OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

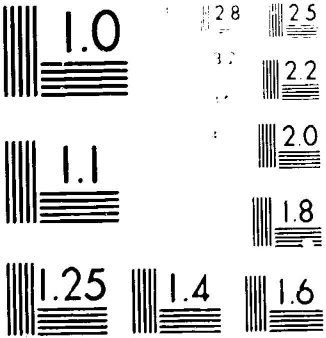
FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org


1.0
2.8
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

09774

Distr.
LIMITED
UNIDO/ICO.366
3 January 1980
ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TEXTILE MONOGRAPHS
UF/GLO/78/115

THE PROVISION, STORAGE AND HANDLING OF DYES AND CHEMICALS FOR TEXTILE DYEING, PRINTING AND FINISHING

Based on the work of I. Holme, Ph.D., C.Text., FTI, C.Col., F.S.D.C.
Lecturer, Department of Textile Industries,
The University of Leeds, England

~~000131~~

000132

80-30207

THE PROVISION, STORAGE AND HANDLING OF DYES AND CHEMICALS FOR TEXTILE DYEING, PRINTING AND FINISHING

Based on the work of I. Holme, Ph.D., C.Text., FTI, C.Col., F.S.D.C.
Lecturer, Department of Textile Industries,
The University of Leeds, England

Explanatory notes

The following abbreviations have been used:

CI Colour Index

S.D.C. Society of Dyers and Colourists

The views expressed are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

Mention of firm names and commercial products does not imply the endorsement of UNIDO.

CONTENTS

Chapter		Page
	INTRODUCTION	5
I.	THE SELECTION AND EVALUATION OF DYES, CHEMICALS AND FINISHES	7
	Technical specifications for the product	7
	Location of suitable products and suppliers	7
	Acquirement of samples	7
	Technical evaluation of the samples	8
	Commercial evaluation	12
	Test methods	12
	Colour value	13
	Evaluation in small-scale equipment	15
	Evaluation on a works trial basis	15
	Quality control	15
	Sampling	16
	Testing of auxiliaries, finishes and chemicals	16
	Evaluation of materials for textile printing	17
II.	SUPPLY OF MATERIALS AND STOCK CONTROL	18
	Provision of supplies	18
	Stock control	20
III.	PACKAGING AND STORAGE	27
	Packaging of materials	27
	Storage	27
IV.	DISPENSING METHODS	32
	Role of the dye store and colour kitchen	32
	Weighing	36
	Practical considerations in weighing and dispensing	39
	Measuring volume	40
	Metering systems	40
	Mixing	41
	Mixing equipment	42
V.	HEALTH AND SAFETY	44
	Chemical hazards	44
	Airborne contamination	48
	Fire and explosion hazards	48
	Hazards of materials used	49
	Appropriate control procedures	50

Preventive measures and environmental pollution control in dyestores and colour kitchens............................ 51

Health and safety considerations in dyestores and colour kitchens.. 51

Storage time limits.. 54

Safety precautions, training and the role of management..... 54

Industrial hygiene and safe working practice............... 54

Effluent disposal.. 55

Emergency planning... 56

The role of plant management................................. 57

REFERENCES.. 58

Specimen table for commercial evaluation of dyes............ 14

INTRODUCTION

Wet processing transforms often dirty and unattractive fibres, yarns and fabrics into marketable textile products with considerable added value largely by varying the style, design, colour and finish. In addition, it enhances the aesthetic and textural properties of the material and renders the performance and durability of the finished product suitable for the intended end-use.

Wet processing includes:

Preparation (desizing, scouring and bleaching etc.)

Coloration (dyeing or printing)

Chemical finishing (softening, resin, durable press, water repellent and flame-retardant finishing etc.)

The planning, direction, organization and control of the provision, storage and handling of all dyes, pigments, finishes, chemicals and auxiliaries used is vital. The reputation of a firm in coloration and finishing for quality, consistency and reliability depends largely on the correct selection and use of chemically based products. Of particular importance are the criteria determining the selection and evaluation of products, and the factors that lead to optimum storage and handling facilities.

In European countries dyes and chemicals have been claimed to contribute some 22-30 per cent of the total dyehouse costs in a modern dyehouse (1-3). In developing countries this may be as high as 35 per cent depending upon whether products are locally manufactured or imported (4,5). The price largely depends upon oil-based products, therefore, the dramatic escalation in the prices of such products is creating considerable financial pressures, particularly in countries where there are foreign exchange problems and no indigenous chemical industry.

The lack of essential products for preparation, coloration and finishing processes can lead to production stoppages, costly production rescheduling, late delivery dates, a deterioration in management-labour relations, and a loss of customer goodwill and future business. This situation is magnified in multiproduct, multifibre and multimachine production plants where the control problems increase with the diversity of the finished textile fabrics produced (6). Therefore, the plant management team, particularly those concerned with purchasing, technical control and production, must work together to optimize the resources of the plant in order to obtain maximum machine utilization efficiency and continuity of production while minimizing costs.

This monograph is designed to provide practical guidelines for controlling the provision, storage and handling of dyes and chemicals in dyeing, printing and finishing plants. The importance of selection and evaluation procedures is discussed in chapter I, with particular reference to dyes, which account for the major raw-materials costs in coloration processes (6).

Control of the dye and chemical inventory requires considerable expertise and knowledge of the network of complex relationships that encompass manufacturers, suppliers, government departments, communications and transport services, and technical, production and sales management. The practical approaches to the control problems of maintaining stocks at an adequate service level are outlined in chapter II.

Individual plant requirements in respect of the packaging, storage and handling of dyes and chemicals vary widely. Possible solutions to the problems of servicing both batchwise and continuous processing units are considered in chapter III, with particular attention being paid to the advantages and limitations of bulk storage systems.

Efficient utilization of the dyestore, and in particular of the colour kitchen, is essential to provide the correct quantities of the necessary products, dispensed in the required form ready for instant use. This is an integral part of the production sequence that is too often neglected leading to a down-grading in finished fabric quality. The many problems posed are described in chapter IV and appropriate procedures suggested to promote greater efficiency, flexibility and overall process control.

There are hazards in the use of such chemicals as dyes, pigments, finishes and auxiliaries, and it is essential that all personnel who handle or are otherwise exposed to such products should be aware of these hazards. Plant management must take a responsible attitude to the handling and disposal of chemical products and to environmental control. The design and implementation of appropriate preventative measures and control procedures to reduce potential chemical hazards both inside and outside the plant are discussed in chapter V, in which some practical guidelines for industrial hygiene and safe working practices are laid down.

I. THE SELECTION AND EVALUATION OF DYES, CHEMICALS AND FINISHES

The procedures involved in the selection and technical evaluation of products for use in coloration and finishing processes depend upon the exact nature of the process, but for dyes, normally include the following:

A definition of the technical specifications for the product
Location of suitable products and suppliers
Acquirement of samples
Technical evaluation of the samples
Commercial evaluation on a price-strength basis
Test methods
Colour value
Evaluation in small-scale equipment
Evaluation on a works trial basis
Quality control
Sampling
Testing of auxiliaries, finishes and chemicals
Evaluation of materials for textile printing

Technical specifications for the product

The substrate and performance requirements for processing and for the intended end use should be clearly defined. These are often specified in detail by the customer, together with a yarn or fabric sample for matching purposes.

Location of suitable products and suppliers

Those charged with the responsibility of product selection and evaluation should have access to detailed sources of information. For day-to-day operation the excellent technical information provided by most of the major dyestuff and chemical suppliers should be stored in the works laboratory, thus facilitating rapid preliminary comparison of pattern cards for colour, fastness etc. The Colour Index (CI), together with the Additions and Amendments to the Colour Index, is an invaluable source of information on colorants (7).

Product guides to auxiliaries, finishes and chemicals, are issued annually in some countries (8,9) and directories of chemical suppliers provide a short list of suppliers, together with limited information on their products. In such publications, the detailed chemical composition and concentration of auxiliaries and finishes are often not specified, for these may consist of complex mixtures specially formulated for highly specific end uses.

Acquirement of samples

Samples of the bulk material should be obtained fresh from the suppliers in dated airtight containers (10). Samples often deteriorate on storage under works laboratory conditions or absorb moisture from the atmosphere thereby leading to difficulties in technical evaluation.

Commercial dyes for textile coloration are marketed at a strength convenient for storage, handling and use. Many contain diluents such as sodium chloride, sodium sulphate, soda ash, phosphates and solubilizing agents, for example, dextrin; anti-dusting varieties also contain small traces of products based, for example, on mineral oils; and other dyes contain dispersing agents (6). The nature and amount of the additives present may affect the dyeing behaviour of the actual dye, for which reason dyes of the same Colour Index number but from different manufacturers may vary in terms of the tinctorial strength on the substrate (10).

The additives present in a commercial dye may alter the uptake of moisture according to the atmospheric conditions so that strict control over this variable by the use of airtight containers is required where price-strength relationships are under evaluation (11-13).

While the strength tolerance for dyes is generally $\pm 2\frac{1}{2}$ per cent of standard, the presence of manufacturing impurities, different amounts of stereochemical isomers or shading dyes in different deliveries may lead to problems of build-up or fastness (6,10). Metameric effects between dyes of the same Colour Index number but from different sources are not unknown.

These factors must be carefully studied where product substitution on the grounds of price alone is attempted. Inadequate evaluation may lead to severe financial penalties resulting from increased matching costs and additions, stripping and redyeing, lower quality and reduced machine utilization efficiency that will often far outweigh the benefits.

Technical evaluation of the samples

The main factors of practical importance for dyes (12) are:

Ease of application and levelness obtained

Tinctorial strength on the substrate to be dyed

Coverage of possible irregularities in the substrate - an important consideration for continuous filament and textured yarns of nylon or polyester

Fastness properties - using standard methods wherever possible and standard adjacent fabrics or multifibre fabric

Compatibility with other dyes to obtain the maximum colour gamut with the minimum number of dyes

Physical state, solubility and particle size

Effects of normal after-treatments on the colour or fastness of the dyed materials e.g. syntanning or backtanning of dyed nylon

Effects on effluent - dyes of high exhaustion minimize effluent problems.

It is essential that the application method for use in bulk dyeing is established for the class of dyes under investigation. This includes the standardization of:

- Choice of auxiliary products
- pH control
- Rate of temperature rise
- Dyeing temperature
- Dyeing time
- Liquor-to-goods ratio
- Washing-off procedure
- Drying and conditioning method

These should be as close as possible to the conditions normally employed in bulk dyeings.

For most purposes yarn and fabric are more convenient substrates for the technical evaluation of dyes and an adequate stock of uniformly scoured or bleached material should be stored to give a consistent moisture regain (10). Substrate uniformity is essential if reproducibility of repeat dyeings is to be obtained.

A wide variety of laboratory dyeing machines utilizing stainless-steel pots are available including single or multibath machines for operation under atmospheric or high temperature conditions with time and/or temperature programmed control. Reproducibility is improved by using these machines particularly if the weights and volumes of the products used are carefully measured (12,14). Freshly made up standard solutions of dyes should be used in all evaluations. The control of pH buffer systems is a particularly important factor in determining the exhaustion of the dyebath (15).

<u>Ease of application and levelness obtained</u>

Any difficulties in dissolving or dispersing, or in the application using the standardized procedure, should be noted. The level dyeing properties may be assessed by the S.D.C. migration test (16) or by a combined strike-migration test (17). In the former test equal weights of dyed and undyed material are boiled in a blank dyebath for an hour and the dye that migrates to the undyed sample is estimated by means of the ISO Grey Scale. In the strike-migration test the dyebath is prepared and brought to the boil. Samples of undyed material of equal weight are entered over a period of one hour and boiling continued for a further hour followed by drying and assessment.

Tinctorial strength on the substrate to be dyed

The colour and build-up properties of the dyes under test are studied by dyeing out to a number of standard depths, as appropriate for the substrate and dye class involved. These dyeings may then be subjected to assessment by standard methods of fastness testing (see below). Similarly evaluations of prints by the strike-off method at a series of depths of colour using standardized conditions for diluting the stock thickener, solvents, fixing agents, and for application, fixation and wash-off can be employed.

