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**The transisition from natural madder to synthetic alizarine in
the American textile industry, 1870-1890**

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Iowa State University, 1989

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The transition from natural madder to synthetic alizarine
in the American textile industry, 1870-1890

by

Judith Lopez

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GENERAL INTRODUCTION

Madder and Alizarine

When the synthetic dyestuff, alizarine, was first extracted from coal-tar in 1868, it signaled the beginning of the end for herbaceous madder's dominance as the world's most widely and continuously used red dyestuff (Schaefer 1941a, 1398). For 5000 years (Appendix A) madder roots provided sun and water resistant red, and during the 17th to 19th centuries, it also gave variations of pink, orange, chocolate, and purple (Knecht, Rawson, and Loewenthal 1919, 42). Madder's several species were cultivated commercially in Turkey, Naples (Hayes 1875, 183), Holland (Miller 1758), and France (Sansone 1887, 8) to supply wool tapestry weavers (Hofenk de Graaff and Roelefs 1976), silk dyers (Rosetti 1548), cotton dyers (Bird 1882), and calico printers (Cooper 1815), with colorful alternatives to natural grey and beige fibers.

During madder's long history, the wispy shrubs rubia tinctoria and rubia peregrina, whose roots contain madder, were crops of great economic importance, and the technology for using them was prized by textile producing countries. Men in France and England learned madder print technology from India during the mid-1700s (Irwin and Brett 1970, 36). Americans borrowed madder technology, which had been refined in England, and bought their madder products from France and

Holland throughout much of the 19th century (Matthews 1920, 497).

The French eliminated some of the waste material in ground madder roots and concentrated its dye strength by making garancine and madder extracts. While both products were useful, cotton printers needed a more consistent and easier-to-use dyestuff.

After William Henry Perkin discovered the synthetic dyestuff, aniline mauve (Edelstein 1956, 598), in England's abundant and nearly worthless coal-tar, chemists sought additional dyestuffs in coal-tar. Men in Germany distilled alizarine, chemically identical to the main dyestuff in madder, from coal-tar in 1868 (Beer 1959, 118). Within 20 years madder cultivation almost completely ceased. Several sources suggest lower cost as a reason for the acceptance of alizarine (Brunello 1968, 287; Irwin and Brett 1970, 101; Scientific American 1879, 232).

Purpose

This study will examine the transitional years from 1870 to 1890 when American dye and print works gradually stopped using natural madder and began using synthetic alizarine. How the transition occurred, and possible factors contributing to the transition, are of interest.

Procedure

I located original company records, from American print

and dyeworks, in several New England libraries and museums (Appendices B1, B2, and B3). Data were compiled from documents including copy books of company correspondence, drug (dye) accounts and inventories, color superintendents' notebooks, and payroll reports.

The alternate manuscript style will be used in this dissertation. Two articles suitable for publication are inserted between the General Introduction to the dissertation and the General Summary. Appendices included for the dissertation will not necessarily be included with the articles when submitted for review. Because each article must be self-explanatory, some repetition occurs. A list of references cited is included at the end of each article, the references for the introduction and appendices are given at the end of the summary.

Article I

"Economic Considerations in The Transition from Natural Madder to Synthetic Alizarine in the American Textile Industry, 1870-1890" will be submitted for review to Textile History. Although this is an English publication, I believe there are enough common elements in the American transition to appeal to their readers, and British editors seem willing to report American research.

Article II

"The Role of Chemistry in the Transition from Natural

Madder to Synthetic Alizarine in the American Textile Industry to 1890" will be submitted for review to American Dyestuff Reporter. They have published articles on dye history in the past.

Previous Research

I explored two topics of research pertaining to the transition from natural madder to synthetic alizarine in the American textile industry. I examined research regarding other natural dyestuffs, especially indigo, which was as durable although not as versatile as madder, and other red dyes which may have competed with madder. Second, because the present research investigates a transition in the textile industry, I studied previous research pertaining to the adoption of other discoveries in the textile industry.

