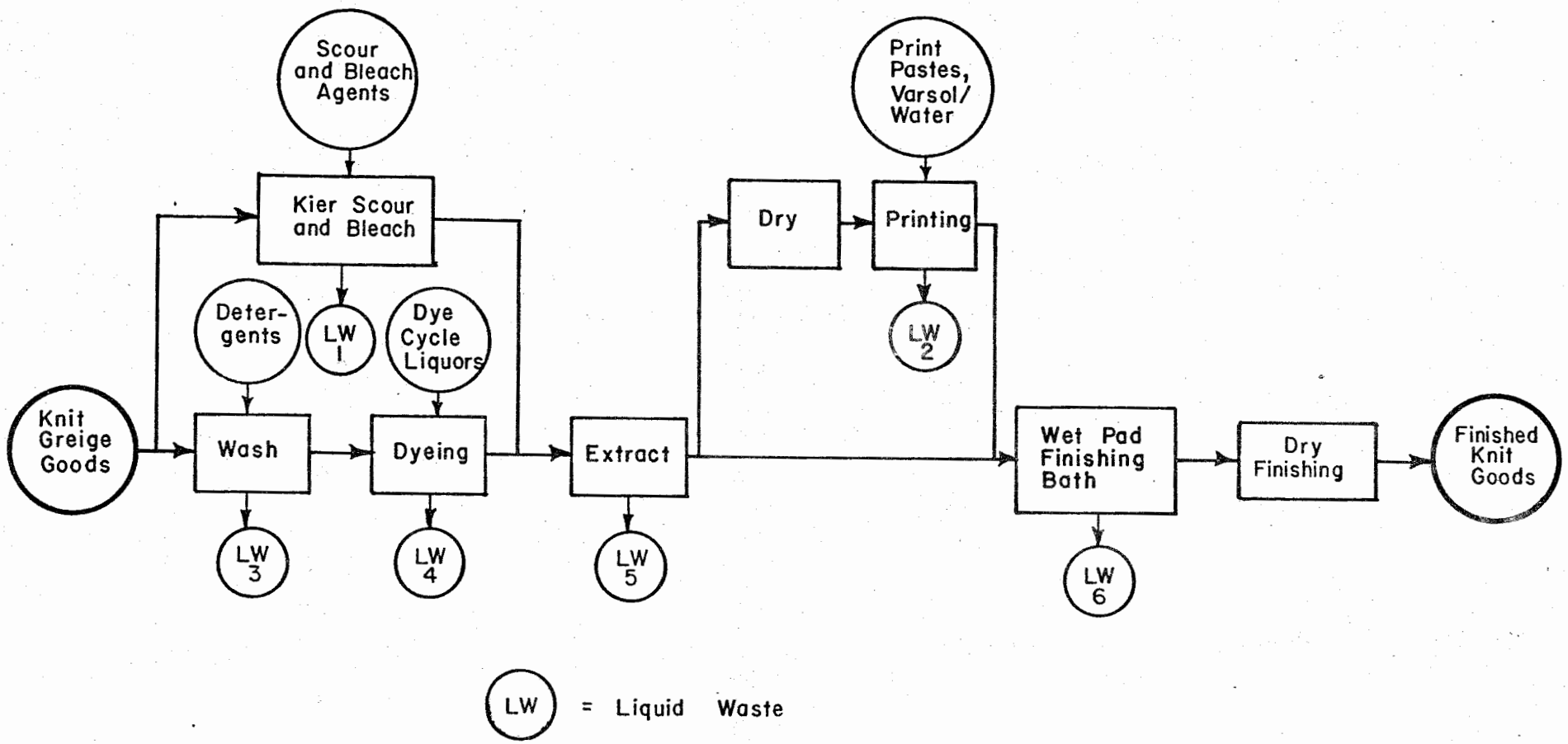


Figure 5. Knit fabric dyeing and finishing processes.

