Textile Dyes: Techniques and their Effects on the Environment with a Recommendation for Dyers Concerning the Green Effect

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Abstract

This thesis examines different classes of dyes, the processes they require, their use on different textiles, and their potential effects on the environment. Additionally, experiments with natural dyes were conducted and documented. Natural berries, roots, and other dyestuffs were collected and used to dye both natural and synthetic textiles. Through research and experimentation, the different types of dyes and techniques were compared and contrasted. Each type of dye has benefits and disadvantages. Every system of dyeing produces waste along with the finished product. Current government standards regarding textile waste are discussed as well as ways to reduce costs while adhering to these standards.

Textile Dyes: Techniques and their Effects on the Environment with a Recommendation for Dyers Concerning the Green Effect

Color has long been an important part of society. Color can denote class, economic position, and style. It is no wonder then that every civilization, dating back even to ancient times, has developed different dye techniques and processes. These processes range from using dyestuffs found in nature, to the chemicals that are sometimes used today.

Textile Dyes

The Development of Dyes

Throughout history, there have been several articles of clothing and dye colors that have made significant impacts on society. In the past, dyes were produced individually by harvesting natural fruits, vegetables and other items, boiling them, and submersing fabrics in the dyebath. It was a long and tedious process. This was the common practice until the mid-1800s (Joseph, 1977). Today, pre-packaged dyes are readily obtainable in almost every color, and are available to anyone who can purchase the end product. The development of different dyes and techniques has made this transition possible.

Dyeing in Ancient times

Primitive society discovered that certain roots, leaves, or bark could be manipulated, usually into a liquid form, and then used to dye textiles. They used these techniques to decorate clothing, utensils, and even the body. This was a religious, as well as functional practice. Records date all the way back to over 5,000 years ago chronicling the dyeing of fabrics. Excavated cloth fragments that date back to 3000 B.C. evidence the intricate dyeing practices and skills of India as well as hundreds of vibrant colors used to dye things in Peru (Belfer, 1972).

Certain hues have historical importance and denote social standing. For example, the color "royal" purple was reserved for royalty and nobility not all that long ago (Belfer, 1972; The ancient Phoenicians). The dye for this was made from the secretions of shellfish. Shellfish produce a clear fluid that oxidizes when exposed to the air; this was used to produce a red to bluish purple. This dye was difficult to create and used only on the finest garments; hence it became associated with aristocrats and royalty. Knowledge of this Tyrian purple was lost during the Middle Ages and not rediscovered until the mid-1800s by a French scholar (Belfer). Blue dyes were particularly difficult to come across and thus were viewed as a sign of wealth (Dye). The colors one wore could even proclaim their sins, as chronicled in Nathaniel Hawthorne's book *The Scarlet Letter.*

Ancient India was particularly advanced in dyeing techniques and has been known since the sixteenth century for their vibrant colors and designs on fabrics. Resist-dyeing techniques probably originated here. Also, Indians discovered the use of mordants to make dyes fast and an integral part of the fabrics, not just a pigment on the surface (Belfer, 1972).

Making Dyes

In the past, only organic matter was available for use in making dyes. Today, there are numerous options and methods for the colorization of textiles. While today's methods capitalize on efficiency, there is question as to whether the use of chemicals is harmful to the environment. A reputation for harming the earth could be detrimental to a company in a society becoming more and more focused on the environment and its preservation.

Some say the discovery of dyes was probably an accident, a simple stain from a berry for fruit, and dates back shortly after the dawn of civilization. Ancient man used almost exclusively vegetable dyes. Known roots and berries and various sorts of dyestuffs were gathered, boiled, and then fabrics and textiles were submerged, resulting in the first dyed products. In this way many new dyestuffs were discovered. In fact, numerous writers have confirmed the knowledge of over one thousand sources of dyes (Leggett, 1944). As trade and commerce developed, certain dyes were regarded as better than others, and some ceased being used. Natural dyes used included vegetable, animal, and mineral dyes.