Dyes Several researchers have examined old textiles to determine their dye content. Until World War I, the Analytical Laboratory of Badische Aniline und Soda Fabrik (BASF), in Germany, tested natural dyestuffs and built up a "useful collection of natural dyes." These dyestuffs included logwood, redwood, fustic, weld, madder, cochineal, saffron, kermes, Tyrian purple, and lichens (Schweppe 1976, 29). Identification of an unknown dye is possible when the spectrum of the known dye is compared to the unknown spectrum. Each dye has a spectrum as individualistic as a fingerprint (Schweppe 1976, 32).

Much has been written about indigo that can be contrasted with madder. Indigo, derived from fermented leaves, was synthesized from coal-tar in 1880 and produced in commercial amounts by 1897 (Ihde 1964, 458). Madder, found in plant roots, was synthesized from coal-tar in 1868 and produced in commercial amounts by 1870 (Schaefer 1941a, 1398). Both synthetics were discovered in the Baeyer laboratories and developed and produced by Badische Aniline und Soda Fabric (BASF).

An interesting account of the first successful cultivation of indigo in America may be found in Holbrook's (1850) personal account of her mother Eliza Lucas. A slightly larger perspective dealing with indigo cultivation in the South between 1740 and 1790 is given by Sharrer (1971). Until cotton production proved to be even more valuable, indigo cultivation was a source of great profits to Southern plantation owners during the last half of the 18th century in America. Madder was never grown on a commercial scale in America (Lopez 1988, 50).

Only two accounts have been found of madder cultivation in America that might qualify as commercial ventures. Aaron Loockock wrote of the 30 acres of madder he cultivated from 1764 through 1775 near Charlestown (sic), South Carolina. Loockock mentions how easily madder was grown and how useful it was. He gives complete directions for cultivation and processing in an un-named newspaper (Loockock 1775).

Loocock considered the lack of English duties levied on madder as one of its advantages. No record has been found of what happened to Loocock's madder.

Joseph Swift, who grew madder on nine acres in Ohio from 1838 to 1842, reported getting a profit of \$200 per acre of madder and gave directions for its cultivation. In the Annual Report of the U.S. Patent Office (1847, 456), Swift strongly, but unsuccessfully, encouraged governmental support of madder cultivation. The Plough, Loom, and Anvil (1849, 447), and The Cultivator (1844, 359) carried reports of his account. Between 1830 and 1850, these, and other farm journals, carried articles promoting madder as a cash crop. None of these efforts, nor Miller's book (1758) written to encourage madder cultivation among English farmers¹, convinced American farmers to grow sufficient madder to eliminate the need to import Dutch and French madder.

Pettit (1974) wrote about a small set of unusual indigo prints thought to have been produced only in America. Katzenberg (1973) also wrote of interesting indigo textile pieces. Polakoff (1980) relates the legend of the origin of indigo, and its cultivation and use in Africa. No legend surrounds the origin of madder and no books entirely about madder-printed textiles have been found.

¹According to the curator of the Library Company of Philadelphia, Miller's book was available in Philadelphia by 1762 (Green, letter to the author, February 19, 1987).

Kermes was the most important red animal dye in the Old World (Donkin 1977, 9). The small worms that produce the dye were found on oaks along the north eastern Mediterranean coast, called the Levant, and in Near East countries and were used by the Greeks, East Indians, Persians, Turks, and Phoenicians. Kermes was found to be the dyestuff used for red in 84 percent of the silk samples taken from tapestries dated 1450-1600 AD, (Hofenk de Graaff and Roelefs 1976, 34). Madder was found in 80 percent of the wool tapestry samples tested.

Polish cochineal, insects gathered from the roots of trees, was quite expensive. When Spanish explorers brought quantities of cochineal back from South and Central America, the price dropped (Donkin 1977, Hofenk de Graaff and Roelefs 1976, 34). Some authors claim that British army tunics were dyed with cochineal (Schuster 1970, 197; Vietmeyer 1987, 44). Others believe madder was used (Abrahams 1976, 15; Liles, letter to the author, June 18, 1987). It may be that different military units used different dyestuffs.

Other red dyes included barwood, brazilwood, annatto, gum-lac, safflower, and pokeberry (Adrosko 1971, 20). They were used by professional dyers, but not as widely as madder. While being inexpensive, these other red dyes were generally less sun and water resistant than madder.