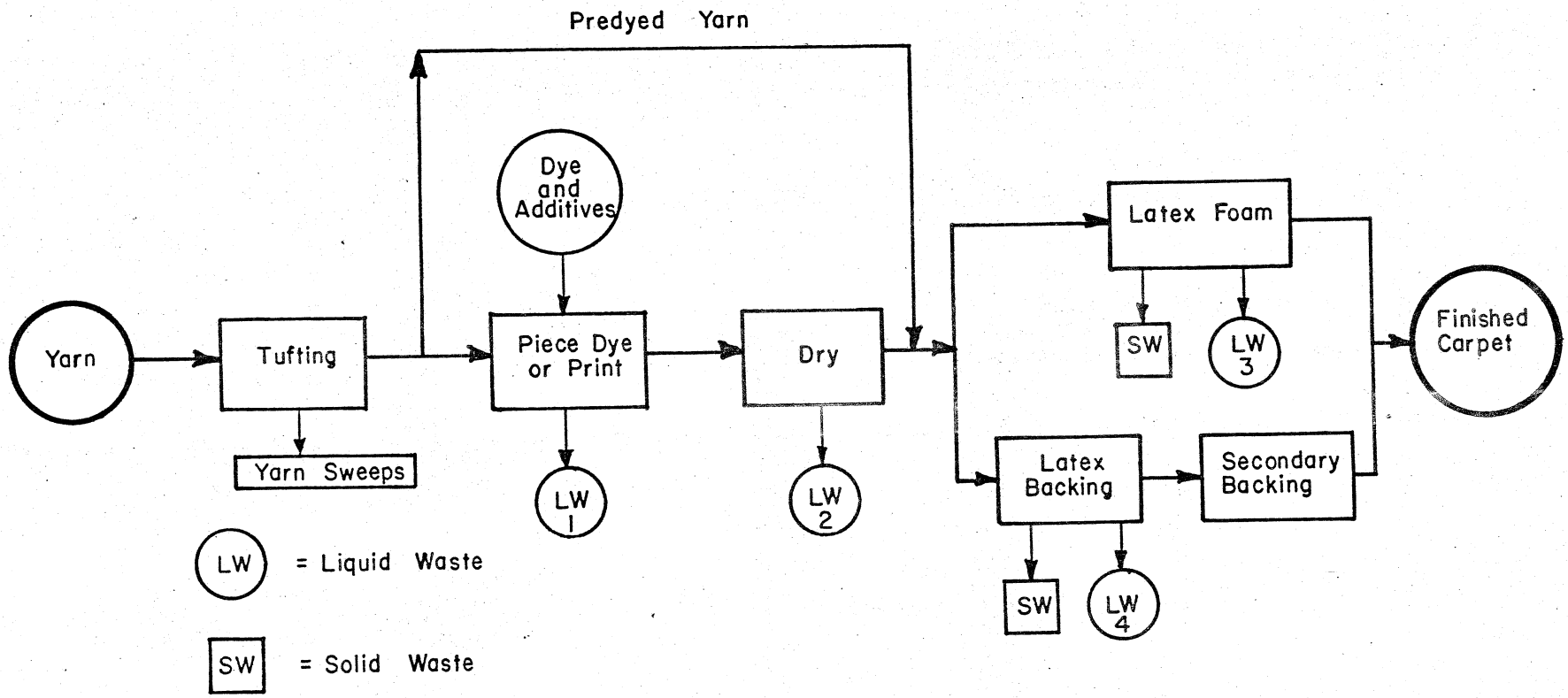


Figure 6. Carpet dyeing and finishing processes.

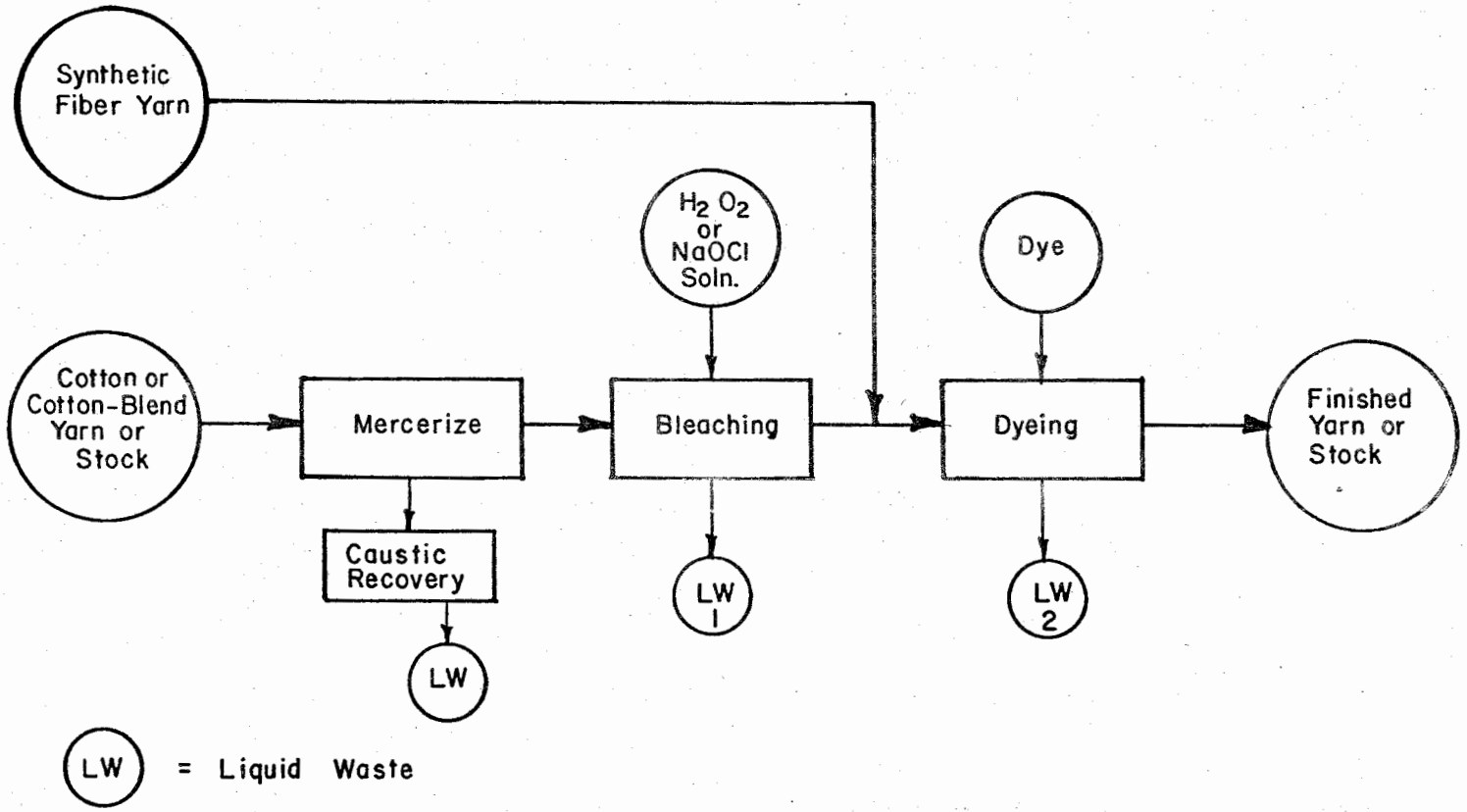


Figure 7. Yarn and stock dyeing and finishing processes.

Table 2. Average Size of Plants in Various Segments of the Textile Industry.

Category	Size of Plant million kg of product/year	Total waste flow kg/year	Volume of wastewater l/year	% water in waste
Scouring & wool top manufacture	5	6×10^7	5.2×10^7	87.3
Wool dyeing & finishing	5	2×10^6	1.13×10^6	56.5
Woven fabric dyeing & finishing	5	2.6×10^7	2.5×10^7	98.0
Knit fabric dyeing & finish	2	2×10^5	4.3×10^4	21.5
Carpet dyeing & finishing	10	4.8×10^5	7.54×10^4	15.7
Yarn/stock dyeing & finishing	10	5×10^5	2.9×10^5	58.0

Table 3. Waste characteristics of an average size plant.