In 1856, Sir William Perkin made a discovery that some even say changed the world. He discovered the color mauve. This was the first synthetic dye. His method for the dyeing of this color, using coal and tar, resulted in many scientific advances and the development of synthetic dyes that are widely used today (Garfield, 2001).

No matter which dyeing technique is used, natural or synthetic, water is required to complete the process. In order for water to be usable, it must be purified. Depending on the source of the water, it may contain an excess of carbon dioxide, bicarbonates, sulphates and chlorides of calcium, magnesium and sodium. Water can be identified in the three following broad categories: Well or spring waters, moorland waters, and surface waters. Well water is usually clear and of constant composition. It may have some sodium bicarbonate, bicarbonates of calcium, magnesium, and iron, as well as free carbon dioxide. Moorland water may be tinted and somewhat acidic. The color and acid in this water is from organic materials. The acidity and some dissolved gases may make this water corrosive. It may contain calcium chloride, magnesium chloride, and sulphates. Surface water contains sulphates, chlorides, calcium bicarbonate, and magnesium bicarbonate as well. These impurities must be removed to the limits of suitable water quality (Peters, 1967). After water is treated for turbidity and color, iron and manganese, alkalinity, and hardness of water, it can be used in textile mills.

Types of Natural Dyestuffs

Because most of the dyes used in ancient times were discovered by accident, they often consisted of natural plants that were common in society. As dyes were developed and experimented with, people became more adventurous and would attempt different mediums as dyes. Hence, the dyeing industry developed.

Some well-known ancient natural dyes include indigo, madder, and cochineal. Indigo has been used throughout East Asia since before recorded history but probably originated in India. Indigo also played a major role in the crops of colonial South Carolina. It was introduced there in the 1740s but did not take off as a cash crop until it was reintroduced by Eliza Lucas Pinckney. It was a staple crop only second to rice between 1763 and the American Revolution (Edgar, 1998). It produces a deep blue color that is prevalent in batik prints from India. Madder produces a rich, deep red color and is made by crushing and grinding the roots of the madder plant. The use of madder as a popular dyestuff quickly dissipated after the invention of the synthetic mauve dye (Garfield, 2001). Cochineal was first discovered in South America by crushing dried Cocus Cacti, an insect. It produces a range of bright red colors (Belfer, 1972). Other popular vegetable dyestuffs include woad, saffron, safflower, weld, brazilwood, logwood, barwood, camwood, the fustics, orseille, cudbear, annatto, and turmeric.

Woad is a two-to-five-foot tall plant. It was once thought by the Greeks to be able to remove skin roughness by putting its leaves on rough parts of the body. This blue dye is thought to have originated in Southern Europe. To prepare the woad plant for dyeing, a lot of processing and fermentation would have to occur. This process would take several weeks before the dyestuff was ready to be sold. Dyes made from young woad leaves would yield a light blue color, mature leaves would yield a darker blue, and fully ripe woad leaves would create a bluish-black color in the dye. Woad dyes were very popular; however, with the rediscovery of Indigo dyes after the Dark Ages, the popularity of Woad greatly subsided. It was even said that woad was "banished by Indigo" (Leggett, 1944). However, even in the early 1700s, the English poet Garth wrote, "When dress was monstrous and fig leaves the mode And quality put on no paint but the woad." (as cited on p. 35).

Saffron was the main dyestuff used to attain the color yellow by the Greeks and Romans. It is gathered from the flowering plant *Crocus sativus* and is taken from the pistils of the flower. Nearly everywhere it was employed saffron was found useful for more than just dyeing. It was used as a perfume for baths, a spice, and even in medical prescriptions. It is still thought of today as a luxury spice for foods. The saffron blossom was even adopted into the coat of arms for the city of Basle, Switzerland. The Saffron War of 1374 occurred when a consignment of 800 pounds of Saffron was seized as booty from a Swiss community and drew attention to the importance of this plant (Leggett, 1944).