Innovations In previous research, the adoption of other textile innovations: the Perrotine press (Capey 1930),

copper rollers (Honey 1894), and the Draper loom (Feller 1966) suggest that adaptation to new technology occurred slowly in the textile industry. Workers feared innovations might not give good results (Honey 1894, 115); new equipment was expensive, and old industrialists were conservative (Feller 1966, 322).

No research has been found to verify whether similar problems and solutions arose during the introduction of a synthetic dyestuff into the textile coloring industry, that traditionally used natural dyes. The statement: none of the workmen previously employed in dyeing would use the new Turkey Red (a madder) process or investigate different dyeing procedures "on account of their attachment to the old methods" (Mellor and Cardwell 1963, 273) is unsubstantiated. It was the only such statement found.

Glossary

The definitions of terms without specific citations included here were derived from common usage in primary sources of 1870 through 1890.

Alizarine is the synthetic dyestuff distilled from coal-tar (Wingate 1979, 13) and is chemically identical to the main dyestuff in madder roots. I will use the French spelling as it appears most frequently in the materials I used. "Alizarin" is the 20th century spelling. The word comes from al-lizari, the Muslim form of its Levantine name (Brunello 1968, 123).

Coal-tar, a by-product of coke production, is formed when coal is burned without oxygen.

Dyeing uniformly covers both sides of cloth with a solid color usually by immersing it in a bath of dye (Wingate 1979, 202).

Garancine is a red dye formerly prepared by treating madder roots with sulphuric acid (Wingate 1979, 250).

Madder refers to a natural dyestuff occurring in minute quantities between the inner core and outer bark of roots from plants of the genus *Rubia*, family Rubiaceae (Bancroft 1813, 224; Schuster 1970, 195). Of the approximately 35 species growing throughout the Middle East and Europe, only a few are of commercial value. The term madder is also used to refer to the roots themselves, the plant, and the ground powder.

Madder-style is a method of printing thickened mordants onto bleached cotton fabric. The fabric is then dipped in a dyebath (of either madder, garancine, or alizarine) to bring up the various colors (Wingate 1979, 351).

Mordants are metallic salts that form an insoluble compound chemically linking dyestuffs to fibers (Wingate 1979, 381). Alum is the most common mordant used with madder (Rees 1809, 13).

Print cloth is cotton fabric woven especially to be printed. It is commonly 64 x 64 threads per inch, smooth, of tabby weave, weighing four and one-half yards to the pound, and sold wholesale in 28-yard-long pieces.

Prints is the commercial term meaning print cloth which has had colored motifs applied to its surface. Names for each design were taken in alphabetical order from the dictionary (Cocheco Swatch Collection).

Turkey Red, an 18-step process using madder, gave an extremely beautiful and durable red on cotton (Wingate 1979, 605). The process was simplified to six steps in 1793 (Bancroft 1813, 248) and alizarine was substituted for madder in the 1880s (Sansone 1887, 6).

A Brief History of Madder Printed Cottons

France

Light and lively painted cottons from India, which are called calicos today, reached France around 1658 (Clouzot 1927, 2). They quickly became very popular alternatives to the heavy, expensive, patterned silk and wool fabrics that were difficult to clean. Soon, inexpensive calico-copies were produced locally and, when added to the imports, alarmed French silk and wool manufacturers who succeeded in getting bans placed on the production and importation of calico from 1686 to 1759 (Chapman and Chassagne 1981, 5; Clouzot 1927, 6). This solidified a fad which otherwise might have enjoyed only a brief lifespan (Clouzot 1927, 2) as the bans were broken capriciously.

After two Frenchmen, M. de Beaulieu in 1734, and Father Coeurdoux in 1742 and 1747, managed to witness the hand-painted cotton process in India, they sent samples and directions back to France (Irwin and Brett 1970, 36). Indians used chay, a plant dyestuff similar to madder. Diderot (1765, 374) gives an account (in French) of the French method of imitating "Indiennes", as the Indian cottons were called. The Indian method of hand-painting various mordants onto bleached cotton fabric was laborious and European printers experimented until, by the last quarter of the 17th century, they developed a thickened mordant process with which the more efficient block-printing

could be used (Chapman and Chassagne 1981, 12).