Coverage of possible irregularities in the substrate

The coverage of possible irregularities in the substrate is particularly important for synthetic fibres in textured yarn form. Fabrics that contain known yarn irregularities can often be prepared by judicious selection of materials and then used to assess the coverage properties of the dyes. Particular care must be exercised in the control of temperature and in the use of carriers that can exert marked effects both on levelling and migration.

Fastness properties

Standard methods of test and assessment should be performed, the methods selected being appropriate for the end use of the dyed material (18) unless special demands are made by the customer.

Strict control over the sample size and test conditions is essential and standard adjacent fabrics should be employed. The use of multifibre adjacent fabric has been described (19) and is useful if staining on more than one fibre is required. However, no other adjacent fabric should be present in the test as this would affect the degree of staining obtained.

Fastness to wet and dry rubbing (crock fastness) is important for heavy depth prints and pigment prints where the performance of the binder used is crucial. Lower standards of light and wash fastness are often acceptable on prints compared with dyed materials.

Compatibility with other dyes

The temperature-strike characteristics of the dye may often be determined by a modification of the strike-migration test (12). The dyebath is prepared and equal weight pieces of fabric are entered and removed successively from the dyebath while the temperature is being raised slowly to the boil and boiling continued for 30 minutes. The strike-migration and temperature-strike tests are particularly valuable for assessing the compatibility of three colour combinations, particularly where these are selected from the ranges of different dye manufacturers. A method for the assessment of the compatibility of cationic dyes on acrylic fibres has also been published (20).

Physical state, solubility and particle size

The physical state, solubility and particle size are of great importance for printing. Methods for determining the solubility of dyes have been described (21, 22) and information is often available from the dyemaker. Information on particle size is of particular value for the beam and package dyeing of disperse dyes; methods employing polyester and cotton fabric (23), or two layers of Whatman No. 4 filter paper sandwiching a piece of cotton poplin (5) have been described. In the latter method it is suggested (5) that the dispersion should leave no residue (a) immediately after preparation; (b) after heating for 10 minutes at 40°C; and (c) after boiling for 30 minutes.

The recommendations of the dyemaker for the correct preparation of the dispersion should be carefully followed.

Effects of normal after-treatments

The effects of normal after-treatments, such as fixing agents, soaping-off processes, softeners, syntanning and backtanning processes, must be assessed in relation to the change in colour under various conditions of illumination and to the change in colour produced as a result of the after-treatment itself. Particular attention must be paid to colour fastness after any subsequent heating or steaming treatments, which often decrease the fastness of heavily dyed materials, particularly when dyed with disperse dyes.

Effects on effluent

The effect on effluent must always be considered in the light of local conditions and statutory regulations. Dyes of high exhaustion are preferable (13) but they are often affected adversely by variations in pH and in liquor-to-goods ratio in production dyeing. The use of biodegradable materials, particularly for detergents and auxiliaries, should be practised wherever possible, and advice may be obtained from manufacturers, water authorities and the relevant government departments. The reduction in effluent charges through using biodegradable materials is an increasingly important cost factor in countries where strict compliance with the regulations is mandatory (6).

Commercial evaluation

In some cases, certain speciality dyes may be chosen because of (a) the nature of special dyeing techniques; (b) fastness considerations; or (c) brilliance of hue. In most cases however the choice is between a number of dyes that are listed as equivalent to each other in the Colour Index and available from a number of suppliers. Evaluation is thus essential to select the product that gives the best colour value on the substrate with regard to price (10, 12).

If identical dyes are to be tested then it is normal to choose one as the standard against which all the other dyes are assessed for strength and value. The choice should be an equivalent dye that is already being used in bulk, if possible, or the dye with the highest technical performance from among the new products under test.

Test methods

The general problems of commercial standardization of dyes and methods employed have been discussed in detail elsewhere (24). The storage and indexing of authentic standard samples must be carried out with care (25,26), and dyes should be obtained from the manufacturer in marked airtight containers. It is essential to obtain a sample, particularly for liquids and pastes, which may require homogenizing. For powders, the top layer of dye should be avoided as this may differ in moisture content (10, 13).

Strength differences between deliveries are often larger than the corresponding differences within a batch, but overall most reputable dyemakers standardize to a tolerance of $\pm$ 2½ per cent as regards strength. From the users' viewpoint $\pm$ 5 per cent is considered satisfactory although there are exceptions (10).

Moisture content should not exceed 3 per cent and is normally determined by accurately weighing approximately 1 g of dye in a weighing bottle, followed by drying to constant weight, taking care not to char or volatilize the dye (10). Drying at room temperature in a desiccator is slow; low temperature drying aided by cooling and drying in a desiccator (preferably under vacuum) may be more rapid. Alternatively, the Dean and Stark distillation method may be employed (27). The moisture content is calculated as a percentage and taken into consideration in any subsequent colour value measurements that are carried out.

Colour value

In optical determinations of the dye solution it is suggested (10) that 0.5 g of dye is weighed (in a weighing bottle) to four decimal places on a suitable analytical balance. The dye is dissolved or dispersed in distilled or deionized water and made up to 1 litre in a volumetric flask. Between 10 ml and 50 ml of this solution is added to 100 ml of a suitable solvent for the dye together with 5 ml of an appropriate buffer solution; this is then made up to 250 ml in a volumetric flask and measured as soon as possible on a suitable instrument. A wide variety of instruments are available ranging from relatively simple types, such as the Hilger Spekker, to more sophisticated and expensive machines of the Unicam SP1800 type. It is important that dye solutions should not be left too long before measurement as some dyes fade rapidly and others exhibit turbidity due to dispersing or anti-dusting agents. At least 10 ml of the solution should be taken for measurement, and the pH must be kept constant to obtain reproducible results. Recommendations on suitable buffers and solvents have been given for specific dye classes, but if the optical reading remains stable it can be taken as an accurate indication for selection (10).

In many cases, sophisticated equipment will not be available in small and medium-sized dyehouses. Recourse must therefore be made to preparing a fresh set of dye solutions or dispersions for the dyes under test and testing these at a series of standard depths. The depths vary according to colour, type and application but, for example, pale depths could be represented by 0.25, 0.3 and 0.35 per cent on the weight of fibre (o.w.f.) and medium depths by 0.95, 1.0 and 1.05 per cent o.w.f.; mordant dyes are dyed at 1.0, 1.05, 1.1 and 3 per cent o.w.f.; and blacks at depths required to give a full black, for example, generally between 4-6 per cent o.w.f. However, the standard depths will vary according to the dye-fibre combination and the degree of exhaustion, and the appropriate depths must be established by trials in the works laboratory.

The dyeings should give a clear indication of the build-up properties of the dyes and a fair assessment of the degree of exhaustion may be obtained by examining the dyebaths at the end of dyeing. Alternatively the depth on the fibre can be determined instrumentally. It should be particularly noted if there is any tendency to build up off-tone as this may be indicative of shading colours.

Paper chromatographic or thin layer chromatographic techniques have been described (28,29) for determining the shading components used; sprinkling some of the powder on wet filter paper may prove to be a relatively quick though not infallible test. If shading dyes are found to be present during the evaluation, the fastness to washing, particularly to multiple laundering, should be checked as this can often give rise to complaints.

Optical measurements are only a guide to dye strength, the actual tinctorial value on the fibre must always be assessed by carrying out laboratory dyeings simulating bulk dyeing conditions. In addition the fastness and levelling properties and compatability, hue and cost play a major role. A check should be made for metameric effects, for example, when six samples of C.I. Basic Red 18 were studied it was shown (10) that three samples were metameric compared with the standard. This can create difficulties when replacing an existing dye that is already used in bulk.

The evaluation of comparative ratings demands that dyeings at a corrected strength against the standard are carried out so that true results can be obtained. Fastness properties can vary from dye to dye and in some dye classes, for example, disperse dyes, further complications are evident where the physical form of the dye affects the ease of dispersing. Differences in dyeing behaviour, colour and fastness can be obtained depending on the dyeing temperature and particularly on the auxiliary products employed in the dyebath.

All price-strength evaluations should be recorded in tabular form as shown in the table together with the appropriate fastness ratings observed for the depths of shade studied and the date of the evaluation. These can then be filed for future reference which, provided that the prices are updated, facilitates the rapid evaluation of alternative dyes if the dye originally selected for bulk use becomes unavailable from the normal supplier.

Specimen table for commercial evaluation of dyes
Colour Index number

Commercial name	Supplier	Strength against standard (%)	Price quoted per kg	Corrected price per kg
A (Standard)	A	100	6.62	6.62
B	B	95	7.40	7.79
C	C	100	7.74	7.74
D	D	90	6.64	7.38
E	E	108	6.70	6.20

It is common when fibre merge numbers are changed that difficulties occur in build up, levelness or fastness compared with the previous merge. Similar differences may be obtained between fibres supplied by different fibre producers, and particular care should be taken to ensure that materials classed as nylon be clearly differentiated as nylon 6 or nylon 66, for the dyeing properties of such fibres vary widely.

Evaluation in small-scale equipment

In certain instances it may be considered desirable to evaluate dyes before use in bulk using small-scale equipment, for example, a single package dyeing machine. Providing the machinery and the liquor-to-goods ratio are similar to those used in bulk, useful supplementary information concerning exhaustion, levelling, filtration and fastness properties may be obtained. The trials must be adequately supervised and all aspects of the dyeing cycle carefully monitored.

Evaluation on a works trial basis

Evaluation on a works trial basis should be carried out by normal production dyers but should be monitored in the normal manner for matching, build-up or fastness problems by a member of the works laboratory, if the dye is to be extensively used. A short report should be written and filed together with the results of appropriate fastness tests. Any adverse reports on the bulk use of the dye should be investigated to establish the true nature of any dissatisfaction.

Quality control

Testing

Where large weights of dye are involved or where the financial value of the dye is high, quality control testing of dye deliveries should be conducted (10) provided that the equipment and trained personnel are available.

All such dyes must be tested by dyeing or printing trials against the standard samples stored in the works laboratory. In one practical case check testing of dye strength in this manner against a standard substrate enabled a package dyeing unit to achieve 85 per cent of dyeings that did not require further additions (10).

Standards

Dye deliveries ± 5 per cent of standard have generally been considered satisfactory, but in critical areas, such as sewing threads, tolerances may be lower and the level of moisture content may be an important factor. Practical experience has shown that dye deliveries tend more to be off-tone than to vary in strength, while metamerism can sometimes be found between delivery and standard. Tolerance of shading colour is 5 per cent of approved dyes. If the delivery consists of drums from different dye batches, samples from both batches should be checked. Particular attention should be devoted to dyes that are components of essential three-colour mixings or are used in large quantities, for variations in strength or hue can lead to a considerable reduction in machine utilization efficiency.

Sampling

Great care must be taken to obtain a representative sample, and random or core sampling followed by homogenization of the final sample is usually practised. Again the top layers of dye in the drum should be avoided and both the optical density and the check dyeings should be carried out at two standard depths, for example, 0.25 per cent and 1 per cent o.w.f. Dyeings must always be carried out on standard substrates to check for depth and hue. Standard forms can be prepared on which the drum number, batch number and all other relevant details may be recorded. The test results are normally recorded on this form and where desired dyed samples or chromatograms may also be mounted. Conclusions and action should be noted and the completed form kept for reference purposes. Control systems for acceptance or rejection of batches may also be instituted.

Testing of auxiliaries, finishes and chemicals

The range of test methods that may be necessary is too wide to be considered in detail here. In general, testing is carried out in the initial evaluation of the product and quality control testing is restricted to those instances where production problems and complaints warrant further investigation.

Standard analytical procedures have been described elsewhere (26,30-32), and typical properties of interest are:

Colour
Physical state (particle size, appearance etc.)
Odour
Specific gravity
Solubility (or dispersibility) in water or appropriate solvents
pH (in a solution of known concentration)
Melting point (of the solid or dried product)
Boiling point (or boiling point range of a liquid)
Flash point

Moisture content (or percentage non-volatiles) - the Karl Fischer method may be employed (33)

Viscosity (at a known concentration)

Percentage ash content

Biodegradability

The works laboratory should maintain a small library of standard analytical procedures considered appropriate for the product range stocked. In addition technical data should be collected on the properties of all auxiliaries, finishes and chemicals. The reference files should be continually updated.