Wool Scouring and Top Manufacture, 5 millon kg product/year.

Parameter	mg/l* (1)	kg/yr** (2)	Parameter	mg/l* (1)	kg/yr** (2)
Total Flow	6×10^7 ℓ/d	6.0×10^7	Metals		
Water	-	5.2×10^7	Fe	5.7	300
BOD	84	6,100	Mn	0.9	47
COD	837	61,000	Zn	0.19	9.9
TS	50,000	3.6×10^6	Ba	0.33	17
TDS	1,650	-	Pb	0.06	3.1
SS	220	11,500	Cr	0.012	0.62
Total organics	15	780.0	Cu	0.02	1
NH_4-N	0.38	19.8	Ni	0.06	3.1
NO_3-N	12.5	650	Sb	.013	.68
P	1.7	88.4	V	0.14	7.3
Cl	1.2	62.4	Ti	0.035	1.8
SO_4	LDL	LDL	Sn	0.03	1.6
H_2S	0.1	5.2	Si	15	780
Ca	94	4,900	Mo	0.021	1.1
Mg	12	620	Co	0.14	7.3
K	660	3,400	Cd	0.013	0.68
Na	8.3	430	As	0.004	0.21
pH	9	-	Hg	0.0005	0.026
SAR	0.214	-	Sr	21.6	1,100
EC	1.25 mmhos/cm	-	Al	0.77	40
Dissolved oxygen	5	260	Ag	0.095	4.9
Total Alkalinity +	950	49,400	B	0.44	22.9

*mg/l unless other units given

**kg/yr unless other units given.

+expressed as calcium carbonate equivalent.

LDL lower than detection limits.

Table 4. Waste characteristics of an average size plant.

Wool Dyeing and finishing, 5 x 10^6 kg/yr.

Parameter	mg/l* (1)	kg/yr** (2)	Parameter	mg/l* (1)	kg/yr** (2)
Total Flow		2 million	Metals		
Water		1.13 million	Fe	4.7	5.3
BOD	400	1.74 kg/d	Mn	1.1	1.2
COD	1,700	7.2 kg/d	Zn	7.5	8.5
TS	600	2.61 kg/d	Ba	0.16	0.18
TDS	1,700	2,000	Pb	0.66	0.75
SS	230	260	Cr	0.88	0.99
Total organics	64	72	Cu	0.021	0.024
NH_4-N	13	15	Ni	0.03	0.034
NO_3-N	5.5	6.2	Sb	0.002	0.0023
P	5.2	5.8	V	0.037	0.042
Cl	1.1	1.2	Ti	0.01	0.011
SO_4	8.5	9.6	Sn	0.012	0.014
H_2S	0.1	0.11	Si	6.9	7.8
Ca	170.	190	Mo	0.008	0.009
Mg	10	11	Co	0.03	0.034
K	8.8	9.9	Cd	0.046	0.05
Na	180	200	As	<17	<19
pH	9.0		Hg	0.004	0.005
SAR	3.6		Sr	170	190
EC	1.5 mmhos/cm		Al	0.29	0.33
Dissolved oxygen	7		Ag	0.002	0.002
Total Alkalinity†	100		B	0.058	0.066

*Units in mg/ℓ unless given.

**Units in kg/yr unless given.

†Expressed as calcium carbonate equivalent.

Table 5. Waste characteristics of an average size plant.

Woven Fabric Dyeing and Finishing, 5×10^6 kg product/yr.

Parameter	mg/l* (1)	kg/yr** (2)	Parameter	mg/l* (1)	kg/yr** (2)
Total Flow		2.6×10^7	Metals		
Water		2.5×10^7	Fe	0.4	10
BOD	24	2.30 kg/d	Mn	0.1	2.5
COD	130	12 kg/d	Zn	0.3	7.5
TS			Ba	0.04	1.0
TDS	1,700	160 kg/d	Pb	0.12	3.0
SS	24	2.30 kg/d	Cr	0.05	1.3
Total organics	15	370	Cu	0.3	7.5
NH_4-N	3.4	85	Ni	0.15	3.8
NO_3-N	23.3	580	Sb	0.007	0.18
P	4	100	V	0.058	1.5
Cl	0.04	1.08	Ti	0.012	0.3
SO_4	40	1,000	Sn	0.05	1.3
H_2S	0.2	5	Si	11.0	280
Ca	21	525	Mo	0.02	0.5
Mg	14	350	Co	0.007	0.18
K	79	2,000	Cd	0.005	0.13
Na	190	4,750	As	0.006	0.15
pH	7.5		Hg	0.0009	0.023
SAR	7.9		Sr	16	400
EC	1.2 mmhos/cm		Al	0.16	4
Dissolved oxygen	7		Ag	0.06	1.5
Total alkalinity†	6.9	170	B	0.53	13

*mg/ℓ unless other units given

**kg/yr unless other units given.

†Expressed as calcium carbonate equivalent.

Table 6. Waste characteristics of an average size plant.

Knit Fabric Dyeing and Finishing 2×10^6 kg product/yr.

Parameter	mg/l* (1)	kg/yr** (2)	Parameter	mg/l* (1)	kg/yr** (2)
Total Flow		2.0×10^5	Metals		
Water		43,000	Fe	0.22	0.044
BOD	59	0.01 kg/d	Mn	0.03	0.006
COD	1,000	0.17 kg/d	Zn	0.12	0.024
TS			Ba	0.028	0.0056
TDS	690	140	Pb	0.032	0.0064
SS	350	70	Cr	0.024	0.0048
Total organics	14	2.7	Cu	0.084	0.017
NH_4-N	73	15	Ni	0.10	0.02
NO_3-N	4.4	0.88	Sb	0.05	0.01
P	5.0	1	V	0.022	0.0044
Cl	2.5	0.5	Ti	0.001	0.0002
SO_4	150	30	Sn	0.004	0.0008
H_2S	0.3	0.06	Si	8.4	1.7
Ca	27	5.4	Mo	0.008	0.0016
Mg	15	3.0	Co	0.007	0.0014
K	10	2.0	Cd	0.007	0.0014
Na	490	98.0	As	<4.8	0.96
pH	7.5		Hg	0.001	0.0002
SAR	18.7		Sr	15	3
EC	0.64 mmhos/cm		Al	0.62	0.12
Dissolved oxygen	7.1	1.4	Ag	0.03	0.006
Total alkalinity†	140	27.0	B	0.52	0.1

*mg/ℓ unless other units given.