Safflower, a thistle also used to produce the color yellow, was originally cultivated in Spain and Egypt. The plant's dye content is made up of a water-soluble yellow and a water-insoluble red component. Dyestuffs of this sort come from the florets of small flowers from this plant. They are picked when in full bloom and dried in the sun. They are hand kneaded and pressed into cakes. Optimally the result is a reddish-yellow dye. However, safflower is very versatile and, when used with different acids and alkalis, and can give off yellow, orange, red and pink shades. However, it is a weak dyeing agent and requires a great deal of dyestuffs (Leggett, 1944).

The Weld plant often grows wild. The whole plant, except for the roots, is used to create dyes. It was the ultimate means for yellow dyes for many centuries and was only replaced when Fustic was brought back to Europe from the Americas in the 1500s. This type of dye was highly prized in antiquity and reserved by the Romans for bridal garments and the clothes of the six Vestal Virgins (Leggett, 1944).

Several stuffs used for dyes come from trees. The wood from these trees is cut into small pieces, dried, mixed with water, and allowed to ferment. The result is many different colors. Brazilwood, which encompasses various leguminous trees, produces a bright red color in all fibers except for silk and if a "bicromate of potash" mordant is used a purple-red color is the result. Brazilwood is still used today in wool dyeing and calico printing. Logwood was used to produce purple colors on wool fabrics, blue and black on cotton and wool, and black and violet on silk. It is used today as an important black dye for cotton. Barwood is used to produce a dark blue color; however, camwood can also be used to produce an intense red. The fustics produce a reddish-orange color and Orseille produces a purple color that was very popular for dyeing wool by the Florentines in the

Middle Ages and after. Similarly, Cudbear produces a lilac color and Annatto a reddish-orange (Leggett, 1944).

Turmeric, which merited use in this experiment, produces a yellow dye from the roots of plants native to China and India. It was very popular for dyeing silk and wool for many centuries (Leggett, 1944).

With natural dyestuffs, colorists encountered a problem. The beautiful colors that they created would initially appear vivid, but soon fade. Very few dyes proved to be colorfast. This problem resulted in the discovery of mordants (Joseph, 1977). This breakthrough resulted in further advancement in coloring and new and additional products used in dyeing fibers.

Commonly Used Dyes

Today, with the invention of synthetic materials used in textiles, many new types of dyes have been developed and put into regular use. There are two basic ways to color textiles: dyes and pigments. Pigments are not a dye but rather resins mechanically bound to fibers. Conventional, or aqueous, dyeing is the most common colorization technique. Dyes are divided into classes according to the types of fibers they are most compatible with. The most notable are: acid dyes, premetalized acid dyes, chrome dyes (mordant dyes), cationic dyes (basic dyes), direct dyes (substantive dyes), direct developed dyes, disperse dyes, naphthol dyes, reactive dyes, sulfur dyes, and vat dyes (Price, Cohen, & Johnson, 2005).

Acid dyes are used on protein fibers, nylon spandex, and special type acid-dyeable acrylic fibers. Acid dyes produce bright colors that have excellent fastness, or the ability of the dye to stay on the fabric and not rub off or fade, to dry cleaning, but not necessarily to washing or light and perspiration. Premetalized acid dyes and chrome dyes are used for the same types of fibers, but premetalized acid dyes are less bright with better fastness to light and sweat. Chrome dyes result in dull colors and have excellent fastness to light, washing, and perspiration. They are great for wool and carpets. Cationic dyes are generally used for acrylic, modacrylic, cationic dyeable polyester, cationic dyeable nylon, cellulosic, and protein fibers. They produce bright colors that have excellent fastness to light, laundering, perspiration, and crocking on synthetics fibers, but poor fastness to washing and light on natural fibers. Direct dyes are used on cellulosic fibers and have excellent fastness to perspiration and drycleaning, but poor fastness to washing and varied light fastness. Direct developed dyes are used on the same cellulosic fibers, but have good to excellent fastness to laundering. Disperse dyes are used for acetate, acrylic, modacrylic, nylon, polyester, and olefin fibers. The wash fastness with disperse dyes varies with the fibers- poor on acetate, excellent on polyester. Fastness to light is fair to good, but there is some gas fading on acetate. However, fastness to perspiration, crocking, and dry-cleaning is excellent. Naphthol dyes are employed for cellulosic fibers. They create bright shades of color with varying fastness to light. However, they have good fastness to washing and perspiration. Reactive dyes are primarily utilized on cellulosic fibers, but occasionally on protein fibers and nylon as well. They generate bright shades with great to excellent fastness in all areas, but are difficult to match shades. Sulfur dyes are used on cellulosic fibers as well to create dull shades such as navy, black, and brown. They have excellent fastness in most areas, but are weak when exposed to chlorine. Vat dyes have excellent fastness in all areas as well, especially to chlorine and bleach, however, if not properly applied, they may crock. Vat dyes are used on cellulosics. Finally, pigments, which are not a dye, can be used on all fibers. This is because pigments are bound to the fiber by resins and do not need to be absorbed. However, they are susceptible to crocking. Dyeing can be done in the garment, fabric, yarn, fiber stage, and sometimes even before, which is called stock dyeing (Price, Cohen, & Johnson, 2005).