The French also were very interested in the complex Turkey Red dye process. This dyeing process, "a secret closely guarded and jealously sought" (Schuster 1970, 198), was practiced in various centers of the Levant. Imported Turkey Red cotton thread was so costly that it was used sparingly in embroidered and woven textiles (Schaefer 1941b, 1408). Thinking that home production would reduce costs, textile industrialists from Rouen brought a Greek dyer, who knew the Turkey Red formula, and his workmen back to France in 1747 (Schaefer 1941b, 1412). The dyers had adjusted the method to French water and climatic conditions by 1762. The dyers then moved to Avignon where conditions were even better for madder and founded the famous Mulhouse dyeworks (Schaefer 1941b, 1412).

Fields of rubia peregrina madder were finally established in 1766 near Avignon by Jean Althens (Clow and Clow 1952, 269) after several unsuccessful attempts to grow madder on French soil, including Charlemagne's edict in the 8th century (Brunello 1968, 130) and Colbert's directive in the 17th century (Schaefer 1941a, 1401). Madder, as described by Miller (1758), was not difficult to grow, but patience was required as madder took up to three years to mature in the ground.

With the Turkey Red formula, and the requisite species of madder, French dyers and printers had the materials they

needed to dominate the cotton coloring industry throughout the 18th century (Cooper, 1815). The Oberkampf Print Works were of particular significance.

Founded near Versailles at Jouy in 1760 by the skilled German, Christophe-Philippe Oberkampf, these print works were patronized by French royalty. Durable colors and unusual designs, plus Oberkampf's considerable political acumen, ensured the popularity of his prints even through the French Revolution. The business failed shortly after his death in 1815 (Clouzot 1927, 39).

England

"Pintados", the Indian painted cottons which the French called *Indiennes*, first arrived in England as Portuguese trade goods in 1613 (Irwin and Brett 1970, 3). Textile firms, begun near London in 1676, and spurred by French immigrants fleeing persecution after the revocation of the Edict of Nantes in 1685, and the French bans of 1686 (Chapman and Chassagne 1981, 5; Clouzot 1927, 4), made poor, but popular, imitations of the *pintados*. Importation and production of these cottons so alarmed self-protecting British wool and silk manufacturers that they, too, succeeded in getting bans placed on calicoes in 1700 (Irwin and Brett 1970, 5). Soon after the bans were repealed in 1774 (Lewis 1937, 254), men in Great Britain began a search for madder printing and Turkey Red methods in order to

compete with France in the lucrative textile market.

John Wilson, of Manchester, England, dispatched an employee to the Levant in 1782 to bring back the Turkey Red formula (Cooper 1815, 286), and in 1785, George Macintosh of Edinburgh hired M. Jacques Papillon, who claimed he knew the French formula for Turkey Red dyeing (Clow and Clow 1952, 169). While there are significant differences between Papillon's formula and that used in France (Bancroft 1813, 248), it led British dyers in the right direction. In 1795, English botanist William Roxburg also reported on Indian cotton-printing methods (Irwin and Brett 1970, 55).

New print works, which benefited from these madder printing and Turkey Red formulas, were started at Manchester and Glasgow (Baines 1835; Clow and Clow 1952; Turnbull and Turnbull 1951). The most notable was that of Robert "Parsley" Peel (Chapman and Chassagne 1981, 34). Peel accepted his daughter's suggestion to make a print that looked like a piece of parsley she had picked in the garden. He named the design the "Nancy Print". Although that name is almost forgotten, his nickname endures.

While England never grew sufficient madder for its own textile needs (Miller 1758; Allan and Schofield 1980, 103), the British developed an economically important textile industry during the 19th century. To protect its dominance and to maintain its markets, England forbade exportation of textile machinery and immigration of men who had knowledge

of textile technology (Appleton 1858, 24).

America

Some English textile workers did manage to slip out to the American colonies. John Hewson was one of the more notable immigrants. He settled in Philadelphia shortly before the Revolutionary War and produced hand-blocked madder-prints in his small shop until at least 1803 (Bagnall 1893, 59; Bishop 1868, 100). Other printers included Herman Vandusen, who cut his own wood blocks and printed in East Greenwich, Rhode Island in 1790 and Schaub, Tissot, and Dobosque who opened a print works in Providence in 1794 (Bishop 1868, 59).