**kg/yr unless other units given.

†Expressed as calcium carbonate equivalent.

Table 7. Waste characteristics of an average size plant.

Carpeting, Dyeing and Finishing, 10^7 kg product/yr.

Parameter	mg/l* (1)	kg/yr** (2)	Parameter	mg/l* (1)	kg/yr** (2)
Total Flow		4.8×10^5	Metals		
Water	2.9×10^2 ℓ/d	7.5×10^4 ℓ/yr	Fe	0.39	0.03
BOD	42	0.012 kg/d	Mn	0.05	0.004
COD	500	0.15 kg/d	Zn	0.45	0.034
TS			Ba	0.015	0.0011
TDS	280	20.8	Pb	0.006	0.0005
SS	5	0.38	Cr	0.004	9
Total organics	27	2.1	Cu	0.063	0.005
NH_4-N	73	5.5	Ni	49	3.7
NO_3-N	1.4	0.1	Sb	0.05	0.004
P	6.1	0.46	V	0.021	0.0016
Cl	1.1	0.08	Ti	0.011	0.0008
SO_4	56	4.2	Sn	0.025	0.002
H_2S	<2	<0.15	Si	2.8	0.21
Ca	16	1.20	Mo	0.003	0.0002
Mg	1.4	0.011	Co	0.011	0.0008
K	2	0.15	Cd	10	0.75
Na	48	3.6	As	<10	0.75
pH	7.5	0.57	Hg	0.028	0.002
SAR	3.1		Sr	33	2.5
EC	0.15 mmhos/cm		Al	0.52	0.04
Dissolved oxygen	8	0.6	Ag	0.009	0.0006
Total alkalinity†	30	2.3	B	0.46	0.035

*mg/ℓ unless other units given.

**kg/yr unless other units given.

†Expressed as calcium carbonate equivalent.

Table 8. Waste characteristics of an average size plant.

Yarn & Stock Dyeing and Finishing, 10^7 Product/yr.

Parameter	mg/l* (1)	kg/yr** (2)	Parameter	mg/l* (1)	kg/yr** (2)
Total Flow		5×10^5 kg/yr	Metals		
Water		2.9×10^5	Fe	0.18	0.05
BOD	13	0.015 kg/d	Mn	0.044	0.013
COD	230	0.26 kg/d	Zn	0.72	0.21
TS			Ba	0.029	0.0084
TDS	730	210	Pb	0.036	0.01
SS	42	12	Cr	0.026	0.0075
Total organics	18	5.3	Cu	0.11	0.032
NH_4-N	0.5	0.15	Ni	0.035	0.01
NO_3-N	14	4.2	Sb	0.005	0.002
P	2.2	0.64	V	0.032	0.009
Cl	2.1	0.61	Ti	0.0013	0.0004
SO_4	460	130	Sn	0.007	0.002
H_2S	3	0.87	Si	8.2	2.3
Ca	110	32	Mo	0.015	0.0044
Mg	4.6	1.3	Co	0.026	0.0075
K	5.3	1.54	Cd	<2.5	<0.73
Na	78	22.6	As	<2.5	<0.73
pH	5.8		Hg	0.66	0.19
SAR	1.4		Sr	40	11.6
EC	0.50 mmhos/cm		Al	0.076	0.022
Dissolved oxygen	4	1.2	Ag	0.001	0.0003
Total alkalinity†	30	8.7	B	6.1	1.77

*mg/ℓ unless other units given.

**kg/yr unless other units given.

†Expressed as calcium carbonate equivalent.

related to correct design, life span of a land application site, methods and scheduling of land application operations, specific pretreatment requirements, and other management factors, and iii) assess economics of the overall system in the short as well as long term.

SOIL ASSIMILATIVE CAPACITY

Assimilation of waste constituents by a soil-plant system is determined by the soil and site characteristics, choice of the crop for vegetative cover, environmental conditions, and management factors. Hence the soil assimilative capacity of all waste constituents is very site specific. For the initial estimation of land treatment technology in the textile mill industry, certain representative site conditions were used. These conditions were common to a number of actual industrial land treatment sites in Southeastern states (Kimbrough, 1979).

Two benchmark soils -- sandy loam and clay loam -- were chosen for the determination of the assimilative capacity. The characteristics of these two soils, representative topographic features, the vegetative cover, rainfall, and other environmental variables are considered for evaluation of each parameter in proper perspective as discussed below.

An in-depth discussion of assimilative mechanisms, quantitative criteria, and required calculations may be found in Overcash and Pal (1979). Since the detailed calculations have been covered in several other sources and since only representative case study values for waste and site properties are used, extensive discussion of assimilative capacity is not included. The focus is on the approximate land area and land limiting constituents so that textile mill management can assess land treatment potential.

WATER

On a well drained sandy loam, the permeability of the surface soil is expected to be high, 5 to 10 cm/hr, compared to a clay loam with lower permeability, 0.5 - 2 cm/hr. The two soils were located on a 5% - 8% slope with 500 m to natural lateral drainage outlets. From detailed field borings to 5 m over the site and subsequent hydraulic property testing, the site-specific water movement properties were established. Hydraulic analysis revealed about 50% deep movement for the clay loam. Simulating rain inputs from North Carolina, evapotranspiration, and soil-water move-

ment over a 25 year cycle the hydraulic assimilative capacity was determined. For year round application potential the sandy loam could receive 2.5 cm/week while the clay loam could assimilate 1.5 cm/week.