Evaluation of materials for textile printing

While many test procedures for textile dyeing are paralleled by similar methods for printing, printing thickeners are of special importance. These should not clog on storage, should dissolve readily using standard methods and preferably give a stable low-solids/high-viscosity paste that retains constant viscosity on storage. Susceptibility to mould formation etc. may be reduced by small additions of suitable auxiliaries.

Dye evaluations, using freshly prepared stock thickener with appropriate dilution (cutting) with a reduction thickener, solvents and fixing agents, require adequate filtration and straining followed by preparation of the necessary strike-offs. The fixation method employed should simulate practical works conditions, for example, cold, saturated steam, superheated steam, drying and baking etc., depending on the class of dye and material to be printed. Standardized wash-off conditions should be utilized.

Subsidiary factors are the clarity of the print, susceptibility to flushing, bleeding or frostiness and effect on fabric handle. The rate of dye strike, degree of fibre penetration, hydrolysis of reactive dyes or reaction with the print paste and the biodegradability of the thickener, solvents and fixing agents may also require evaluation.

II. SUPPLY OF MATERIALS AND STOCK CONTROL

Provision of supplies

The provision of adequate supplies of dyes, chemicals, finishes and auxiliaries is essential:

To ensure the execution of current and future orders

To facilitate production planning

To reduce stock-outs

To avoid the creation of excess stockpiles

To minimize the product and production costs

This key operation comprises four essential stages:

Defining the correct quality and quantity of product for the process

Selecting suppliers who will meet the specified requirements

Ensuring the supplier understands what is required

Monitoring goods delivered and taking appropriate action

The main factors influencing purchasing decisions have been discussed in detail elsewhere (6) but include:

Price

Technical specification

Delivery

Manufacturer's services

Previous experience of supplier

Credit facilities

Overall it is considered that price, technical specification and delivery are the primary motivational factors in the selection of suppliers of dyes and chemicals (6). Particular attention should therefore be devoted to these factors by the management team. In general the following points should be carefully considered.

Price

Price affects (a) market competitiveness in commission work; and (b) the current and future cash-flow position of the company. Percentage price rises on high-price items may lead to high cash-flow and to greater difficulties in generating foreign exchange. In Western Europe, cost analyses data vary (1-3), but all underline the importance of the cost of dyes and chemicals (34,35):

Cost	Percentage of total cost
Dyes and chemicals	30
Fuel and water	20
Equipment	15
Internal transport	21
Process labour and supervision	14

Price negotiations, if conducted by a professional buyer, should be supported by appropriate technical advice on quality etc. and with reference to a known strength or active content of the material under consideration as dyes nominally of the same Colour Index number are often marketed by different suppliers at different strengths, or in different forms, for example, powder or liquid.

The greater the quantity ordered, in general, the lower the price (6), for example, for a typical textile auxiliary:

Quantity	Price units (%)
22 l	100
200 l	86
1 ton	83
5 tons	83
10 tons	77

The costs of storage, specialized handling facilities, interest charges etc. must be carefully calculated and offset against the potential cost benefits of purchasing bulk quantities.

Technical specifications

Technical specifications are of the greatest importance for dyes, pigments and finishes, but are often less critical for textile auxiliaries and chemicals. Factors such as percentage active content, stability and ease of storage, ease of dissolving, dispersing, presence of diluents, impurities, dispersing agents, compatibility, fastness, toxicity, flammability and effect on effluent should be considered.

Delivery

Rapid delivery and ability to supply are vital in preventing production stoppages, general frustration, loss of confidence in management, extended delivery times, short-time working, cancellation of orders and loss of customer goodwill. Adequate provision should be made against delivery times being extended owing to:

Shortages of materials or intermediates
Increases in consumption in the plant and in the industry
Transportation difficulties
Strikes, industrial disputes etc.
Delays caused by government departments, customs and excise etc.
Foreign exchange difficulties

In many countries, major suppliers hold stocks either in their own plant or through their agent. The reliability of a supplier to supply rapidly, consistently and punctually should be monitored.

The most rapid reliable and economic method of ordering supplies should be selected from those available, for example, telephone, telex or post, and care taken to ensure that errors due to incomplete information do not occur.

Manufacturer's services

Major suppliers of dyes and chemicals generally provide excellent technical information on their products and often first-class technical service facilities are available for the use of customers.

The formulation of specific products, special forms of packaging, testing facilities or other miscellaneous forms of service may give greater production flexibility and machine utilization efficiencies.

Aid in problem-solving and attention to complaints are appreciated by many customers.

Previous experience of supplier

Such factors as the reliability of the supplier to deliver consistently and punctually, quality of technical expertise, stability of price level, flexibility of approach and attention to complaints are important considerations to many plant managements.

Credit facilities

The area of credit facilities is a difficult one to specify, but a flexible approach is often required where trading conditions fluctuate considerably throughout the year.

Stock control

Stock control is an essential function of the dyestore for preparation, coloration and finishing. Where separate stores are allocated for preparation, dyeing, printing or finishing, certain essential information must be recorded separately in a suitable format for management action, and for information retrieval, costing and forecasting operations.

In many dyeing and finishing units in the developed countries such information may be stored in a central computer, with stock control programs for generation of orders when the reorder levels are reached (36,37). Such a degree of sophistication is not always necessary however and separate ledgers for each storage area incorporating separate sheets for each product stocked are convenient to use, and can be periodically updated by the removal and storage of old records and the insertion of new pages. Alternatively numerous card index systems may be employed, but these are generally less convenient.

The basic information recorded should be:

Product name

Technical specification (if necessary)

Name, postal address, telephone number of supplier and extension number of sales department. Telex number

Manufacturer (if different from above)

Separate column for:

Date of order

Order number

Price

Space for changes in price (date)

Running stock level

Usage per week, per month

Reorder level

Container size in which the order, for example, 100 kg, may be received as 2 x 50 kg or 4 x 25 kg drums

The inventory thus consists of all the dyes, finishes, chemicals and auxiliaries held in stock, and in a typical dyeing, printing or finishing plant, particularly those with multiproduct, multifibre and multimachine production runs, hundreds of items may be stocked, therefore, careful segregation into various categories is essential for the satisfactory control of stock and the efficient servicing of production (6).

The larger the inventory the greater the problems of control, but because these items are a major cost element, for example, approximately 25 per cent of total dyehouse costs, the control systems employed should be considered in terms of the value of the items stocked and must be flexible in order to cope with periods of rapid change, when the demands of production continually fluctuate (6, 38).

The advantages and disadvantages of keeping large or small inventories are well known and have been discussed in detail elsewhere (6). However, to maintain flexibility, it is safer to selectively overstock to safeguard against stock shortages occurring with essential items, particularly if long lead times between ordering and delivery of the product are common. Commission bleaching, dyeing, printing or finishing units may require a larger inventory in order to cope with the wider product mix of yarn or fabric types and colours required, or batch sizes and fabric widths demanded by customers. The greater the number of fibres and of fibre blends processed, the greater will be the range of products stocked.

The problems of operating continuous production ranges are compounded if preparation, coloration and finishing are carried out sequentially in the same plant, for in such circumstances the shortage of any one product, for example, in bleaching, may lead to early disruption of the coloration and finishing processes and to late delivery. In certain instances extra expense is involved with additional drying operations, and storage of partially processed fabric, for example, on A-frames, may lead to further production difficulties.

In practice those in charge of stocks have to minimize the many problems arising from:

Minimizing ordering costs
Anticipating lead time problems
Avoiding shortages
Avoiding unexpected stock-outs
Dealing with complaints
Avoiding excess stocks
Ensuring adequate safety stocks
Ensuring continuity of supply and delivery

This is a very demanding task, but may be alleviated by correctly categorizing the products and keeping the records of stocks scrupulously up to date.

The complete range of products stocked and the records of consumption should be studied to separate the materials into different classes, for example, dyes, finishes, auxiliaries, and chemicals; and to ascertain the percentage contribution of each class to the total financial value. In most cases, because of the high costs of dyes, these will normally be some 50-70 per cent of the total cost of all products (6, 38). However, a detailed examination within any one class reveals that approximately 20 per cent of the total number of products stocked contributes some 80 per cent of the total financial value of the inventory for the particular class (6). Thus by rationalized forecasting, purchasing and stock control procedures the maximum cost benefits can be achieved in relation to a particular service level for the production.

Groups of dyes

In practice three groups of dyes can be identified within the dye inventory.

Group A. These are main runners (large movers), that is, the dyes in most constant use and constituting the major financial value of the dye inventory. The combination of high consumption coupled with high price, for example, for reactive dyes, clearly demands considerable attention to forecasting demand requirements.

Group B. These are dyes in common use, but not used in large amounts, such as disperse dyes used, for example, in pastel colours on acrylics. These dyes may be regarded as comprising the slow-moving group.

Group C. This group consists of obsolescent or redundant stocks, materials that have physically deteriorated or whose normal shelf-life has been exceeded, that is, products that are surplus to current and anticipated production requirements.

From the dyestore records of the pattern of consumption all dyes, chemicals, auxiliaries and finishes may be categorized into Group A, B or C. The closest control must be kept over the highest-priced materials, generally to be ranked as dyes > finishes > auxiliaries > chemicals, and control of Group A within each product class will yield the maximum production benefits. In very large organizations sophisticated inventory or stock control procedures may be required (6,37). In practice, however, simple rules if correctly implemented, may yield benefits and be a major factor in ensuring the continuity of production. For each product stocked an accurate assessment must be made of:

- Future demand pattern
- Current stock level
- Type of reorder level policy
- Mean lead time, that is, the time between ordering and receiving materials from the supplier
- Cost of placing an order
- Cost of holding stock
- Minimum order level set by the supplier
- Minimum stock level demanded by production control

In addition, the general cash-flow position of the company, the climate of trading conditions and the credit levels set by the supplier may play an important role.

This is a complex situation. A certain minimum stock level is essential to ensure production continuity. Forecasts for demand must be based on information supplied by sales and production control. A safety or buffer stock is usually necessary to allow a margin of error arising from inaccuracies in scaling-up from laboratory matchings to bulk dyeings and allowance for spillage, losses and reprocessing etc. Both the demand and the lead time for a given product may fluctuate widely because of the pattern of trading.

It is recommended that careful analysis of the dyes, finishes, auxiliaries and chemicals in Group A of the inventory be conducted to establish the previous pattern of demand, for example, per week, per month, together with a record of the number of stock-outs that occurred during the period for which the demand was not satisfied. A regular pattern for the main runners often emerges and the demand over previous quarterly periods may often be related to future demand during the same period of the year. By revising the mean stock levels and recorder levels for each product within Group A, a satisfactory degree of production servicing will be attained consistent with the other constraints on holding stocks (6).

With the slow-moving items it may be decided to ensure a minimum stock, for example, of at least that equivalent to the mean lead time for the product, in order to minimize the risk of stock-outs. This has to be viewed against the background of the likely future pattern of demand, whether this be a regular low off-take or a sudden large demand over a short period. Other methods include ordering when the last remaining drum of the product is opened. However, if recipes containing Group B products are identified early on by the sales and production control, those in charge of the inventory often have time to effect satisfactory delivery except in unusual circumstances. Essentially a fast feed forward of information from sales can reap considerable benefits so that the co-ordination between sales/production/stock control should be of a high calibre (39).

Since the main control over Group A covers 80 per cent of the total financial value of the stocks, an inflation of 50 per cent in the financial value of Group B will have only a small effect on the total financial value of the stocks, and such a safety margin may be considered acceptable from a cash-flow viewpoint compared with the financial losses incurred when stock-outs take place. However, individual companies must develop their own internal stock control policy to satisfy their own highly individual requirements.

Regular scrutiny of the Group A products may reveal changing demand patterns such that some of these should be transferred to Group B. This policy should be instituted, and transfer in the opposite direction, that is, Group B to Group A, also controlled. The control system must be flexible to cope with a rapidly fluctuating pattern of demand, particularly in dyeing and printing.