Dyeing Techniques

There are several ways to conduct the dyeing process. Many techniques are intricate and decorative. Resist dyeing is an old technique that dates back to the B.C. era. This decorative technique is achieved when certain parts of the textile product are treated or prevented from accepting the dyes that the rest of the fabric receives. Common resist-dyeing techniques include tie-dyeing, hot wax resist technique, starch paste resist, tritik, and clamping methods. Batik fabrics and their intricate designs are created using some, all, or a combination of these techniques. The tie-dye technique involves various methods of folding fabrics, tying and binding them, then dyeing the fabric in a dye bath. Parts of the fabric do not receive the dye because of their bindings and in this way designs are created. Different cultures have different names for this technique. In Indonesia it is called Plangi, in India Bhandhana, in Nigeria Adire Eleso, and in Japan Shibori (Belfer, 1972).

The hot wax resist technique of dyeing is known as the Batik process through Japan, India, and Indonesia. It consists of creating designs on fabrics using hot wax. When the fabric is dyed, the parts of the fabric with the now-cooled wax resist the dye and do not accept color. This process can be repeated with many different colors and designs for a truly unique and intricate fabric outcome (Belfer, 1972).

Starch paste resist dyeing is similar to hot wax resist dyeing, but a soluble flour paste is applied to the fabric instead of hot wax. This technique was widely used throughout Asia. It was also very popular and well known throughout Africa, particularly Nigeria where it was called Adire Eleko. The tritik technique refers to simples stitches sewn into the cloth. They are tightly gathered to form the resist. This is traditionally an Indonesian technique, but other cultures have also adopted it. The clamping methods are just like what they sound. They involve clamping solid flat objects to the fabric to form the resist (Belfer, 1972).

Mordants are an important part of successful dyeing techniques. According to Belfer, mordants are, “chemical solutions which can be used before, during or after the dye bath, thus preparing the fiber to receive the color and also to control the actual hue obtained.” The use of mordants affects the color outcome. Use of a different mordant will result in a different shade of color. To duplicate a color, not only the dyestuff but also the mordants must be exactly the same. Common mordants used include acetic, tartar, and tannic, which are organic acids, and the salts alum, tartar emetic, and Glaubers salt (Belfer, 1972).

Dyeing techniques changed in 1856 when Sir William Perkin, an English chemist, discovered a new dye. The dye was for the color mauve and was prepared using coal and tar. The vibrant color created not only had a tremendous impact on the fashions of the day, but also spurred on many other scientific discoveries. Upon accidentally discovering this dye, Perkin colored a piece of silk cloth and saw that its color did not fade. He shared the discovery with friends and colleagues and was urged to attempt large-scale production. This new dye shortly replaced the natural dye of madder (Garfield, 2001).