NITROGEN

Crop uptake and ultimate harvesting of nitrogen lead to the satisfactory assimilation of this waste constituent. Substantial losses of nitrogen occur by volatilization, immobilization and denitrification. As a result, about 1.25 times the crop uptake has been recognized as the sandy soil assimilative capacity, if crops are harvested from the application site (Carlile 1976). For clayey soil, the assimilative capacity can be taken as 1.5 times the crop uptake because of greater potential of N losses by denitrification and immobilization in a clay soil. Nitrogen uptake by various crops have been referenced by Carlile 1976, Overcash and Pal 1979, and EPA 1977. Using a double crop scheme of Coastal Bermudagrass and annual rye on the sandy soil, assimilative capacity is taken as 750 kg N/ha/year. For clay loam soil, the same crop pattern would lead to an assimilative capacity of 900 kg N/ha/year. This double cropping scheme is quite an intensive management effort at maximizing the N assimilative capacity. A less intensive scheme would result in lower N utilization, but could be accomodated in the design in a manner similar to the procedure described.

PHOSPHORUS

The assimilative capacity for the phosphorus constituent is based on crop uptake and soil ability to retain or fix phosphates. From the determination of the P-adsorption maximum from soil samples collected at a site, the zone of soil assimilation (200 cm), and the projected system life (50 years), the annual soil fixation capacity was determined (Overcash and Pal, 1979). To this was added the annual crop uptake of P for a double crop of Coastal Bermudagrass overseeded with rye. The resultant plant-soil assimilative capacity for phosphorus was 280 and 1400 kg/ha/year for the sandy loam and clay loam soils, respectively.

SALTS

Salts are present in all irrigation waters and the salts of textile mill wastewater would behave in soils similar to that of any irrigation water applied to land. When the evapotranspiration from a soil-plant system on an annual basis exceeds the total water input by precipitation or irrigation it is expected that the probability of soils to become salt-affected in the surface is high. Considerable amounts of good quality water would then have to be applied to leach the salts through the root zone. In regions where annual rainfall exceeds the evapotranspiration and

adequate natural or artificial drainage systems exist, no long term build-up of salts in the soil surface is expected. Wastewaters from the six segments of the textile mill industry possess salts much below the critical concentration limits for irrigation water (Table 9). Thus no salinity build up or salt concentration restrictions for these wastes in soils of Southeastern United States is anticipated.

In addition to salinity, sodium imbalance must be considered in industrial land treatment design. From the measured concentration of the Ca, Mg, and Na, the sodium adsorption ratio (SAR) was calculated as follows:

$$SAR = \frac{Na^{+}}{[(Ca^{++} + Mg^{++})/2]^{1/2}}$$

where Na^{+}, Ca^{++}, Mg^{++} concentrations are expressed in meq/1. The values of SAR obtained by the above calculation is given below in Table 9 for each segment of the industry.

Table 9. Electrical conductivity (EC) and Sodium Adsorption Ratio (SAR) of the textile industry wastewater.

Industry Wastewater	EC mmhos/cm	SAR
Wool scouring	1.25	0.2
Wool finishing	1.5	3.6
Woven fabric finishing	1.2	7.8
Knit fabric finishing	0.64	18.7
Carpet finishing	0.15	3.1
Yarn and stock finishing	0.55	1.4
Critical level for irrigation	>2	>12

Since the SAR values of all segments, but knit fabric finishing, are much less than the critical value, no problem may occur with regard to the Na hazard in land application systems. The wastewater from knit fabric dyeing and finishing is nonsaline but sodic with SAR value exceeding the critical level. This wastewater must be pretreated probably using in-plant source control (Kimbrough 1979) to bring down the SAR value below 12. The other five segments have EC and SAR values which are much less than those of irrigation water and can thus be applied on most soils under farming conditions at a reasonable irrigation rate and schedule.

ANIONS (Arsenate, Chloride, Borate)

The anionic species of industrial waste may be applied to land at rates determined by allowable concentrations in ground or surface waters. That is, using drinking water standards and the second calculational tool described in the land treatment design section early in this report, the required land areas were determined. For the anionic species it is more convenient to determine the land area directly for each constituent rather than calculate the assimilative capacity followed by the land area requirement. The constituent land area is what is utilized in the LLC analysis.

The water standards selected for usage were drinking water criteria, where available, so that liquid reaching receiving waters is better in quality than that required for public health standards. Concentration values are given in Table 10. Mass balance equations have been developed to determine land area as follows.

$$A = \frac{(C_i - C_D)}{D_r[C_D(1-\alpha)-C_r]} \quad [100\ Q]$$

where

A is area, m^2

C_i is the concentration of the anionic species in the industrial waste

C_D is the concentration of the anionic species in the soil-water draining to receiving waters e.g. drinking water standard

D_r is the rainfall input, cm

α is the ratio of evaporative losses to rainfall as determined by geotechnical and vegetation investigation of water movement

C_r is the concentration of the anionic species in the rainfall

Q is the industrial waste volume, m^3/yr.

If the anionic parameter concentration in the waste is less than the receiving water criteria then there is no area requirement per se for that constituent. That is, liquid with that low a concentration would be tolerable, for that particular constituent, in any receiving water. Thus no restriction for land application exists with respect to that constituent. Results of these calculations for anionic species in each textile mill subcategory are presented in Table 11.

Table 10. Anionic species concentrations for liquid reaching receiving waters.

Compound	Drinking water recommendation, mg/ℓ
As	0.05
B	0.75*
Cℓ	125

*Irrigation water criteria only.

Table 11. Area requirements for anionic species in textile mill waste.

Segment	Constituent	Area, ha		
		As	B	Cℓ
Wool scouring		0*	0	0
Wool dyeing and finishing		<44	0	0
Woven fabric finishing		0	0	0
Knit fabric finishing		0.47	0	0
Carpet finishing		1.7	0	0
Yarn and stock finishing		1.6	0.23	0

*Waste concentration less than drinking water standard - area = 0.