Early work in madder dyeing and printing involved a great deal of trial and error. Natural dyestuffs do not have uniform and reliable properties due to the variations in their growing conditions and processing practices. To counteract these problems, madder "receipts" included such things as blood, urine, dung, rancid olive oil, nut galls, bran, buttermilk, and egg albumen that were thought to improve the final color and permanence of color (Bemiss 1815; Duerr and Turnbull 1896; Ellis 1798). Many of these substances later were found to be useless (Bancroft 1813). As long as only small amounts of cotton fabric were printed with madder, this trial and error procedure sufficed.

Madder was used on a much larger scale in American cotton print works founded in the 19th century. A few companies include the Merrimac Print Works of Massachusetts that opened in 1824 (Clark 1916, 548), Hamilton Manufacturing begun in Massachusetts in 1825 (Van Slyck 1879, 67), and Hudson Calico Printing Works of New York that opened in 1826 (Ward 1911, 165). Madder was the principal dyestuff used (Crace-Calvert 1876, 22; Parnell 1860, 105; Sansone 1887, 99), and American companies consumed large quantities of it. For example, in 1867, Gloucester Print Works in Pennsylvania madder-printed 7,000 pieces weekly (Bishop 1868, 56). Recipe books show that one and a half pounds of madder were used to print 13 yards of fabric (Ellis 1798). At this rate, I calculate that Gloucester could have consumed as much as 565 tons of madder in 1867. Much of this bulk was due to the useless vegetable matter in madder roots. Only two to four percent of the root was active dyestuff (Ender 1970, 204; Schuster 1970, 196).

Germany

While Germany is not known for its madder-printed cottons, it will be included here because of its critical discovery that effected madder prints in other countries. Germany grew commercial amounts of madder only in Silesia (now in Poland), and imported the remainder needed for its

textile industry (Von Lengerke 1841, 112)². What German farmers failed to grow, German scientists soon supplied. In 1868, Carl Graebe and Carl Liebermann succeeded in finding a synthetic substitute for natural madder by distilling alizarine coal-tar (U.S. Patent Office Annual Report, 1869 1871, 568). Because of its importance as a madder substitute, alizarine was the key product that helped Germany capture the synthetic dye market (Ender 1970, 203) that it maintained as a near-monopoly until World War I (Matthews 1920).

Limitations

Unfortunately, company records do not exist for all the American dye and print works known to have flourished between 1870 and 1890 (Pettit 1970, 237). Some records, such as those from the Cranston Print Works, were given to biographers a year before this research began, and are inaccessible until after publication (H.J. Gray, letter to the author, August 31, 1988). Other records, such as those of the American Print Works of Fall River, have disappeared (H.G. Borden, letter to the author, March 2, 1987) and may have been destroyed.

²Article located and translated from German by Mark Finlay of Iowa State University.

An ever-present hazard in historic research is that additional pertinent materials may surface after a study is finished. While every possible effort has been made to locate records, conclusions drawn here will be limited to the materials studied.

ARTICLE I

ECONOMIC CONSIDERATIONS IN
THE TRANSITION FROM NATURAL MADDER TO SYNTHETIC
ALIZARINE IN THE AMERICAN TEXTILE INDUSTRY, 1870-1890

Introduction

Red madder flowed as the life blood in 19th century cotton printworks; no other dyestuff was more important (Crace-Calvert 1876, 22; Matthews 1920, 496; Parnell 1860, 105; Reoch 1916, 237; Sansone 1887, 99). To illustrate the extent of madder's popularity: in 1870, the 42 printworks in America, located primarily in the New England states, produced 453,809,000 yards of madder-printed calico (Bolles 1881, 425). Yet within 20 years after its discovery in 1868, alizarine, a synthetic coal-tar derivative chemically identical to the main dyestuff in madder (Slater 1882, 9), had almost completely replaced the natural roots (Duerr and Turnbull 1896, 81; Sansone 1887, 98; Schaefer 1941a, 1403).