Effects of Dyes

Historically, the interiors of a home furnished in rich, deep colors indicate a great amount of affluence and high standing. Today, as in the past, warm hues lend a feeling of comfort and warmth to a home. The task of making clothing and home furnishings fell to the lady of a house, or on her servants, until the mid 1800s. This included dyeing the necessaries textiles (Dye, 2008). Fabric remains dating back to over 1000 B.C. have been identified as dyed using madder and cochineal (Wouters, Maes, & Germer, 1990), and colonists in America used plants such as indigo to color their garments (Edgar, 1998). Wealthy families could afford to purchase pre-made fabrics, or even to have a seamstress construct garments. These pieces of clothing, however, were couture: made and tailored for a specific person. There were no stores to purchase ready-made items and dyeing was typically done at home.

The ready-to-wear apparel industry is only about 180 years old. Records date clothing factories back only to 1825 (Stamper, Sharp, & Donnell, 1988). As the responsibility for the making of clothing and textiles moved from within the home to factories, the stigmas and importance of color began to slacken. This is not to say, however, that colors do not have importance in society today. Recent studies have shown certain colors to give advantages to sports teams. For example, a study by Durham University found that, when other factors are equal, competitors wearing red had a considerable advantage in sporting events (Rincon, 2005). Also, certain hues denote feelings and power. Blue generally symbolizes peace and tranquility, while many men consider their red ties a “power tie.”

The ever-developing dye industry has effects other that psychological. As with any industry, production creates a considerable amount of waste. Textile manufacturers generate about 384,000 tons of waste each year. Much of this can be eliminated through recycling. In New York City, for example, a law has been passed requiring that "any company generating more that 10% of its waste as textile scrap must recycle that material along with the other mandated commercial recyclables (paper, cardboard, etc.)" (Ganiaris & Okun, 2001). Internal recycling, or the reusing of products inside the plant is ideal and several textile manufacturers have begun to utilize these practices, but many more need to implement them. The EPA cites this case:

> Ti-Caro, a North Carolina textile manufacturer that produces dyed and finished fabrics, implemented several process modifications and chemical substitutions to reduce its effluent discharge levels. These pollution prevention applications not only brought the firm into compliance and reduced its water usage, but resulted in over $15,000 per year in savings. Americal Corp., a nylon hose producer, is realizing $35,000 per year in savings by applying similar pollution-prevention strategies to its dyeing and discharge and wastewater treatment processes. (Ganiaris & Okun).

Some of the most difficult pertinent problems for dyers to consider are water use reduction and eliminating color and salts from waste water. Cotton dyers and those using fiber reactive dyes deal especially with these issues (Best management practices, 1996). Wash water can be reused for cleaning in the facility and certain waters reused for desizing, scouring, and other tasks in textile plants. Also, utilizing countercurrent washing, flow control on washers, high extraction of the materials (to reduce drag out), detection and repair of leaks, and general recycling and reuse of waters can make significant reductions in the amount of water used (Best, 1996). Other methods that may be utilized to prevent pollutants from being released into the environment are awareness of potentially hazardous materials, such as aryl phenol ethoxylates, chlorinated aromatics, and metals, and using pad batch dyeing. This removes the need for salts and other chemicals from the dye bath and has been linked to reducing casts and pollution source reduction (Effluent Limitation Guidelines, 2008).

As one can easily see, recycling and waste management is not only beneficial for the environment, and Americans in turn, but it is extremely cost effective. Efforts should focus on managing resources, recycling, and proper disposal of waste.

Government Involvement

As with many scientific discoveries, many advances in the dyeing industry were not particularly healthy for the environment and the United States Government became involved. In 1972 Title III of the Federal Water Pollution Control Act established the Effluent Guidelines Program. It was amended in 1977 by the Clean Water Act Amendments and in 1987 by the Water Quality Act (Textile Mills, 2007). Today these actions are all commonly referred to as simply the Clean Water Act. Through the Environmental Protection Agency, or EPA, these acts set limits for the amount of toxic discharge legally allowed to be returned to the environment. Different regulations apply to different industries, as each utilizes the use of different chemicals. A list of all these regulations can be found on the EPA's website (epa.gov) (Effluent Limitation Guidelines, 2008). The National Pollutant Discharge Elimination System (NPDES) program strives to control water pollution by issuing permits and "regulating point sources that discharge pollutants into waters of the United States" (National Pollutant, 2008). Point sources are places that discharge pollutants directly into the water; they may include pipes or man-made ditches. Any organization that uses a point source to dispose of pollutants, or if their discharges go directly to surface waters, must obtain a permit from the NPDES. Private homes that are connected to a municipal system, have a septic system, or do not have surface discharge do not need this (National Pollutant). The NPDES program has improved the United States' water quality since it began in 1972, but there is still work to be done. Conflict with Textile Mills and outsourcing to other countries are big factors to deal with.