SULFUR

Sulfide applied to a recommended land treatment system, in which predominantly aerobic soil conditions are maintained, will be readily oxidized to sulfate. Hence the assimilative capacity is based on total sulfur and the plant-soil response to sulfate.

Crop uptake can be used as a conservative method to determine sulfate assimilative capacity. Again, a double crop management plan of Coastal Bermudagrass and annual rye would assimilate 70 kg S/ha/yr. Since a restrictive receiving water concentration of sulfate is 250 mg/ℓ, considerably more assimilative capacity exists beyond crop uptake. However further modification would be more prudently done using actual site characteristics.

METALS

Assimilative capacity for essential and non-essential metals is dictated by the long-term accumulation in the surface zone and the projected time of use of the application site. As a first estimate, the surface 15 cm is considered the usable treatment zone. From the U.S. EPA (1976), Illinois EPA, the Council of Agriculture Report (1976), and a thorough search of literature, the safe accumulation levels for a sandy soil (CEC 5 meq/100 g) and clayey soil (CEC 15 meq/100 g) were established as shown in Table 12.

A projected site life of 50 years was used to allow for long term waste treatment. Alternative longer or shorter periods may be substituted based on individual corporate policy. That is, after reaching these design life times, the soil-plant system will have reached a level of acceptable agricultural limit of heavy metals and a new site will have to be selected. It is clear from Table 12 that soil assimilative capacity for Cd is the lowest and for Si is the highest.

Table 12. Permissible Heavy Metal Loadings.

Parameter	Loamy Sand (CEC 5meq/100 g)			Clay Loam (CEC 15meq/100g)		
	Accumulation Limit* kg/ha	Annual Loading 100 yr kg/ha/yr	50 yr	Accumulation Limit* kg/ha	Annual Loading 100 yr kg/ha/yr	50 yr
Fe	5,000	50.0	100	10,000	100.0	200
Mn	500	5.0	10	1,500	15.0	30
Zn	250	2.5	5	1,000	10.0	20
Ba	100	1.0	2	1,000	10.0	20
Pb	500	5.0	10	2,000	20.0	40
Cr	125	1.25	2.5	500	5.0	10
Cu	125	1.25	2.5	500	5.0	10
Ni	50	0.5	1.0	200	2.0	4
V	100	1.0	2.0	500	5.0	10
Ti	500	5.0	10.0	2,000	20.0	40
Sn	250	2.5	5.0	1,000	10.0	20
Si	10,000	100.0	200	10,000	100.0	200
Mo	10	0.1	0.2	20	0.2	0.4
Co	50	0.5	1.0	200	2.0	4.0
Cd	5	0.05	0.1	20	0.2	0.4
Hg	25	0.25	0.5	100	1.0	2.0
Sr	1,000	10.2	20	2,000	20.0	40.0
Al	5,000	50.0	100	10,000	100.0	200.0
Ag	100	1.0	2.0	200	2.0	4.0
Sb	200	2.0	4.0	500	5.0	10.0

*The accumulation limits are good only in neutral soils (pH 7 - 7.5) that are maintained aerobic. Soil pH is never allowed to go below 6.5, nor any extensive leaching or surface erosion is anticipated to move metal-sediments into streams.

ALKALINITY

For normal soils, the wastewater should possess neutral pH. For acid soils, alkaline wastewaters can be applied for a few years as such to correct soil acidity but as soon as soil pH is raised between 6.5 and 7.5, the alkaline wastewaters from wool scouring, dyeing and finishing operations must be neutralized by sulfuric or phosphoric acids to lower pH from 9 to 7 prior to land application. Wastewater from other segments of the textile

mill industry shows a neutral reaction with pH ranging from 5.8 for yarn and stock dyeing and finishing to 7.5 for knit and woven fabric finishing and carpet dyeing and finishing operations. These wastes would be satisfactorily assimilated by most soils without any problems emanating from the alkalinity.

ORGANICS AND OXYGEN DEMAND

Under aerobic conditions, organics are broken down by soil microorganisms at a much faster pace than under anaerobic conditions. In other words, the soil assimilative capacity for many, if not all, organics is higher under aerobic situations than under anaerobic conditions. To maintain aerobic decomposition, the oxygen demand of a wastewater should not exceed the available oxygen supply. The daily reaeration rates calculated for the benchmark soils are 2,300 kg/ha/wk for the sandy loam and 960 kg/ha/wk for the clay loam (Carlile 1976). Total oxygen demand (TOD) of the wastewater is defined as total carbonaceous demand (roughly equal to chemical oxygen demand, COD) plus the oxygen required to nitrify all the ammonia and organic - N.

$$TOD = COD + 4.56\ (NH_4\text{-}N + \text{organic N})$$

The computed values of TOD for all segments of the textile industry considered in this report are presented in Table 13. Total oxygen demand of the entire waste from all segments is less than a daily aeration rate of both soil types and if the irrigation schedule is every other day on one hectare land area, oxygen supply should not limit land assimilation of total organics.

Table 13. Total Oxygen Demand (TOD) of the Organics in the Textile Industry Wastewater.

Segment	Waste TOD in kg/day
Wool scouring	167.8
Wool dyeing and finishing	7.4
Woven fabric finishing	13.8
Knit fabric finishing	0.23
Carpet dyeing and finishing	0.24
Yarn & stock dyeing and finishing	0.26

LAND LIMITING CONSTITUENT ANALYSIS AND PRELIMINARY ECONOMIC EVALUATION

At this stage in the analysis of land treatment, the waste has been characterized on a constituent-by-constituent basis for an average size plant in each textile mill subcategory. Correspondingly, the plant-soil assimilative capacity has been determined for all constituents; although such values are only representative since actual site data can require substantial alterations. For this report two representative soils and a site life of 50 years have been used.

Comparison of waste constituent generation, kg/yr, with plant-soil assimilative capacity, kg/ha/yr, establishes the land treatment area for each parameter. Then the waste component needing the largest land area is the controlling or land limiting constituent (LLC). Use of the LLC area will assure that all the other constituents are applied to a much larger area than would be required by assimilative capacity alone. Thus the LLC analysis,

i) defines the critical waste parameters controlling the land treatment area and performance

ii) determines the actual land requirements for the particular textile mill and site data under consideration.