Surplus materials (Group C)

The changing pattern of trading conditions often leads to production of materials that are either obsolescent or surplus and regular stock-taking should take place, possibly at three-month intervals; this is also necessary to reconcile losses due to spillage, and errors in weighing, calculation or recording.

Slow-moving materials should be examined and if there has been no demand for a product during the three-month period, the material should be removed from the dye store to create space for rapidly moving items, and stored with other surplus stocks. Items whose storage life has expired should be disposed of, usually by dilution with the effluent (preferably the stored effluent from bleaching in which prior oxidation can occur before the effluent is released), if it is safe to do so with the product concerned. This should be done gradually to minimize the effect on the quality of the effluent. If an item is used slowly but regularly it may be advantageous to purchase it in powder rather than liquid form because of the longer shelf-life of the powder.

In one instance where the routine procedure of creating surplus items had not been carried out for some years it was discovered that more than 270 items, nearly half the total inventory, were surplus. Over 50 items were disposed of because the storage life had been exceeded; some 20 auxiliary products were used up at the plant on selected dyeings, and the rest were sold yielding some 15 per cent of the capital value. As a result, the mean monthly capital value of the inventory dropped by around 25 per cent, and the following benefits accrued:

(a) The products stocked were reduced by 50 per cent;

(b) Stock-taking was simplified and took only 40 per cent of the time previously required;

(c) Book-keeping and recording were simplified;

(d) Thirty per cent more storage space was created;

(e) The service to production dyeing was improved;

(f) Access and handling were improved.

III. PACKAGING AND STORAGE

Packaging of materials

The packaging methods for dyes and chemicals have been discussed in more detail elsewhere (6,40). Briefly, products may be supplied in:

- Metal drums
- Fibreboard drums
- Plastic moulded cans and containers
- Polycrates
- Glass carboys
- Paper sacks
- Hessian bags
- Compressed gas cylinders

Storage

Conditions

Climatic conditions vary widely in different countries and at different times. Dyes and chemicals should be stored under cover to minimize problems arising from materials being subjected to direct sunlight, heavy rain or freezing temperatures (6). In some cases storage at a high altitude may be hazardous with flammable materials. High relative humidity leads to problems such as clogging of dyes, condensation, uptake of moisture by the dyes and corrosion of the container. Therefore, control over ambient temperature and relative humidity, particularly through the night, is desirable, though not always possible, to maintain uniform storage conditions.

Areas

The design and number of storage areas varies widely according to the nature of the business conducted. Commonly separate storage areas are set aside for preparation, dyeing, printing or finishing. These are situated adjacent to the particular working area to minimize handling and transportation times and improve machine utilization efficiencies.

Deliveries and collections may be made at one central area or at a variety of points around the plant. The routes for materials-flow through the plant must therefore be carefully planned and kept freely accessible (41). Particular attention should be devoted to the routes for mechanical handling aids such as fork-lift trucks and pallet trucks; the flooring must be smooth, and sound enough to support heavy loads. Special care is necessary in the design of hazard warning systems, the width and height of doorways, the use of transparent push-through doors, the aisle width on the plant and the movement of heavy loads up or down inclined ramps.

Individual storage areas reduce fire and contamination risks and often simplify storage procedures and materials handling because of the lower number of products stocked in each area. However, the problems of adequate supervision, overall control and security are increased. Installation of sprinkler systems or individual types of fire-fighting equipment may be required for specific storage areas.

Attention should be given to all forms of materials handling, particularly where heavy drums are involved; circular platforms fitted with lockable castors are useful for such drums. Elsewhere, if space permits, the use of cranes, drum-handling equipment, fork-lift loaders, pallet trucks etc, is often of great benefit from the production and safety points of view.

The racking system should be flexible to cope with different sizes of containers and conveniently sited for access, and the heaviest containers should be stored off the floor on the lowest level. Where drums of liquids are stored horizontally in racks for dispensing purposes, they must be firmly held in the rack, situated at a convenient height and fitted with a tap. Spillage trays should be provided and in addition a safety wall built to contain major spillages in the event of drum rupture. Adequate space must be allowed for manoeuvring and stacking heavy loads while the flooring in the storage area should be sound, able to withstand substantial loads and level in the racking area. Drains of an adequate capacity are required for cleaning-down, and it is desirable to connect them to the main effluent treatment plant to avoid pollution problems outside the plant.

Handling methods

Bulk storage units are generally immobile tanks or containers servicing some part of the plant where consumption of a particular product is very high. However, increasing use is now being made of smaller containers that can be moved and stacked using mechanical handling and lifting equipment (6, 40). Portable units of this type are used for dispersing agents and for resin finishes and often consist of 1,000 litre-capacity polythene tanks, usually enclosed by a protective metal exterior shell and mounted in a stackable metal framework. The price for the product may depend on whether or not the container is returnable to the manufacturer for recharging. In larger dyeing and finishing plants the mobility of such units may be an important factor in saving space and in providing rapid flexibility if production schedules have to be changed.

Both solid and liquid products may be delivered by tanker and discharged by an electrical motorized pump or compressed air into large fixed vertical hoppers, silos, tanks etc. Solid products, such as sodium chloride, starches and dextrins, can be stored in vertical hoppers and transferred to automatic mixing units or dispensed manually using gravity-feed, screw-feed or rotary-feed conveyor systems. For liquid products, storage tanks are often sited under the working-floor level in order to save working space and minimize hazards due to spillage. A disadvantage of storage below floor level is that pumping equipment is then required to meter the product up to the dispensing point. However, more viscous (and hence more concentrated) liquids can be stored and pumped than when employing gravity feeding arrangements, in which viscous products take a long time to dispense.

For each product considered, the advantages and disadvantages of using a bulk storage system must be carefully evaluated, as follows:

Advantages

- Lower bulk prices
- Lower reordering costs
- Fewer deliveries
- Elimination of manual dispensing methods
- Installation of automatic dispensing method
- Improved stock control (less spillage in dispensing)
- Improved process control through automatic dispensing
- Improved product quality (material from within one batch is used)
- Elimination of disposal of drums etc. thereby saving space and eliminating handling

Disadvantages

- High initial costs of containers, installation, automatic dispensing and pipe work, possible costs for heating and installation of high/low level alarms
- Cost of health and safety measures to prevent hazards due to flammability, static, toxicity, leakage and corrosion
- Cost of connection to delivery point involving pipework, valves, lagging etc.

Loss of floor space if sited above working level

Cost of metering/pumping equipment for underground storage systems

Possible limitations on product strength stored and quantities that can be dispensed

Poor storage conditions leading to sedimentation/layering, decomposition of product, build-up of sludge deposits and clogging of powders due to moisture

The financial implications must be carefully studied before installing such a system.

Liquid products - such as concentrated acids and alkalis, for example, 40 per cent and 80 per cent acetic acid, 100°Tw caustic soda, or detergents, auxiliaries, and levelling and dispersing agents - can be quite readily dispensed in this manner to batchwise dyeing plants, and it is also possible to store bleaching solutions, such as hydrogen peroxide and sodium hypochlorite, in storage vessels below the working floor level.

Specially fabricated or moulded tanks reinforced with wire- or glass fibre-reinforced polymers, for example, wire-reinforced polythene and glass fibre-reinforced polyester resin, are normally mounted on a convenient supporting frame, sufficient to distribute the load satisfactorily (6,42,43). The repair of such tanks, should cracks develop, must be carried out carefully according to the manufacturer's instructions, and if welding under nitrogen etc. is required, outside expertise may be necessary. The tank should be drained and flushed clean before repair, particularly if it normally contains toxic, corrosive or inflammable liquids. It is essential that all delivery points, tanks, valves and pipework should be clearly labelled to facilitate identification of the product and potential hazards, and to avoid the accidental mixing or release of the wrong product.

Appropriate precautions must be taken with regard to siting and general ventilation, and specialist advice sought if toxic, corrosive or flammable materials are stored. Particular problems may be experienced due to static electricity. Static electricity can cause a fire or explosion only in a flammable or explosive atmosphere and the general precautions to be taken have been described (44,45). However, low resistance bonding and earthing can generally minimize the occurrence of static. Safety walls or catchment areas, suitable lined and of an appropriate capacity, can reduce hazards due to overfilling, leakage or damage, while recovery of the product for subsequent reuse or disposal into the effluent can be arranged by appropriate design of the storage area. Particular care must be exercised if strong acids and alkalis are stored in adjacent tanks because of the fierce reactions and heat that are generated on mixing, and separate catchment areas are essential.

All connection points for tanker delivery should have clear access for authorized personnel, be clearly identified, and suitably lagged or heated by a small steam coil or electricity if freezing of the product can occur in cold weather (6,44). The connection to the bulk storage unit should not allow the possibility of air-locks developing. Overfilling can be avoided by fitting a high-level alarm in the tank and a tank level (or capacity) indicator at the connection point. All bulk storage units should have a vent pipe leading to drains in case of overfilling. Washing or hosing-down facilities and fire-fighting equipment should be installed close to the connection point, and the drains should be conveniently sited to dispose of spillages after dilution with water.

The capacity of the tank should preferably be larger than the volume demanded per delivery by the supplier to obtain the benefit of bulk prices. In this way accommodation for some degree of overfill and for late delivery can be built in without stock-outs occurring. It is essential to ensure tanker delivery for automated dispensing systems, for if products are delivered in drums there may be considerable extra handling and difficulties in filling the bulk storage unit. The bulk storage unit should be large enough to satisfy current production demands, and the reorder level can be set when the normal mean lead time for delivery of the product is established.

The storage life of the product must not be exceeded; if film-forming materials are stored a regular schedule of cleaning and maintenance will be necessary. Where stratification, settling or cracking out of emulsions is likely, solid deposits or crystallization on the walls of the storage vessel may often be prevented by incorporating some rudimentary form of paddle stirrer operating on a time switch basis to stir the contents of the tank for a short period every hour (6). Specialist advice on the design and construction of storage tanks, stirrers, safety precautions and level sensors etc. is usually available from the manufacturer of the product stored.

IV. DISPENSING METHODS

In order to apply dyes, pigments, auxiliaries, chemicals and finishes to fibres, yarns or fabrics, the products must first be accurately weighed, measured or metered according to the recipe, and then mixed. Mixing processes include dissolving, dispersing, emulsifying or homogenizing in order to obtain a uniform or homogenous distribution of the products in the application medium, which in most cases is water or an organic solvent. The mixture must then be stored and distributed to the dyeing, printing or finishing machine.

Close control of such operations is vital if first-class work is to be obtained, and a careful scrutiny of the methods and equipment employed may reveal sources of errors, inconsistency in quality, poor management and outmoded training methods. These can lead to high "damaged and kept" levels, customer complaints, poor delivery, extended processing times, costly reprocessing, production rescheduling and extra drying operations, or unnecessarily high levels of additions to attain the shade demanded.

Role of the dye store and colour kitchen

In dyeing the greatest control must be exercised over the following variables (46):

Colour value of the dye
Weight of dye
Dissolving (dispersing) of the dye
Volume of liquor
Weight of electrolyte, chemicals or auxiliaries
Time of dyeing
Dyebath temperature
pH of dye liquor

Other variables during dyeing, such as rate of temperature rise and liquor-to-goods ratio, are also important.

The colour kitchen thus plays an essential role, for in dyeing, the second, third, fifth and eighth variables mentioned above are controlled directly, while the colour value of the dye depends on the control exercised over the storage conditions and the age of the dye, that is, the stockholding method and policy adopted. In addition the liquor volume used for mixing may also affect the volume of the dye liquor, depending on the type of dyeing machine and working methods employed.

In printing the important factors are:

Colour value of dye

Weight of dye

Dissolving, dispersing, emulsification or homogenization of liquor, particularly the fineness of a dispersion

Weight or volume of solvent or printing assistant

Weight of binder

Weight of thickener or gum

Total volume of print paste

pH of print paste

Thus in printing all the factors listed are controlled directly or indirectly by the colour kitchen, and here the emphasis is on the quality of the print paste produced in terms of the fineness of dispersion or uniformity of dissolution and the homogeneity, particularly of viscosity, of the mixture. In many dyeing, printing and finishing operations the storage stability of the resultant product is often of great importance, particularly in the use of reactive-type resin finishes applied by pad-dry-cure techniques with which, if the ambient temperature is high, precipitation and polymerization problems may occur. Problems are also experienced with products that exhibit skin-forming tendencies (6).