Madder, obtained from the ground roots of plants cultivated primarily in the Levant, Holland, and France, was used to color wool and bleached, mordanted cotton. Alizarine was used for the same purposes as madder. It was distilled from coal-tar, the viscous by-product of coke production.

Textile historians suggest that price was a major factor in the transition from madder to alizarine (Brunello

1968, 287). When alizarine was synthesized by the Germans in 1868, it was so expensive (Crace-Calvert 1876, 44) that it was considered only a scientific wonder, not a commercial product (Edelstein 1956, 601), and so was not adopted. English researcher William Perkin developed an economical formula (Scientific American 1878, 106), and produced 220 tons of alizarine in 1871 (Edelstein 1956, 601); he made 435 tons in 1873 (Read 1958, 17). As more alizarine became available, the price of alizarine dropped from \$3.37 a pound in 1872 to \$0.16 in 1890 (Amoskeag mss. G-3).

Nevertheless, factors other than cost influenced dyers' and printers' use of madder. Madder was valued because it produced a variety of colors: pink, orange, red, purple, and chocolate depending on the mordant used (Gibson 1873, 46; Knecht, Rawson, and Loewenthal 1919, 42), whereas commercial alizarine in 1876 (Appendix C) did not give orange or brown (Slater 1882, 9). Madder had also been prized for centuries for its sun and water resistance (Knecht, Rawson, and Loewenthal 1919, 362), whereas the commercial alizarine of 1876 was not as "fast" as madder (Sansone 1887, 319).

Purpose

The term madder has almost completely disappeared from common textile knowledge in 1989, yet it was of vital commercial importance for centuries. Alizarine also, so

highly touted at one time, has become a little-known dyestuff. This research explores reasons for that importance, but also seeks reasons for the decline in importance.

Much has been written about European use of madder and alizarine (Clow and Clow 1952; Crookes 1874; Duerr and Turnbull 1896), but nothing has been found on the transition from madder to alizarine in the American textile industry. This research seeks to discover when the transition occurred and which factors contributed to the transition and eventual demise of the two dyestuffs.

Procedure

Alizarine was on the world market by 1870, giving a beginning date to this research. The year 1890 was chosen as the cut-off date in accordance with the stated transition period given in both 19th and 20th century literature.

I located inventory records from several American textile companies for 1870 to 1890 in East Coast libraries and museums. I recorded madder, madder products and alizarine purchased, consumed, or otherwise mentioned in American textile company records dated 1870 to 1890. This information was arranged to form tables that suggested how and when the transition from madder to alizarine occurred. These data appear in Part I.

I culled madder and alizarine prices from company records and used secondary sources as needed to chart the figures to test whether price was the main factor in the transition from madder to alizarine. Part II contains this material.

Bruce (1987) suggested that economic history is a combination of the interactions of various human activities. Consequently, in Part III, I discuss additional factors in society that might be involved as influences in the transition process from madder to alizarine.

Part One

Transition in Consumption

Few of the American textile company records available span the entire research period 1870 to 1890 (Appendix B3), but the transition from madder to alizarine is apparent in the Hamilton Manufacturing Company records. Hamilton was founded in 1825 at Lowell, Massachusetts and is judged to be the largest of the companies studied according to the amount of its madder and alizarine consumption.

Many madder types and derivatives, which I am calling madder products (Appendix C), were used by large 19th century companies, such as Hamilton, to meet their dyeing and printing needs. In fact, I found single recipes often contained two or three madder products. The number of products used seems to imply that American textile companies

were trying everything available in order to find a satisfactory dyestuff; that no single dyestuff possessed all the desired qualities.

Madder roots, purchased in dried bundles from the Levant, were ground by the user to produce all the madder colors, including Turkey Red, on fine cotton (Hayes 1875, 183). The roots were very bulky with up to 96 to 98 percent waste materials (Ender 1970, 204). At Hamilton, their use dropped from less than eight percent of the total madder consumed in 1870, to zero by 1874 (Table 1).

Dutch and French madder were purchased as a ground powder which saved the dye user some labor (Bancroft 1813, 224). Of the two types, French madder gave results similar to Levantine madder, while Dutch madder more commonly gave a terra cotta shade on wools or inexpensive cottons. Dutch madder accounted for, at most, one-fifth of the madder consumed at Hamilton in the early years of the research period, and was no longer used after 1875. French madder accounted for a weighted average of 43.64 percent of the total madder products consumed at Hamilton from 1870 to 1879, with a high of 81 percent in 1876 and a low of 11 percent in 1879. French madder was not used after 1879. Its place was taken by French garancine.