The LLC analysis for each subcategory is given in Table 14. A summary of the LLC(s) and total land areas for each soil and textile mill subcategory has been prepared in Table 15. Next to be determined was, how can this information be effectively used?

For each textile mill subcategory, the land area needed for the average size plant (Table 2) to take advantage of land treatment technology is displayed in Table 15. A difference between the sandy loam and the clay loam soils is presented as well as the difference in area for the LLC versus the second and/or third constituents affecting land area. That is, if these chemical analyses and waste flows were verified for an average mill then the area associated with the LLC would be needed for land treatment.

The reader should note that for some textile mill categories, the difference between the area for the most restrictive constituent, the LLC, and the second or next lowest area requirement is very large (3-6 times). This signifies the real importance and savings of reducing the LLC usually in process and obtaining a good chemical analysis of the waste. Thus in the following economic analyses the cost of a land treatment is based on the area for the LLC as well as that assuming the LLC is removed and the second greatest constituent requirement is applicable.

Table 14. Land Area Required for Different Constituents of Industrial Waste in 6 Segments of the Textile Mill Industry.

Parameter	Assimilative Capacity		Wool Scouring			Dyeing and Finish			Woven Fabric Finish			Knit Fabric Finish			Carpet Dyeing & Finish			Yarn & Stock Dyeing		
	Loamy Sand	Clay Loam	WGR	Land Area, ha		WGR	Land Area, ha		WGR	Land Area, ha		WGR	Land Area, ha		WGR	Land Area, ha		WGR	Land Area, ha	
	kg/ha/yr		kg/yr	LS	CL	kg/yr	LS	CL	kg/yr	LS	CL	kg/yr	LS	CL	kg/yr	LS	CL	kg/yr	LS	CL
Water	2.5 cm/wk	1.5 cm/wk	10ha cm/wk	4	6.7	0.22cm/wk	0.1	0.15	4.8	1.9	3.2	0.0083	0.003	0.006	0.015	0.006	0.01	0.056	0.022	0.037
Organics T.O.C.	$1.2x10^5$	5×10^5	44,000	0.36	0.09	1900	0.016	0.004	3,600	0.03	0.007	60	0.0005	0.00012	62	0.005	0.00013	68	0.0006	0.00014
K	310	370	3,400	11.0	9.2	10.0	0.03	0.03	2,000	6.4	5.3	2.0	0.006	0.005	0.15	0.001	0.0004	1.5	0.005	0.004
TKN	750	900	670	0.89	1.8	21	0.028	0.055	670	0.89	8	15	0.021	0.061	5.37	0.0074	0.015	4.3	0.0058	0.012
P	280	1,400	88	0.31	0.06	5.9	0.021	0.004	100.0	0.36	0.07	1.0	0.0040	0.0010	0.46	0.002	0.003	0.64	0.002	0.004
Cl			62			1.2			1.1			0.5			0.83			0.6		
SO_4	70	70	0	0	0	9.6	0.14	0.14	1,000	14	14	30	0.43	0.43	4.22	0.06	0.06	130	1.9	1.9
S	20	10	5.2	0.26	0.52	0.11	0.006	0.011	5.0	0.25	0.5	0.06	0.003	0.006	0.15	0.0075	0.015	0.87	0.044	0.087
AsO_4			0.21			19	44	44	0.15			0.96	0.47	0.47	0.75	1.7	1.7	0.73	1.6	1.6
Borate			23	0	0	0.066	0	0	13	0	0	0.10	0	0	0.035	0	0	1.8	0.23	0.23
Mo	0.5	2.5	1.1	2.2	0.44	0.009	0.018	0.0036	0.5	1.0	0.2	0.0016	0.0032	0.0006	0.0002	0.0004	0.0001	0.004	0.0088	0.0018
Fe	100	200	300	3.0	1.5	5.3	0.15	0.027	10.0	0.1	0.05	0.044	0.0004	0.0002	0.029	0.0003	0.00015	0.052	0.0005	0.00025
Mn	10	30	47	4.7	1.6	1.2	0.12	0.04	2.5	0.25	0.08	0.006	0.0006	0.0002	0.004	0.0004	0.00013	0.013	0.0013	0.0004
Zn	5	20	10	2.0	0.5	8.5	1.7	0.43	1.5	1.5	0.38	0.024	0.0048	0.0012	0.034	0.006	0.0015	0.21	0.04	0.001
Ba	2	20	17	8.5	0.85	0.18	0.09	0.009	1.0	0.5	0.05	0.006	0.003	0.0003	0.001	0.0005	0	0.008	0.0042	0.0004
Pb	10	40	3	0.3	0.08	0.75	0.075	0.019	3.0	0.3	0.08	0.006	0.0006	0.00015	0.0005	0.00005	0.00001	0.010	0.001	0.00025
Cr	2.5	10	0.6	0.24	0.06	0.99	0.4	0.10	1.3	0.5	0.13	0.005	0.002	0.0005	0.0003	0.00012	0.00003	0.0075	0.003	0.00075
Cu	2.5	10	1.0	0.4	0.1	0.024	0.01	0.0024	7.5	0.19	0.75	0.017	0.0068	0.0017	0.005	0.02	0.0005	0.032	0.013	0.0032
Ni	1	4	3.0	3.0	0.75	0.034	0.034	0.0085	3.8	3.8	0.96	0.02	0.02	0.005	3.7	3.7	0.93	0.010	0.01	0.0025
Ti	10	40	1.8	0.18	0.045	0.011	0.0011	0.0003	0.3	0.03	0.008	0.0002	0	0	0.0008	0	0	0.0004	0	0
Sn	5	20	1.6	0.32	0.08	0.014	0.0028	0.0007	1.3	0.25	0.062	0.0008	0	0	0.0020	0.0004	0.0001	0.0020	0.0004	0.0001
Si	200	200	780	3.9	3.9	7.8	0.039	0.039	280	1.4	1.4	1.7	0.0084	0.0084	0.21	0.0011	0.0011	2.318	0.012	0.12
Co	1	4	7.3	7.3	1.8	0.034	0.034	0.0085	0.18	0.8	0.044	0.0014	0.0014	0.0004	0.0008	0.0008	0.0002	0.0075	0.0075	0.002
Cd	0.1	0.4	0.7	7.0	1.75	0.052	0.52	0.13	0.13	1.3	0.31	0.0014	0.014	0.004	0.75	7.5	1.9	<0.73	7.3	<1.81
Hg	0.5	2	0.03	0.06	0.015	0.005	0.01	0.0025	0.023	0.046	0.012	0.0002	0.0004	0.0001	0.0021	0.004	0.001	0.19	0.38	0.1
Sr	20	40	1,100	66	33	190	9.6	4.8	400.0	20.0	10.0	3.0	0.15	0.075	2.5	0.13	0.062	11.6	0.560	0.2
Al	100	200	40	0.4	0.2	0.33	0.0033	0.002	4.0	0.04	0.02	0.12	0.0012	0.0006	0.039	0.0003	0.00015	0.022	0.00022	0.00011
Ag	2	4	5	2.5	1.25	0.0023	0.0012	0.0006	1.5	0.75	0.38	0.006	0.003	0.0015	0.0006	0.0003	0.00015	0.0003	0.00015	0.00008
V	2	10	7.3	3.7	0.73	0.042	0.021	0.0042	1.45	0.72	0.14	0.0044	0.0022	0.0004	0.0016	0.0008	0.0002	0.0093	0.0045	0.0009
Sb	4	10	0.67	0.17	0.07	0.0023	0.0006	0.0002	0.18	0.044	0.018	0.011	0.0028	0.001	0.004	0.001	0.0004	0.0015	0.0005	0.0002
pH	6.5-7.5	6.5-7.5	9.00			9.0	-	-	7.5	-	-	7.5	-	-	7.5	-	-	5.8	-	-
E.C., mmhos/cm	2	2	1.3			1.5	-	-	1.2	-	-	0.64	-	-	0.16	-	-	0.56	-	-
SAR	12	12	0.21			3.6	-	-	7.9	-	-	19	-	-	3.08	-	-	1.4	-	-
Land Limiting Constituents				Sr K	Sr K H_2O		As Sr	As Sr		Sr SO_4 K	SO_4 Sr K		As SO_4 Sr SAR	As SO_4 SAR			Cd Ni As	Cd As Ni		Cd SO_4 As	SO_4 Cd As