Automatic control at the dyeing stage only controls the second order variables (46). The first order variables usually lie within the province of the dye store and, particularly, the colour kitchen, and the necessity for attention to detail and control increases with the precision of the colour matching required and the quality demanded by the customer. Batchwise dyeing of yarn, fabric or garments demands close tolerances so that dyes must be carefully standardized and kept in closed containers to prevent ingress of moisture from the atmosphere, for this affects individual dyes to a different extent and leads to inaccurate weighing and poor colour matching (11,47). Where loose fibre (raw stock) dyeing is practised subsequent blending operations during carding and spinning lead to an acceptable colour uniformity, but in yarn dyeing the standards of uniformity of shade from package to package, demanded, for example, for knitting plain colours, are necessarily higher than for multi-coloured or jacquard designs. The tolerances in dyeing must therefore be carefully monitored and information fed back to the dyestore and colour kitchen from production control in order to achieve the highest standards of work and of reproducibility.

Investigations into shade variations in batchwise dyeing have demonstrated that one or more of the following factors may be involved (48,49):

Wrongly calculated recipe (errors and approximations)

Misread dye-lot recipe card (hastily written)

Misnamed dyes on recipe cards

Inconcise or non-existent dyeing instructions

Wrong dye weighed out

Change in fibre substrate

Unintimated strength change in the dye

Preprinted dye-lot recipe cards, on which are shown the percentage, weight and name of the dye, can be used for batch dyeing processes, which will eliminate the first four sources of error and reduce the likelihood of the fifth (48,49). Collaboration between the fibre supplier or customer, the works laboratory and production control minimizes the consequences of changing fibre merges or quality. Close control over the colour value of the main dyes by regular monitoring and testing may reduce the occurrence of tinctorial strength differences, but it requires the constant attention of colour kitchen operators to ensure that the wrong dye is not weighed out. Additional benefits are:

(a) Standard quantities based on fibre weight or machine liquor volume may be used, simplifying methods of calculation;

(b) Automatic methods for dispensing exact quantities may be installed, particularly where the machine sizes are the same;

(c) Dispensing errors are reduced because operators become more familiar with the quantities issued;

(d) Time and effort in dispensing are reduced;

(e) Reproducibility of dyeing is improved;

(f) Quality is improved thereby reducing reprocessing costs;

(g) Stock control is simplified and improved;

(h) Paperwork is simplified by the use of preprinted dye-lot recipe forms;

(i) The preprinted dye-lot recipe forms may be incorporated in a control system to check the work flow through the plant. (The installation of such a system is to be strongly recommended in vertical orgarizations, particularly for batchwise processing, and may also be useful where standard procedures are employed for additions and corrections, that is, redyeing.)

In one case, the amount of reprocessing on a combined scouring and bleaching process for textured yarns was reduced from 3 per cent to 0.2 per cent, while yarn quality in subsequent coning was considerably improved and the need for stripping instructions to coning to reduce inside-outside levelness variations was eliminated except where dirt in the processing water caused problems. Thus an improvement of some 4 per cent in overall yarn utilization from coning was achieved, with significant increases in the efficiency of winding through (a) less yarn breakages from filamentation and snagging; and (b) the winding of the complete package onto the cone.

Although automatic methods help to eliminate some errors, additional ones may occur. For instance, in the automatic dispensing of 100^{o}Tw caustic soda by gravity from a bulk storage unit into individual tanks fitted with level controls, problems arose as a result of variations in the amount dispensed because of differential rates of corrosion of the probes. These were solved by the substitution of polytetrafluoroethylene-coated probes. Another problem was that the control valves used to empty or fill the sidetank on the dyeing machine did not always function correctly; if they stayed open, a considerable loss of caustic soda and of yarn strength and quality occurred as a result of gravity drainage and if they stayed closed, the yarn remained untreated. Therefore, a central shut-off valve should be installed in any bulk storage unit circuit.

Some typical errors in the dye store or colour kitchen, which may lead to variations in the quality or amount of a product dispensed, occur in the:

	Cause
Selection of product	Incorrect labelling of products Recipe errors Inadequate checking procedure
Product strength	Deterioration on storage Contamination Absorption of moisture Stratification or settling of product Crystallization of product Resin formation Oxidation or attack by micro-organisms Variations around manufacturer's tolerance
Weighing	Inaccurate weighing machine Lack of balance sensitivity Effects due to vibration Air currents Taring errors Incorrect tolerances on weighing Spillage Omission of products Issuing double quantities

Dispensing of liquids	Incorrect measurement of liquor level Residual liquid in measuring vessel Incorrect preparation or mixing Incorrect tolerance or accuracy
Mixing and issuing	Poor mixing Dilution errors Contamination Spillage Lack of filtering or sieving Losses during filtering Product delivered to wrong dyeing machine Incorrect labelling

Particularly where liquids are transferred via borosilicate glass pipework from mezzanine floor dispensaries, care should be taken to install plastic ducting underneath the pipework to contain any spillages. In the event of pipe fracture, any spillages should be transferred safely to an appropriate drainage system. While stainless steel pipework may pose fewer hazards, leaking joints and glands often lead to losses of dyes and chemicals. Thus incorrect priming of the dyebath may ensue and a severe safety hazard to personnel may arise if concentrated acids or alkalis are accidentally sprayed over the working area of the dyehouse during dispensing.

Weighing

In modern colour kitchens, dyes and chemicals are weighed to a satisfactory degree of precision on a variety of balance types, for example, multi-revolution dial scale, load cell platform or electronic balance (37, 50-53). However, electronic balances combined with automatic check weighing and print-out facilities are becoming more common, for an automatic print-out of the weight can either be programmed directly into a computerized stock control system or be used in the conventional system for periodic stock balancing of the materials consumed (37,53). More sophisticated systems enable the cost per recipe dyed and the dye and chemical costs to be determined. For prin works, an autoweigh system provides a sophisticated dispensing, weighing and recording system (54). In one version an automatic trolley instructed by a punched card collects a number of liquid components by moving its electronic weighing platform under a series of valves that operate with three rates of flow to combine accuracy of weighing with high speed.

The system employed for dyehouses must often be sufficiently versatile to weigh very small additions as well as heavy weights of dyes or chemicals and for this reason many dyehouses use at least two and possibly three balances with specific weight capacity, for example, light (up to 1 kg), medium (1-10 kg) and heavy (10-50 kg) - depending on the weights dyed or printed (37, 51-53). The majority of cases may often be served by using two balances: one, say, of a capacity of 1.2 kg or 3 kg to 0.1 g accuracy and a larger one of 15 kg or 25 kg capacity with a 5 g accuracy. In general, the small weights may be weighed in movable pans or containers and the larger weights in stainless steel buckets, the capacity of which is generally around 12 kg each. Above 12 kg, larger stainless steel containers are used and it is important that the taring range on the balance is flexible enough to accommodate such containers. The container should be of a convenient design for handling and at an appropriate height for weighing etc.

Four basic types of equipment may be envisaged (37) depending on the degree of complexity required:

Simple system with print-out on tally rolls
System with weight tolerance
Stock control computerized systems
System with complete computer control

The second method is widely used because an indication is given to the operator that the weighing is within the acceptable tolerance of the set weight (normally ± 1 scale division, or ± 1 per cent of the set weight). Using such systems, dye consumption may be slightly lowered, production increased, and the reproducibility of shade improved thereby reducing redyeing (37). In one case, the total non-productive dyeing hours, expressed as a percentage of the total machine hours available, were reduced from 37 to 8 per cent, redyes were reduced from approximately 15 to 5 per cent and the additions reduced from 11 to approximately 4 per cent, all within one year of such a system being installed.

In large dyestores or colour kitchens it is essential to have an adequate supply of stainless steel utensils, for example, spoons, ladles, spatulas, scoops, pans and buckets, in order to carry out weighing quickly and have sufficient time for cleaning etc. to prevent contamination, particularly with dyes, during subsequent weighing and mixing operations. A careful analysis of the work-flow pattern and of the movement of materials and associated materials handling in the dyestore and colour kitchen may lead to a more convenient access of materials to the weighing area, simplified handling etc. Provision of duplicate scales is a useful back-up facility, particularly in case of balance damage; all balances should have a regular schedule of inspection, check-weighing and maintenance. Of particular importance are the siting and mounting of the balances to minimize the effects of draughts and especially of the vibration that in many balances leads to internal damage and weighing errors.

The most accurate weighing is nullified by poor handling methods and inadequate training, such as, spillage of solid dye prior to dissolving, for example, during mixing; spillage of dye solution during transport from the dissolving area to the dyeing vessel; and failure to ensure that any undissolved dye, which may be filtered out through a sieve during addition to the dyebath, is reprocessed and subsequently added.

One practical study showed that some 27 per cent of all weighings were in error to a significant degree (14). In long liquor dyeing processes the additive effect of volume errors may not be great but in short liquor processes, particularly in padding operations, the measurement of volume is vital because the combined effect of weighing errors and volume errors may lead to undesirable variations.

Operators must weigh dyes on a balance of the appropriate capacity because weighing 25 kg on a 5 kg balance in five separate operations could lead to large errors. If the scale pan is too small for the weight to be dispensed error accumulation may occur or the number of weighings may be miscounted. Conversely, the insensitivity of large balances to small weights leads to considerable errors in the weights dispensed, often when the dyeing is at the crucial "first addition" stage. The weighing of more than one dye onto the same scale pan should be prohibited because an error in weighing one component may be carried through to the others in trying to reach the correct total weight of dye for the dyes being weighed out.

Storage of dye drums in cold outside stores followed by immediate exposure to a hot steamy atmosphere may lead to condensation occurring inside the drum and on the contents. Therefore, drums of dye should be allowed to equilibrate to the temperature of the colour kitchen, the neck of any polythene liner should be twisted and the drum lid replaced to minimize absorption of moisture, which can vary considerably and lead to changes in weight of approximately $\pm$ 3 per cent. In most cases the moisture is absorbed in the uppermost layers of the drum. Thus if only a small quantity of dye is required for a pastel depth dyeing, a small dye-lot or a trace of shading colour, it should be taken from lower down the drum by carefully displacing the upper layers. The sensitive upper layers should be used when a large quantity of dye is required in order to minimize these surface effects. The more drastic examples of irreproducibility occur when only small quantities of dyes are weighed (14). While print-out systems may provide a check on the weight actually dispensed, this provides no information on the state, quality or moisture content of the product, all possible sources of error in subsequent dyeing. Thus in weighing dyes particular attention must be paid to the equipment and techniques used for weighing; to the close control of the volume of water used in padding operations; to minimizing spillage and filtration losses by training in appropriate methods using approved handling techniques; and to minimizing variations in moisture contents of the dyes during storage and handling.

Such attention to detail will minimize the economic penalties resulting from inaccurate weighing, for example, loss of production, additions, stripping and redyeing.

Practical considerations in weighing and dispensing

Mixtures of products, such as reduction clearing agents composed of sodium dithionite (hydrosulphite) and a stabilizer for holding loose colour in suspension, formulated in the correct proportions, may be purchased. Thus only one weighing is required, saving time and expense in dispensing. In addition incorporation of stabilizers can reduce the normal fire hazards associated with sodium dithionite.

Many liquid products must be stirred or shaken before use, for example, emulsions and defoamers, and have a limited storage stability ($<$3 months). Dilution of such products requires strict adherence to the manufacturer's instructions, particularly in respect of temperature and pH. Many emulsions precipitate or crack out if added to water at too high a temperature, and cationic softeners behave similarly if added to alkaline solutions. Thus if the bucket or container contains traces of other products, complex formation, aggregation or inadequate mixing may result.

The sizes of the containers purchased are important in relation to the design of the dye store layout and to the use of mechanical handling aids (40). Health and safety hazards can occur when the operator has to reach inside large drums of powdered products to dispense the remaining dye or chemical. Anti-dusting varieties of dyes should accordingly be purchased and precautions taken in the dispensing of the final layers in the drum.