Effluent Guidelines for Textile Mills were first promulgated in 1982 and limitations and standards exist concerning the Best Practicable Control Technology Currently Available (BPT), Best Available Technology Economically Achievable (BAT), and New Source Performance Standards (NSPS). The EPA set BPT limitations for three types of pollutants: conventional, toxic, and non-conventional. Conventional pollutants include: biochemical oxygen demand (BOD5), total suspended solids, fecal coliform, pH, oil and grease, and any additional pollutants defined by the Administrator as conventional. There are 65 pollutants and classes of pollutants that have been identified as toxic by the EPA. Everything else is considered non-conventional (Effluent Limitation Guidelines: Frequent Questions, 2008). Factors considered when specifying BPT include

> Total cost of applying control technology in relation to effluent reduction benefits… age of the equipment and facilities, the processes employed and any required process changes, engineering aspects of the control technologies, non-

water quality environmental impacts (including energy requirements), and such other factors as the EPA Administrator deems appropriate (Effluent Limitation Guidelines: Frequent Questions).

When considering BAT standards, “the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the process employed, potential process changes, non-water quality environmental impacts, including energy requirements and other such factors” are considered (Effluent Limitation Guidelines: Frequent Questions, 2008).

Finally, NSPS standards are considered with “the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements” in mind. The NSPS is important because new sources have the opportunity to utilize the latest and most advanced control technology, whereas older plants, for example, will have more difficulty implementing new technology; The NSPS ensures that new developments are taken advantage of. Even with the consideration of economic concerns of the businesses these legislatures effect, these laws have been blamed for past hard times of textile mills (Effluent Limitation Guidelines: Frequent Questions, 2008).

As of February 7, 2008, the Electronic Code of Federal Regulations (e-CFR) has listed eight categories in which regulations exist concerning pollutants in effluents from textile mill point sources. The categories are: wool scouring, wool, finishing, low water use processing, woven fabric finishing, knit fabric finishing, carpet finishing, stock and yarn finishing, nonwoven manufacturing, and felted fabric processing. For example, when finishing in the stock or yarn phase, sulfides in wastewater must not exceed 0.24 Kg/kkg (or pounds per 1, 000 lb) of finished product and total chromium must not exceed

0.12 Kg/kkg of finished product. Similarly, when finishing woven or knit fabric structures, sulfides and total chromium must not exceed 0.20 Kg/kkg and 0.10 Kg/kkg, respectively (Electronic Code). It is important to look at the Best Available Technology Economically Achievable (BAT) and New Source Performance Standards (NSPS) because these are the most pertinent to the companies aiming to implement and sustain these standards. Complete charts for the BAT and NSPS government standards for the above categories are listed as follows:

Woven fabric finishing

Pollutant or pollutant property	**BAT limitations**	
	Maximum for any 1 day	**Average of daily values for 30 consecutive days**
	Kg/kkg (or pound per 1,000 lb) of product	
COD	60.0	30.0
Sulfide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05

Pollutant or pollutant property	**NSPS**	
	Maximum for any 1 day	**Average of daily values for 30 consecutive days**
	Kg/kkg (or pounds per 1,000 lb) of product	
BOD *5*	3.3	1.7
COD	41.7	26.9
TSS	8.8	3.9
Sulfide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05
pH[1]	([1])	([1])

[1]Within the range 6.0 to 9.0 at all times.