WGR - Waste generation rate, LS - loamy sand, CL - clay loam

Table 15. Land Limiting Constituents in the Textile Mill Industrial Category.

Subcategory	Sandy Loam		Clay Loam	
	LLC	Area, ha	LLC	Area, ha
Wool scouring	Sr	66	Sr	33
	K	11	K	9.2
			H_2O	6.7
Wool dyeing and finishing	As	44	As	44
	Sr	9.6	Sr	4.8
Woven fabric finishing	SO_4	20	SO_4	14
	Sr	14	Sr	10
	K	6.4	K	5.3
Knit fabric finishing	As	0.47	As	0.47
	SO_4	0.43	SO_4	0.43
	Sr	0.15	SAR	-
	SAR	-		
Carpet dyeing and finishing	Cd	7.5	Cd	1.9
	Ni	3.7	As	1.7
	As	1.7	Ni	0.93
Yarn and stock dyeing	Cd	7.3	SO_4	1.9
	SO_4	1.9	Cd	1.8
	As	1.6	As	1.6

Table 16. Economic Estimates for Land Treatment of Entire Textile Mill Raw Waste.

Segment	Total Raw Waste		Total Raw Waste with Inplant Removal of LLC	
	Approximate total investment cost, thousand dollars		Approximate total investment costs, thousand dollars	
	clay loam site	sandy loam site	clay loam site	sandy loam site
Wool scouring	250 - 600	500 - 1,200	70 - 160	80 - 190
Wool dyeing and finishing	330 - 770	330 - 770	70 - 170	35 - 85
Woven fabric dyeing and finishing	100 - 230	150 - 350	75 - 175	100 - 230
Knit fabric dyeing and finishing	3.5 - 8	3.5 - 8	3 - 7.5	3 - 7.5
Carpet dyeing and finishing	15 - 35	55 - 130	13 - 30	30 - 65
Yarn/stock dyeing and finishing	14 - 33	55 - 130	14 - 33	14 - 33

The area for land treatment may be already owned or may be acquired within a radius of about two miles of the textile mill. Based on preliminary data from a variety of industrial land treatment systems (Nutter 1978), a very simplified economic analysis was prepared for each textile mill subcategory. In Table 16, the initial investment cost range was determined to allow management and environmental personnel in the textile mill industry to assess the use of land treatment technology. These costs include the complete land system e.g. transmission, storage, application system, monitoring, vegetative cover, pumps and pumphouse, purchase of land, etc. For those wastes in which pH or sodium imbalance was of concern the cost of in-plant source control or pretreatment would have to be added to these land system costs to determine the total investment.

The results on Table 15 can be used to further reduce the cost of land treatment. The LLC is the parameter controlling the required land area, so a reduction in the LLC can reduce the land system size. In each textile mill a program could be implemented to assess the feasibility and cost of reducing the mass of LLC generated. Each subcategory and each soil type would require a different pretreatment or in-plant program. Thus the identification of the LLC is important in attempting to reduce the cost of the total system via pretreatment or in attempting to reduce the area requirements to fit available land.

The results in Tables 15 and 16 emphasize the importance of site-specific data in the design of land treatment. Between two common soils used in this report, the land area requirement for a given waste changed in some subcategories by a factor of 2. In other instances, the actual constituent controlling the land area and subsequent design changed depending on the site conditions. Thus actual design must be based on detailed field testing at intended sites.

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