Measuring volume

Errors in the measurement of volume are common largely because of the inaccurate methods employed to measure the depth of liquid in a tank of complex shape (14). All too often the depth gauge is a stick or sight-glass, not always at eye level, which has not been accurately calibrated. If read off accurately the result will often show a persistent bias that can be corrected by experience. However, the volume in a conical mixing vessel is dependent on the height of the liquor, and the errors may often be large. Clearly containers with a small surface area and large depth are to be preferred, for an error of 1 cm in measuring a depth of 20 cm is a greater discrepancy than when measuring 100 cm. If at an inconvenient height, random errors may be introduced by inaccurate reading and this should be taken into account in the design and installation of containers, particularly for bulk storage units. Many methods of measuring liquor level in bulk storage units, for example, based on simple float systems or more complex types based on conductivity, resistivity etc., are available, but it is essential to ensure that the initial calibration of the depth of the liquid with the volume is accurately carried out. If calibrated by a weighing procedure, allowance must be made for the specific gravity of the liquid dispensed from the tank. This may be important if a change of product or a change in the concentration of the product stored alters the specific gravity of the liquid in cases where the weight dispensed is the important parameter.

Metering systems

Metering systems are becoming more common, particularly for continuous preparation dyeing or finishing processes, the degree of sophistication demanded depending essentially upon the process. Typical installations (6,53,55,56), have been described elsewhere. Systems for metering wet-on-dry and wet-on-wet in fabric processing are available (6,55) and considerable savings may often be gained through improved machine utilization; improved consistency and reproducibility; avoidance of reprocessing; and more efficient use of chemicals.

Metering systems are particularly advantageous where bulk storage systems are used, for the chemicals are usually obtained at lower prices. Continuous metering is particularly beneficial in chemical preparation processes (57) and cathodic reduction for sodium dithionite (hydrosulphite) has proved its potential using appropriate electrode systems (55,57,58).

Mixing

For materials that can only be dispersed or emulsified in water or solvents, the mixing process is a vitally important part of the correct preparation routine in the colour kitchen (6). Inadequate mixing or addition of products to the mix in the incorrect order during mixing may lead to subsequent costly reprocessing and loss of quality in dyed and finished fabric.

Another equally important factor for the highest machine utilization efficiency in dyeing, printing or finishing is that the preparation of the mixture must take place in advance of the production requirements so priority in mixing, and the cleaning-down times required for various mixing processes, must be carefully considered.

During the mixing operation, distribution, intermingling and homogeneity of the substances to be mixed are attained by differential rates of flow of the substances (6). These are normally accomplished by direct physical contact between the substances to be mixed and the mixer, of which the container must be considered to be an important part, by a state of motion imparted to these substances by the mixing element, or by both of these methods.

The most important factors are the shearing action of the mixer, particularly for highly viscous materials such as gums and printing thickeners, and a satisfactory rate and movement of the entire body of the material. These lead to satisfactory mixing in the shortest possible time, thereby providing optimum machine utilization efficiencies.

Both portable and fixed mixers and mixing vessels may be employed in coloration and finishing, the mixing operations falling into one of three classes:

Simple physical mixture of two or more miscible fluids
Mixing processes involving a physical change of the products
Mixing processes involving dispersion of the products

The temperature of the mixture and the storage time before use may be critical, particularly for dispersions and emulsions, and aggregation and separation problems may occur unless the mixture is stirred occasionally. This also helps in preventing stratification or settling of dispersions. The prior addition of dispersing agents and the slow addition of disperse dyes into the vortex of a large volume of water at around 30-40°C stirred by a high shear mixer are generally recommended.

All dye solutions etc. should be strained or filtered before being added to the dyebath, care being taken to reprocess any dye that has filtered out. Stainless steel mesh sieves are widely used, being easy to use and keep clean and commercially available.

Mixing equipment

The main factors concerning mixing operations are discussed elsewhere (6), but mainly depend upon the viscosity of the materials to be mixed since this determines:

The type of mixer necessary to establish and maintain the required flow
The size of the mixing elements necessary
The optimum mixing speed
The power requirements at the mixing speed

The flow pattern is dependent upon the container shape; round-bottomed rather than flat-bottomed containers are preferable from the mixing, dispensing and cleaning points of view. In printing the thickener is added gradually to the water in order to minimize gelling and the rise in viscosity, thereby easing the strain on the mixing element; in addition the use of knock-down defoamers may sometimes be employed to eliminate entrained air from the thickener.

Heavy mixers may be hung vertically, counterbalanced by weights to facilitate movement. Where possible, totally enclosed fan-cooled motors are preferable and for portable mixers a lower voltage, for example, 110 volts AC, is considered satisfactory; the mixer must be wired correctly. Electrical cables to such mixers must either be kept off the ground or protected in conduits to avoid damage from the movement of heavy trucks in the vicinity of mixing.

The correct siting of the mixing equipment, attention to good mixing practice, siting of appropriate local exhaust ventilation and good housekeeping will minimize dust and spillages. A regular schedule for cleaning and maintenance is necessary, and in printworks, drum-washing equipment has proved to be very successful. Careful scheduling of the mixing programme in relation to future production requirements is necessary, and the movement and handling of the mixing containers to the point of coloration in production must be carefully considered.

The degree of sophistication required depends upon the products involved; a detailed account of the normal types of mixer and their modes of action has been elsewhere (6). This covers the use, merits and limitations of:

Flow mixer types, for example, open coil steam pipe in a bucket

Paddle mixers, usually used on bulk storage systems

Propellor mixers, usually used for maintaining consistency of a mixture

High shear mixers, with adjustable deflector plates, disperser sleeves and liquor flow reversal - widely employed for mixing and dispersing dyes in powder form

The colloid mill, for a high quality dispersion of a coarse premix

Ultrasonic homogenizers, for a high quality dispersion

As the quality of mixing demanded increases, in general, the last three methods may be employed. However, specialist adviee on specific mixing problems should always be sought from product suppliers and manufacturers of mixing equipment.

V. HEALTH AND SAFETY

Chemical hazards

All dyes, finishes and auxiliaries, being chemical substances, may be considered as potentially hazardous (59-63), particularly if they are allowed to enter the human body via one or more of the following routes:

Absorption through contact with the skin

Inhalation into the respiratory tract as dust, fumes, vapours etc.

Ingestion into the digestive tract, through swallowing contaminated saliva, food or drink

Chemicals, properly stored, handled and used, present small risks to health and safety (59), but knowledge is required of the potential hazards and appropriate control procedures for the materials stocked and of measures to be taken in case of accidents (6). Increasing importance is also attached to control of the plant environment, reduction of effluent pollution and contingency planning for an emergency (64, 65).

The hazard classification system for chemicals of the United Nations lists nine classes of primary hazards (66).

Class	Hazard
1	Explosives Mass explosion hazard - a very insensitive substance
2	Gases: compressed, liquefied or dissolved under pressure
3	Flammable liquids Flash point 23-60.5°C
4	Flammable solids Spontaneously combustible substances Substances giving off flammable gases in contact with water
5	Oxidizing substances other than organic peroxides Organic peroxides
6	Poisonous substances Infectious substances
7	Radioactive substances
8	Corrosive substances
9	Miscellaneous dangerous substances

In preparation, coloration and finishing, there are potential hazards in the use of:

Poisonous substances (Class 6)
Corrosive substances (Class 8)
Flammable liquids and solids (Classes 3 and 4)
Oxidizing substances (Class 4)
Gases: compressed, liquefied or dissolved under pressure (Class 2)

Apart from the primary hazards, additional hazards may arise from the decomposition of chemicals during storage by interactions arising from mixing, contamination, spillages, disposal or fire. Great care is therefore required by those charged with the responsibility for the safe storage, dispensing, use and disposal of such materials.

It is important to draw clear distinctions between (a) the toxicity of a chemical substance; (b) the toxic hazard of that chemical substance; and (c) the toxic hazard of an industrial process in which that chemical substance is used.

Toxicity

Toxicity is the capacity to cause injury and is often related to dose response (67), where a physiological or toxicological response is correlated with the dose (the product of time of exposure and effective concentration).

Toxicity hazard

The toxicity hazard is the measure of potential risk and must therefore incorporate information on intended use, anticipated mode of entry, and frequency and duration of exposure (60,64,67). Chemicals that are either volatile and more readily inhaled or readily absorbed through the skin create a greater toxicity hazard (6).

The toxic hazard of an industrial process

The toxic hazard presented by any preparation, coloration or finishing process depends upon the toxicity hazards of the compounds employed and the circumstances surrounding their use. Thus the extent to which the environment is allowed to be contaminated, leading to absorption of chemical substances by the human body and the possibility of toxic effects, is important (6,64).

Toxic substances and their effects

The toxicity of a substance is its potential to cause injury by direct chemical action with the body tissues (61,62). Toxic effects can be described as local or systemic. Local injuries are those limited to the area of the body that has come into contact with the toxic material and systemic injuries are those produced in any of the organs after the toxic substance has been absorbed into the bloodstream (60-62).

Both local and systemic effects exhibit considerable variation in type, duration and danger to health and life. The susceptibility of individual persons may not only vary widely but may also depend upon the state of health during the period of exposure to the hazard.

Chemicals show a greater or lesser differenee in toxicity depending upon whether they act on the body for a short or a long time. Acute toxicity is defined as that which is manifest on short exposure (61). However the nature of the toxic injury producea may differ according to the duration of the exposure and where exposure is over long periods, chronic toxicity effects may become apparent. In many cases the injured person may not recognize these effects until chronic toxicity has reached an advanced stage and has created considerable permanent damage.

Toxic effects may thus be subdivided into four main types (60-63):

Acute local - rapid action at a specific body site
Acute systemic - rapid action over the whole body
Chronic local - long-term action at a specific body site
Chronic systemic - long-term action over the whole body

The potential hazards of many chemicals have already been assigned to one of the above types, but in the case of new chemical products the toxicity may not be known (63).

Action of toxic substances

When considered in terms of the action on the body, toxic substances may be classified into five main groups (60).

Irritants. These in general affect the respiratory tract and the mucous membranes, for example, formic acid, acetic acid, ammonia, formaldehyde, chlorine dioxide.

Asphyxiants. This class of toxicant, for example, carbon monoxide from motor vehicle exhaust fumes, is rarely found in coloration and finishing processes, except as a result of thermal decomposition of materials during fires.

Anaesthetics and narcotics. These often have a depressant action on the central nervous system and include many alcohols, such as isopropanol and aliphatic ketones, for example, acetone, methyl ethyl ketone. These may be used as solvents for dyes or as components of textile auxiliary formulations.

Systemic poisons. This class includes methanol, halogenated hydrocarbons, oxalic acid, organic isocyanates (e.g. 2,4-toluene diisocyanate), tartar emetic and other mordants and a wide variety of compounds used for flame retardancy, rot-proofing and insect-proofing (moth-proofing). Particular caution is advised in the control of storage and use of such products.

Particulate matter other than systemic poisons. These are solids in dusts, powder or crystal form and include fine dye powders, resins, fibres and other air-borne particulates. They are frequently encountered in the storage, dispensing and mixing work areas.

The above list is not extensive and it is strongly recommended that the degree of toxicity for all the products used in preparation, coloration and finishing be ascertained, either from the extensive general chemical literature (63) government departments, or from the manufacturer concerned. In some cases the toxicity may be unknown.

The measurement of toxicity

Lethal dose, 50 per cent kill (LD_{50}). This represents the dose which, when administered to laboratory animals, for example, rats and mice, kills half of them. It is expressed in mg/kg (milligrams of toxicant per weight in kilograms of the animal) and the route of administration (oral, skin, intraperitoneal) is usually stated (61). Thus if a chemical is considered to be as toxic to man as to the animal on which the chemical is tested, the LD_{50} for a person of a known body weight can be calculated. This extrapolation, while not always accurate, gives some guide in calculating relative toxicities. Compounds with LD_{50} values of less than 50 mg/kg are generally considered to be highly toxic.

Lethal concentration, 50 per cent kill (LC_{50}). The units are parts per million (ppm) per time period of exposure, and the weights are not needed.