Knit fabric finishing

Pollutant or pollutant property	BAT limitations	
	Maximum for any 1 day	**Average of daily values for 30 consecutive days**
	Kg/kkg (or pounds per 1,000 lb) of product	
COD	60.0	30.0
Sulfide	0.20	0.10
Phenols	0.10	0.05
Total Chromium	0.10	0.05

Pollutant or pollutant property	NSPS	
	Maximum for any 1 day	**Average of daily values for 30 consecutive days**
	Kg/kkg (or pounds per 1,000 lb) of product	
BOD *5*	3.6	1.9
COD	48.1	31.0
TSS	13.2	5.9
Sulfide	0.20	0.10
Phenols	0.10	0.05
Total chromium	0.10	0.05
pH	([1])	([1])

1Within the range 6.0 to 9.0 at all times.

Stock and yarn finishing

Pollutant or pollutant property	BAT limitations	
	Maximum for any 1 day	**Average of daily values for 30 consecutive days**
	Kg/kkg (or pounds per 1,000 lb) of product	
COD	84.6	42.3
Sulfide	0.24	0.12
Phenols	0.12	0.06
Total chromium	0.12	0.06

Pollutant or pollutant property	NSPS	
	Maximum for any 1 day	**Average of daily values for 30 consecutive days**
	Kg/kkg (or pounds per 1,000 lb) of product	
BOD *5*	3.6	1.9
COD	33.9	21.9
TSS	9.8	4.4
Sulfide	0.24	0.12
Phenols	0.12	0.06
Total chromium	0.12	0.06
pH	([1])	([1])

[1]Within the range 6.0 to 9.0 at all times. (Electronic Code)

Experimentation

With the many effects that dyes and colors have on society, it is important to understand them. One of the best ways to do this is through personal experimentation. In the words of William Harris,

> …if we examine color in terms of its performance in light and its origin in the world of living organisms, we can establish identities much more exactly than through the historical written record. In short, using eyes to see with and a modest touch of imagination, one can open doors to the ways hues were seen in other times and places.

In order to determine the dyeing capabilities of different natural dyes, an experiment was performed. In the experiment, six different fabrics, with differing fiber content, were each dyed in six different dyes. The fabrics were of the following contents: 100% silk, 55% flax 45% viscose, 100% polyester, 65% polyester, 35% cotton, 100% acetate, and 100% cotton. Dyeing fabrics of these different 100% contents and fiber blends in the same dyes gives an effective means of comparison between the affinity for dyes of the fibers used. Creating all of the dyes involved mixing water with a dyestuff. The following dyestuffs and ratios where used:

1. Peels of three yellow onions: four cups Water
2. Peels of three red onions: four cups water
3. Skin of one eggplant: three cups water
4. One pomegranate, chopped: four cups water
5. Two cups ground coffee: four cups water
6. .95 oz ground Turmeric: three cups water

The dyes were brought to a boil in a large pan, then allowed to simmer for an hour. After one hour, the dye was strained and the dyestuffs removed. The fabrics were then added to the pot of dye and allowed to soak for 30 minutes. In order to enhance the dyeing ability of the fabrics, they were allowed to soak in a mixture of one part vinegar: two parts water. This helps to open up the fibers to aid in dye acceptance and as a color fixative. Also, Alum was added to the fixative mixture to help set the color and prevent fading (Making natural dyes). The fabrics were soaked in this mixture for one hour, then rinsed and added to the dye bath still wet.

It was expected that the fabrics made up of natural fiber contents would accept the dyes well, while man-made or synthetic fabrics would not. Blends were expected to be somewhere in between these two extremes. The dyes that were created were recommended on Pioneerthinking.com, except for the pomegranate and eggplant dyes. I thought these two items would make good dyes, and so they were included in this experiment. As expected, the natural fibers took the dyes well and the synthetic fabrics did not. The one exception to this was with the turmeric dye, where all of the fabrics were brightly colored yellow.

The yellow onion peel dye resulted in an orangish-yellow color in the 100% silk and 100% cotton content fabrics. The linen blend fabric, which was already a brownish hue, in its natural form, had a yellow tint. The 100% polyester, the polyester blend, and the 100% acetate fabric did not accept the dye well and were barely tinted an orangish color.