French garancine had four to five times the dyeing power that madder had (Matthews 1920, 497). Made from French madder, French garancine produced brighter colors,

but not the range of colors that madder gave. French garancine accounted for an average of 30.48 percent of the madder products consumed from 1870 until 1885 at Hamilton (Table 1). Garancine consumption peaked in 1883 when French garancine accounted for almost 63 percent of madder-related dyestuffs used at Hamilton. It was no longer used at Hamilton after 1885. The garancine made from Dutch madder was used in small amounts only in 1872 and 1873 at Hamilton, and was not listed in any other drug (dye) account found.

As French garancine consumption declined at Hamilton, alizarine consumption increased erratically from less than one percent in 1871, to 86.9 percent in 1885. In 1886, alizarine was the only madder-type dyestuff used at Hamilton Manufacturing.

Total amounts of madder consumed declined from a high of almost 629,000 pounds of madder products and substitutes in 1871 to just under 180,000 pounds in 1879. At the same time, garancine use increased from 12 percent of the total amount used in 1871 to 40 percent in 1879. Some of the drop in total pounds consumed is due to the increasing use of lighter weight garancine.

The amounts of French garancine and alizarine fluctuated widely relative to each other between 1880 and 1885. Whether this is due to experimentation, stock on hand, cost advantages, or something else is not known.

Table 1. Madder Products and Substitutes Consumed at
Hamilton Manufacturing Company (Hamilton mss.
575-585)

Year	Percentages of Total Amount ^a						Total Amount
	DhMd ^b	FrMd	MdRt	DhGr	FrGr	Aliz	Pounds
1870	17.4	65.7	7.9	-	9.0	-	314,761
1871	19.6	53.5	5.9	8.2	12.1	.6	628,741
1872 ^c	15.9	45.6	1.9	7.8	25.7	2.3	516,037
1873 ^c	10.5	31.3	2.0	-	53.5	2.6	341,507
1874 ^d	9.5	23.7	-	-	59.3	7.5	465,547
1875 ^d	1.7	42.6	-	-	42.5	8.7	496,756
1876	-	81.6	-	-	5.4	13.0	291,373
1877	-	53.5	-	-	35.4	11.1	373,921
1878 ^c	-	2.0	-	-	60.5	37.1	247,199
1879	-	11.3	-	-	40.3	48.4	179,874
1880	-	-	-	-	27.7	72.3	77,806
1881	-	-	-	-	47.5	52.5	83,975
1882	-	-	-	-	59.4	40.6	86,803
1883	-	-	-	-	62.9	37.1	102,094
1884	-	-	-	-	23.1	76.9	134,894
1885	-	-	-	-	13.1	86.9	145,456
1886	-	-	-	-	-	100.0	115,747
1887	-	-	-	-	-	100.0	169,991
1888	-	-	-	-	-	100.0	193,871
1889	-	-	-	-	-	100.0	252,847
1890	-	-	-	-	-	100.0	236,254

^aI divided the individual dyestuff amounts inventoried by the total amount of madder-related dye consumed to get the percentages used.

^bDhMd refers to Dutch madder, FrMd to French madder, MdRt to madder roots, DhGr to Dutch garancine, FrGr to French garancine, and Aliz to alizarine.

^cMadder extract accounts for less than .5 percent of the total consumption during 1873 and 1878, and .8 in 1872. Due to its infrequent use, it has been included in my calculations, but is not listed in the Table.

^dNaples madder appears only in 1875. It accounts for 4.5 percent of the total consumption, and was included in the calculations, but does not appear in the Table.

A further drop in total dyestuff consumption occurred during 1880, when the use of madder products amounted to less than 78,000 pounds. This drop is likely due to the increased amount of highly concentrated alizarine being used. Total dye consumption gradually increased to 145,000 pounds in 1885. Several factors could have contributed to this situation.