Airborne contamination

Threshold limit values (TLV) are estimates of the average airborne concentrations of substances to which nearly all workers may be exposed day after day without adverse effect (68). This however will not prevent problems arising with a small percentage of workers who may be hypersusceptible, experience discomfort, or be affected more seriously by aggravation of a pre-existing medical condition or by development of an occupational illness (61). Three categories of TLV have been specified (68).

TLV time-weighted average (TLV-TWA). The time-weighted average concentration for a normal eight-hour workday, or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

TLV short-term exposure limit (TLV-STEL). The maximal concentration to which workers can be exposed for a period of up to 15 minutes continuously without suffering from (a) irritation; (b) chronic or irreversible tissue change; or (c) narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted with at least 60 minutes between exposure periods and that the daily TLV-TWA is not exceeded.

TLV ceiling (TLC-C). The concentration that should not be exceeded instantaneously.

It is essential to liaise with the relevant government department concerning the statutory requirements regarding threshold limit values for the chemical substances used. The legislation may vary from country to country and the values are continually under revision.

Fire and explosion hazards

Explosions in preparation, coloration and finishing are rare, but fires occur more frequently (64). The fire hazard of a liquid may be gauged from the flash point and the auto-ignition temperature (61,63).

The flash point is the lowest temperature at which a liquid will give off enough vapour to ignite when exposed to a flame.

The auto-ignition temperature is the temperature at which the substance will self-ignite in the absence of a flame or spark.

A concentration of 1 per cent or more by volume of flammable gas or vapour must be present if mixing with air makes it flammable (62-64); one quarter of the lower flammable limit should never be exceeded. Planning for contingencies, such as possible leakages, spillages, static and the unexpected loss of flammable solvents, must be carried out. Where solvents of low flash point ($<21^{o}C$) are used, special precautions are often necessary, for example, the earthing of storage vessels and pumping equipment and installation of flame-proof electrical equipment. Other precautions include minimizing the quantities of flammable solvents used and the provision of secure flame-proof storage areas situated some distance from the main plant.

Installing suitable fire-fighting equipment, ensuring all personnel are trained and familiar in its use and providing fire-detection equipment, fire alarms and adequate means of escape from all parts of the plant are of primary importance; these factors are discussed in detail elsewhere (69,70).

Hazards of materials used

Wherever possible, relevant information on the parameters given below for all products stocked should be stored by the Safety Officer in some appropriate rapid retrieval system, and continually updated by information supplied by manufacturers and government departments.

Product name
Name of active chemical constituents and chemical synonyms
Supplier
Hazards in use
Precautions in use:
  General storage and handling
  First aid
  Disposal methods for spillage
  Disaster control

Toxicity
TLV
Flammability hazards:
  Boiling point
  Flash point
  Explosive limits

Auto-ignition temperature

Products of combustion

Fire-extinguishing agents

Reference sources of information.

This information should be utilized in the design and control of appropriate safe methods of storage, handling and use for each product.

A considerable body of information is available on environmental health and safety and the Safety Officer for the plant must continually update plant management on these important matters. The wide scope of the topic and considerable variations in practices mean that only a brief discussion of health and safety can be given here, together with suggestions on suitable preventive measures and safety precautions.

Appropriate control procedures

Potential hazards to health and safety exist in all industrial plants and processes. These may be markedly reduced in preparation, coloration and finishing by implementing the following control procedures:

Work within the framework of the statutory regulations

Provide adequate records of the hazards of the materials used

Institute safe working procedures for storage, handling, use and disposal of materials

Inform all personnel likely to be exposed of the potential hazards, and train them to act responsibly

Enforce good industrial hygiene standards

Provide the requisite personal protective equipment, and maintain it properly

Train personnel in fire-prevention, fire-fighting procedures, first aid and appropriate emergency procedures

Control and minimize the release of harmful pollutants into the working environment

Conduct regular monitoring of the working environment on the safety audit principle

Preventive measures and environmental pollution control in dyestores and colour kitchens

The environment in the dyestore should avoid temperature and humidity extremes and the lighting should be of good standard overall, avoiding contrasts of light and dark areas and not giving rise to glare. Materials should be clearly labelled and stored off the floor to facilitate cleaning. The lines of access to the materials should be clearly marked and a regular schedule for cleaning instituted using suitable non dust-producing methods.

Construction materials should be resistant to corrosion, should minimize dust collection and should be capable of being hosed down at appropriate intervals. The flooring should be fitted with drains of suitable capacity and slope to allow satisfactory run-off. Impervious tiles are easy to wash and clean and a wide variety of surfaces, giving a better grip for footwear, are available, minimizing accidents.

The overall ventilation should be good without causing excessive draughts, and should be exhausted safely without recirculation. Where weighing and, particularly, mixing processes are carried out the local exhaust ventilation must be adequate, and ideally the fresh-air inlet should draw the dust and fumes away from personnel at head height into the local exhaust hood. The exhaustion of heavy organic vapours that may collect near floor level must also be accommodated so that careful siting and monitoring of the ventilation system is necessary.

Health and safety considerations in dyestores and colour kitchens

The hazardous nature of each product must be considered individually and also in relation to other products that may be stored in the same area. A combination of substances stored together should not constitute a greater hazard than each individual substance stored (71). Thus, for convenience, the inventory may be grouped into the following general categories:

- Flammable materials
- Toxic materials
- Oxidizing and reducing agents
- Corrosive chemicals
- Compressed gases

Products may often be grouped under more than one category, particularly those under the heading corrosive where combinations of properties exist, namely, corrosive oxidizing agent, for example, conc. H_2SO_4, HNO_3.

Flammable materials

Inside storage of flammable liquids, such as methanol, ethanol, isopropanol, kerosene and ketones, in drums etc. should be limited, and the quantity stored should be kept to a realistic minimum. Storage outside, some distance away from the buildings (at least three metres) is desirable, with protection from the sun. Warning notices should be installed. Drains should be located to prevent spillages spreading to other materials. If large quantities must be stored then a separate building with a fire-resistant liquid storage vault and an automatic water sprinkler system should be provided (61). Ventilation adequate to safely remove normal or accidental vapours must be provided; and all drains should be trapped and discharged to a safe location. All electrical equipment in the vicinity must conform to the highest standards of safety; and smoking must be prohibited (72). Flammable materials should not be stored adjacent to toxic materials, oxidizing agents or compressed gases. Consideration should be given to the provision of fire-fighting equipment, supervision and security measures.

Toxic materials

Careful planning must encompass, apart from toxic materials such as isocyanates, oxalic acid and tartar emetic, those materials that decompose to give toxic materials on contact with heat, acids and, in certain instances, moisture. For outside storage, precautions similar to those proposed for flammable materials are recommended; inside storage areas should be well ventilated and cool. Access by unauthorized personnel must be prevented by adequate security measures (6). Warning notices and the provision of the correct respiratory and fire-fighting equipment is necessary. Precautionary measures against inhalation, ingestion and absorption through the skin are essential (73). Appropriate antidotes and first-aid cabinets should be provided.

Oxidizing and reducing agents

Oxidizing agents, such as sodium and calcium hypochlorite, sodium chlorite, hydrogen peroxide, peracetic acid, sodium perborate, and sodium nitrite, dichromate, chlorates and permanganates, should not be stored near materials that will effectively act as a fuel leading to combustion, for example, flammables, organic chemicals, dehydrating agents, and, in particular, reducing agents such as thiourea, thiourea dioxide, sodium dithionite (hydrosulphite), sodium sulphoxylate formaldehyde, zinc sulphoxylate formaldehyde, sodium bisulphite and sodium metabisulphite. In one case, a three-metre high fire was caused by the accidental contamination of a 25 kg drum of thiourea with traces of sodium chlorite from a metal scoop used for issuing both chemicals. Trace contamination of this kind may lead to no immediate noticeable change until the material is disturbed by shaking or the insertion of a scoop, when a considerable fire may be created. Therefore, scoops must be clearly marked and used only for issuing one material in order to prevent contamination occurring.

The storage area for oxidizing agents should be cool, well ventilated, and separate from other areas. Preferably fire-resistant construction materials should be used, and a sprinkler system installed or fire-fighting equipment must be available in the vicinity. Particular care must be taken to ensure good housekeeping; cleaning materials and wood flooring impregnated with such materials as dried-out solutions of sodium chlorite may cause fires, therefore, all spillages must be cleaned up immediately. The potential fire hazard may often be reduced by purchasing brands of chemicals that contain stabilizers; advice should be sought from manufacturers on this point.

Corrosive chemicals

Typical corrosive chemicals, such as caustic soda (sodium hydroxide), caustic potash (potassium hydroxide), sodium sulphide, sulphuric acid (brown oil of vitriol), nitric acid, hydrochloric acid, phenols, acetic acid, formic acid and ammonia, may lead to corrosion of the container, other materials in the storage area or body tissue as a result of careless handling methods (74).

The storage area should be cool, but maintained above the freezing point of the product, well ventilated and dry, and drums should be conveniently sited and fabricated in suitable corrosion-resistant material. Strong acids rapidly corrode cement floors and pipework. Containment of any spillage by building lined bond walls for bulk storage units is essential. Segregated areas for materials that react chemically must be provided, for example, caustic soda and acetic acid. Protective clothing, particularly eye protection and eye wash facilities, must be provided conveniently at hand, and employees should be instructed in the correct procedures and use of such materials. First-aid training and appropriate first-aid cabinets etc. should be provided, particularly for corrosive and toxic chemicals (75).

Compressed gases

Compressed gases, classified as liquefied, non-liquefied or in solution, are rarely used directly in textile wet processing. The hazards arise from the high pressure and any flammability or toxicity hazards. Cylinders are normally colour coded to avoid mixing and there should be separate storage areas for full and empty cylinders. All cylinders should preferably be stored in the vertical position and secured so that they will not fall. Flammable gas cylinders and oxygen cylinders should be kept apart and all normal precautions observed. Outside storage with protection against excessive variations in temperature and corrosion is often the most satisfactory solution, with proper manifolds and distribution piping to points of use.

Storage time limits

The activity of many products deteriorates on prolonged storage, for example, sodium hypochlorite, and such deterioration or decomposition may be hastened by extremes of temperature or presence of moisture. In general, solids deteriorate less quickly than liquids. A recurrent problem with outside storage can be the damage or corrosion of containers, which may contaminate the product. In well organized dyestores, materials are used according to a first-in, first-out stock-keeping principle minimizing the storage time for any product. In large textile groups, surplus materials may be consumed by plants in other parts of the organization, used as an alternative to a similar product, or sold or disposed of by some other means minimizing potential hazards. Alternatively the material, if considered particularly valuable, may be transferred to another container. Advice on the acceptable storage time limit for materials should be obtained from individual manufacturers.

Safety precautions, training and the role of management

Safety precautions for accident prevention against burns, scalds and corrosive substances have been discussed in detail elsewhere (73,74). The use of a training manual, the provision of safe working methods and of a code of practice should enable personnel to be trained to the necessary degree of competence. In addition all personnel likely to exposure should be aware of the potential hazards of the products used in the plant.

Industrial hygiene and safe working practice

The following points should be scrupulously observed (6,61,63,70,74,76,77):

(a) Protective clothing should always be worn when dealing with chemicals in bulk. As a minimum, gloves, eye protection and overalls should be worn; in other cases polyvinyl chloride (PVC) coated gloves and aprons, which are impervious to most liquids, should be worn, as should appropriate footwear of the safety type;

(b) Regular cleaning of protective clothing and equipment and clean storage conditions should be provided;

(c) Adequate ventilation should be provided where dyes or chemicals are mixed, heated or otherwise processed or where fumes may be present to avoid inhalation problems; protective equipment, such as respiratory masks, should be provided where necessary. Smoking should be banned to avoid dangers from inhalation of vapours and fire;

(d) Food and drink should not be brought into, stored, prepared or consumed in the areas where chemicals are handled or otherwise used in order to avoid ingestion problems;

(e) All chemicals should be clearly marked, stored safely and handled only by authorized personnel who have been appropriately trained;

(f) All dyes and chemicals should be stored, weighed and dispensed in the areas reserved for the purpose. The illumination and ventilation of these areas should be adequate and regularly maintained;

(g) Any potential hazards and unusual handling precautions should be clearly marked on the product containers;

(h) Washing facilities should be provided close to the area where chemicals are stored and used and should be sited to encourage personnel to wash before taking food or drink;

(i) Emergency washing facilities may be required in certain areas so that the face and eyes may be douched easily; chemical splashes on the skin or eyes should be treated promptly by copious irrigation with clean water, and, particularly in the latter case, medical attention should be sought as a sensible precaution;

(j) Proper utensils for handling dyes and chemicals, for example, scoops, buckets and jugs, should be provided, and all spillages should be cleaned up immediately;

(k) Personnel in problem work areas should be examined regularly and medical records kept. In certain cases job rotation may be practicable;

(l) Personnel susceptible to skin complaints and allergies should be identified and redeployed;

(m) Skin-sensitizing material should be replaced by a non-dermatitic type if possible;

(n) Toxic or environmentally undesirable chemicals should be replaced by safer alternatives;

(o) Safe clean working methods should be established;

(p) Training schemes and suitable methods of instruction should be established;

(q) Personnel should be trained in first aid, fire-fighting, and how to cope with emergencies, and appropriate equipment should be provided.