The red onion peel dye had a similar outcome. The 100% silk and 100% cotton content fabrics turned a purpley-mauve color. The silk had a bit of blotchiness and a green spot on it. The linen blend fabric was tinted pink and the synthetic fabrics and the blended polyester and cotton fabric were barely affected by the dye.

The eggplant dye was not very effective. None of the fabrics took the dye well, although the mixture was a dark blackish-purple in the pot. Cotton had the most change out of all the fabrics, with a slight grayish hue.

The pomegranate dye was successful. It resulted in a beautiful pinkish-mauve color in the natural fibers. The cotton and the linen blend fabric had fairly even coloring. However, the silk fabric, which turned more of a yellowy-pink shade, had a pink spot on it. While these fabrics did take the dye wonderfully, after only one day the color had already faded dramatically. As expected, the synthetic and synthetic blend fabrics were barely affected by the dye. It would be recommended to use some sort of mordant or color fixative with the pomegranate dye.

The coffee dye was largely successful as well with an even stronger tint on the synthetic fabrics than the previous dyes. This dye resulted in a brownish-orange tone on the fabric. The 100% silk content fabric, which was the most orange, took best to this coloring. The cotton fabric had more of a brown hue was pretty evenly colored. The polyester fabric took the brown coloring quite well, although it was not even. The polyester-cotton blend fabric had the most resistance to the die, which is curious because both the 100% polyester and 100% cotton fabric took the color quite well. The 100% acetate fabric was slightly yellowy.

Finally, the turmeric dye was by far the most successful. All of the fabric took very well and were a bright yellow color at the end of the experiment. The silk and cotton fabric were deeper shades of yellow, but the other fabrics were bright as well. Even the acetate and polyester fabrics, which had the lowest dye acceptance with the other dyes, were very brightly colored.

Popularity of Green

Today, it seems that everyone is advocating “going green.” Ads boast of new eco-friendly products, celebrities talk about it, politicians warn of global warming, and some cities even offer free public parking to those with eco-friendly hybrid cars. Considering the current economic state of this country, saving money in electric bills and lowering gas usage is very appealing. Society is becoming more and more focused not only on the environment, but on saving money as well. This time, it is not a peace, love, and happiness revolution like in the 70s, but a movement advocated by many well-to-do individuals, politicians, and celebrities. The need to practice an earth-friendly lifestyle concerns everyone. Many companies, such as BP and Honda, are supporting this movement through donations, research, and new products to reduce consumption and waste. With the Green movement in full swing, implementing earth-friendly practices can not only help the environment, but also attract new customers. Going green is more than just the latest trend, it has become a call to action for many people.

Recommendations

Many industries have seen decline, or even slowed progress, due to the common outsourcing of labor and low prices of imported goods. The textile industry took a considerable blow because of this. Also, the restrictions of the EPA create added responsibilities and thus added costs for textile companies resulting in less profit. The combination of foreign competition and new restrictions from the EPA has resulted in many textile mills closing their doors.

Today, there is an increasing desire to purchase American-made goods and also a growing concern for the environment. Going “green” is the growing trend. There have been huge awareness events, such as Live Earth, and the issue of Global Warming can scarcely be avoided. With consumers focused in this mindset, now is an ideal time for textile companies to embrace this trend and advertise “green” products. Today some consumers go as far as to advocate organically grown textile products. If textile-producing companies embrace these trends, they can not only capitalize by increasing profits, but also sleep better knowing that they are doing their part to protect our environment.

Adopting friendly practices such as reusing and recycling wastewaters is a great start for accomplishing these goals. Being aware of new technology, such as pad batch dyeing, can accomplish both economical and ecological goals. Being abreast of the latest technology and scientific discoveries is a great advantage for American textile companies. In doing this, they will be able to plan for the future incorporating the latest technology. This will not only save the company money in the long run, but allow them a competitive advantage by utilizing time and energy conserving practices which will result in higher profits.

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