Effluent disposal

Effluent disposal has been treated in depth elsewhere (78) and only some general points will be considered. The statutory regulations in the country concerned must be the working guidelines. Factors of importance are:

(a) The method of disposal may be continuous or discontinuous. While a few products may be released into the air, the majority will probably be released suitably diluted with process water. Other products may be disposed of via soil or sewer or transported to some form of aqueous effluent treatment;

(b) The composition and quantity of waste products per point of disposal and per unit of time must be carefully studied as well as the disposal rate and temperature under normal and abnormal conditions;

(c) Control and supervision should include the necessary monitoring procedures for particularly hazardous materials and for general monitoring, for example, pH, temperature, colour and suspended solids. Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) tests may also be conducted where appropriate, particularly where discharge to rivers etc. is envisaged;

(d) The disposal of waste products by burning should be considered, taking into account the products that may be released;

(e) Process conditions may often be adjusted either to recycle products or to reduce the quantity of effluent produced or by suitable treatment on site to convert the waste products to a form more suitable for subsequent treatment and disposal.

Emergency planning

It is essential to develop a plan to cope with major emergencies. This should attempt to minimize any event that could affect or threaten to affect a large number of personnel or extends beyond the boundary limits of the factory and affects members of the public. Individual circumstances vary widely but it has been suggested that the following elements should be examined in depth (79):

(a) Define all hazards that could result in a major emergency and locate high risk areas on the site;

(b) Calculate likely effects of the hazards identified, and construct case studies for the most serious risks;

(c) Plan a control system to minimize the effects and estimate the resources that might be required;

(d) Establish a communications network sufficient to provide warning and to maintain control in an emergency;

(e) Train personnel involved in control systems and those responsible for the communications network;

(f) Establish regular exercises for personnel involved and review the results.

The release of toxic gases or fumes or the possibility of fires or explosions are particularly important and any contingency planning should include such emergencies. Special attention should be paid to reagents of high reactivity that may interact either with fire-fighting materials, for example, water and steam, with materials of construction or with oxidizing and reducing agents.

The role of plant management

Plant management should foster and encourage, by training and example, the use of good standards of industrial hygiene and safe working methods throughout the plant. All personnel should take a positive attitude to ensuring that the health and safety environment of the plant is maintained at a high level. This can only take place where competent planning, organization and control are continually practised and where top management personnel are intimately involved at all stages.

References

1. D.H. Squire, Journal of the Society of Dyers and Colourists, vol.92, 1976, p.109.
2. C. Duckworth and J.J. Thwaites, Journal of the Society of Dyers and Colourists, vol. 85, 1969, p.225.
3. B.J. O'Hare, Journal of the Society of Dyers and Colourists, vol.95, 1979, p.401.
4. C.B. Kothari. Textile Industry and Trade Journal, March-April 1975, p.9.
5. M.J. Wadia, Colourage, vol.24, No.11A (26 May 1977), p.16.
6. I. Holme, Journal of the Society of Dyers and Colourists, vol.94, 1978, p.375.
7. The Colour Index, 3rd ed. (The Society of Dyers and Colourists and The American Association of Textile Chemists and Colorists, 1971).
8. "A.A.T.C.C. Buyers Guide", Textile Chemist and Colorist, vol.11, No.7A (July 1979).
9. Index to Textile Auxiliaries, 6th ed. (London, Textile Business Press Ltd., 1978).
10. S. Davis and J. Park, International Dyer, vol.149, No.8 (1973), p.432.
11. R.L. Adamczyk, Textile Chemist and Colorist, vol.6, 1974, p.183.
12. J. Park, International Dyer, vol.144, No.10 (1970), p.676.
13. New Techniques in Wet-Processing of Textiles with Emphasis on Cotton (United Nations publication, Sales No. 76.II.B.1), p.10.
14. H.H. Sumner. Journal of the Society of Dyers and Colourists, vol.92, 1976, p.84.
15. T.L. Dawson and B.P. Roberts, Journal of the Society of Dyers and Colourists, vol.95, 1979, p.47.
16. Standard Methods for the Determination of the Colour Fastness of Textiles (U.K., Society of Dyers and Colourists, 1962, Supplement, 1966).
17. Journal of the Society of Dyers and Colourists, vol.66, 1950, p.213.
18. Standard Methods for the Determination of the Colour Fastness of Textiles, 4th ed. (U.K., Society of Dyers and Colourists, 1978).
19. I. Holme and J.K. Skelly, Journal of the Society of Dyers and Colourists, vol.88, 1972, p.299.
20. "Basic dyes on acrylic fibres committee", Journal of the Society of Dyers and Colourists, vol.89, 1973, p.292.
21. "Technical information note D 645," I.C.I.
22. Sandoz Colour Chronicle, No.4, 1978, p.6.
23. Ciba Review, Nos. 5-6, 1965, p.48.
24. R.W. Shackleton, Journal of the Society of Dyers and Colourists, vol.66, 1950, p.221.
25. J. Brown, Journal of the Society of Dyers and Colourists, vol.53, 1937, p.87.
26. W. Garner, Textile Laboratory Manual, 3rd ed. (London, Heywood, 1967) vol.4, p.20.
27. British Standards 756: 1952
28. Sandoz Colour Chronicle, No.4, 1977, p.7.
29. Sandoz Colour Chronicle, No.1, 1978, p.5.
30. J.A. Rayburn, "Analytical methods for a textile laboratory", A.A.T.C.C. Monograph No.3, 2nd ed. (North Carolina, The American Association of Textile Chemists and Colorists, 1968) chap.3, p.65.

31. N.S. Saraiya and S.M. Doshi, Colourage, vol.24, No.11A (26 May 1977), p.21.

32. W. Garner, "Resins and finishes", and "Detergents" in Textile Laboratory Manual, 3rd ed. (London, Heywood, 1967), vols. 2 and 3.

33. Textile Chemist and Colorist, vol.10, 1978, p.260.

34. H.E. Bille, A. Kretschmer and G. Schmidt, Textilveredlung, No.7, 1972, p.749.

35. A. Kretschmer, Melliand Textilbericht, No.54, 1973, p.271.

36. International Dyer, vol.155, No.9 (1976), p.396.

37. F. Bulmer, Journal of the Society of Dyers and Colourists, vol.95, 1979, p.104.

38. J. Park, International Dyer, vol.158, No.2 (1977), p.70.

39. I.F. Duff, Textile Institute and Industry, No.11, 1973, p.156.

40. International Dyer, vol.147, No.6 (1972), p.334.

41. I. Holme, International Dyer, vol.159, No.4 (1978), p.165.

42. J.F. Burbridge, International Dyer, vol.153, No.11 (1975), p.579.

43. H. Kinder, International Dyer, vol.156, No.8 (1976), p.398.

44. Industrial Safety Handbook, W. Handley, ed. (New York, McGraw Hill, 1969).

45. H. Petersen, Textilbetrieb, vol.91, No.3 (1973), p.53.

46. J.R. Bell, I. Gailey and S. Oglesby, Journal of the Society of Dyers and Colourists, vol.87, 1971, p.432.

47. I. Gailey, Textile Chemist and Colorist, vol.9, 1977, p.25.

48. I. Pringle, International Dyer, vol.153, No.5 (1975).

49. I. Pringle, American Dyestuff Reporter, vol.64, Nov. 1975, p.15.

50. E.R. McLean, Textile Chemist and Colorist, vol.1, 1969, p.192.

51. International Dyer, vol.155, No.8 (1976), p.342.

52. Textile Month, March 1976, p.48.

53. P.G. Noble, Journal of the Society of Dyers and Colourists, vol.92, 1976, p.34.

54. M.J. Topham, International Dyer, vol.156, No.6 (1976), p.286.

55. S.A. Short, Journal of the Society of Dyers and Colourists, vol.95,1979,p.112.

56. International Dyer, vol.153, No.5 (1975), p.262.

57. F. Oehme, "Textile finishing", 62nd Annual Conference of the Textile Institute, Edinburgh, September 1978.

58. New Techniques in Wet Processing of Textiles with Emphasis on Cotton (United Nations publication, Sales No. 76.II.B.1.), p.22.

59. T. Gadian. Review of Progress in Coloration and Related Topics, vol.7, 1976, p.85.

60. S.J. Silk, Journal of the Society of Dyers and Colourists, vol.85, 1969, p.458.

61. Guide for Safety in the Chemical Laboratory, 2nd ed. (New York, Manufacturing Chemists Association, Van Nostrand Reinhold Co., 1972).

62. G.D. Clayton and F.E. Clayton, eds., "General principles", Patty's Industrial Hygiene and Toxicology, vol.1 3rd rev. ed. (New York, John Wiley, 1978).

63. N.I. Sax, Dangerous Properties of Industrial Materials (New York, Van Nostrand Reinhold Co., 1975).

64. G.W. Madaras, 10th Shirley International Seminar, 9-11 May 1978 (Manchester, Shirley Publications), p.161.

65. G.J. Parish, 10th Shirley International Seminar, 9-11 May 1978 (Manchester, Shirley Publications), p.179.

66. "Transport of dangerous goods; Recommendations prepared by the Committee of Experts on the Transport of of Dangerous Goods" (ST/SG/AC.10/1).

67. J. Golden and others, Environmental Impact Data Book (Michigan, Ann Arbor Science Publishers, 1979), p.699.

68. "Threshold limit values for 1977, Guidance note EH 15/77" (London, Health and Safety Executive, Her Majesty's Stationery Office, 1978).

69. G.W. Underdown, Practical Fire Precautions (London, Gower Press, 1971).

70. P. Nash and J. Newell, Industrial Safety Handbook, W. Handley, ed. (New York, McGraw-Hill, 1969), chaps. 3A,3B, pp.72,92.

71. A.W.M. Balemans and others, "Loss prevention and safety promotion in the process industries:Proceedings of the 1st International Loss Prevention Symposium, The Hague/Delft, the Netherlands", C.H. Buschmann, ed. (Amsterdam, Elsevier Scientific Publishing Company, 1974), p.7.

72. A Guide to Fire Prevention in the Chemical Industry (London, Chemical Industries Association, 1968).

73. "Toxic substances: A precautionary policy, Guidance note EH 18" (London, Health and Safety Executive, Her Majesty's Stationery Office, 1978).

74. J.L. Worsley, Journal of the Society of Dyers and Colourists, vol.94, 1978, p.471.

75. Lord Taylor and P.D. Wright, First Aid in the Factory, 4th ed. (London, Longman Group Ltd., 1973).

76. A Guide to the Safe Handling of Chemically Based Products; Product Hazard Data (United Kingdom, B.A.S.F., 1979).

77. P. Arscott and M. Armstrong, An Employer's Guide to Health and Safety Management - A Handbook for Industry (London, The Engineering Employers Federation, 1976).

78. A.H. Little, Water Supplies and the Treatment and Disposal of Effluents; Textile Institute Monograph No.2 (Manchester, The Textile Institute, 1975).

79. G.M.S. Duff and P. Husband in Loss Prevention and Safety Promotion in the Process Industries, C.H. Bushman, ed. (Amsterdam, Elsevier Scientific Publishing Company, 1974), p.121.