America experienced an economic depression in 1882-1886 (Mohl 1985, 151) but surprisingly, economic depressions were not always times of decreases in clothing purchases (Winakor 1989, 200). The truth of this is seen during the depression of the early 1870s, when madder dyes were used every week in the years 1873 and 1874 (Appendix D, Table 15).

Unfortunately, this was not the case in the depression of the 1880s. No madder dyes were used for 9 weeks in 1882 and 8 weeks in both 1883 and 1884 (Table 15).

A more likely explanation for the decline in dye use in the early 1880s is due to print manufacturers' response to customer demands for finer goods (Clark 1928, 407; Strassmann 1959, 100). This change lessened the amount of dyestuffs used because in finer fabrics small designs were printed on largely white backgrounds in such prints as lawns, satines (sic), shirtings, and foulards (Figures 1, 2, 3, and 4) as compared to the heavier, almost solid madder-prints.



Figure 1. Lawn 1882
(Cocheco Swatch #8793)



Figure 2. Foulard 1882
(Cocheco Swatch #8736)

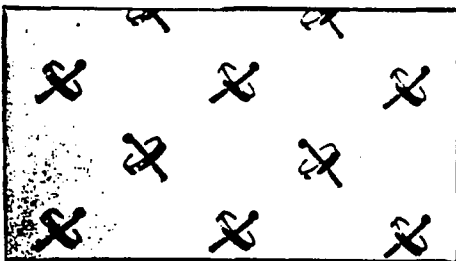


Figure 3. Shirting 1884
(Cocheco Swatch #1449)



Figure 4. Satine 1886
(Cocheco Swatch #2425)

American tariff policies may also help to explain the drop in dyestuffs consumed at Hamilton from 1880 to 1883. In 1880, the import duties were 35 percent ad valorem and 50 cents on the pound specific (Schoellkopf 1911, 182). This was sufficient protection from foreign dyestuffs to encourage nine American manufacturers to begin the manufacture of synthetic dyes. What seemed like a golden opportunity to buy local American synthetic dyes was really a double edged sword. An anonymous American author bitterly referred to the "German protection doctrine and its evils in the United States" (Textile Manufacturer 1880, 12) in that prices were fixed, and supplies were cut off to consumers who bought elsewhere (O'Neill 1883a, 14). When American

tariff rates were drastically reduced by new tariff laws in 1883, five of the American dye businesses folded (Schoellkopf 1895, 66). In this uneasy time, it is little wonder that American dyers and printers used quantities of dyes cautiously.

In 1886, alizarine was the only madder-product used at Hamilton Manufacturing and the total madder dyestuff consumption dropped from 145,456 pounds to 115,747.

Alizarine was more concentrated and lighter in weight than garancine, which it replaced, and fewer pounds of dyestuff were needed to dye the same amount of fabric. Consumption ratios will be given later to show that the 252,847 pounds of alizarine used in 1889 could be used to print 10 times more yards of fabric than with the 628,741 pounds of madder products in 1871. Despite this difference in dye strength, consumption of alizarine jumped from 37 to 76 percent in 1884 at Hamilton (Table 1), suggesting larger amounts of fabric were being printed. As one author playfully expressed it, "Alizarine must have had strong germs of life or it would not have forced itself into so prominent a position ..." (Bird 1882, 177).

A more plausible explanation for the increase in alizarine consumption might relate to an improvement in its quality as dyehouses became more experienced in alizarine production (O'Neill 1883b, 39). In its early days, alizarine was used only for dyeing, not printing, due to the

impurities in it (Scientific American 1870, 32). Even as late as 1886, Bancroft and Sons complained to their supplier, Sehlbach of New York, that the "sulphureted hydrogen" smell in the alizarine made it unusable (Bancroft mss. 703).

Consumption Ratios Amounts of madder given in dye recipes range from eight ounces of madder per pound of fabric (Ellis 1798, 56; Haigh 1813, 252), to 12 ounces of madder per pound of fabric (Haserick 1869, 37), to one pound of madder per pound of fabric (Bishop 1868, 197), with the lesser amount being most common. To dye 100 pounds of fabric, 13 pounds of garancine (Hayes 1877, 228), or 2 pounds of alizarine would be used (Wade's July 10, 1886). To print fabric with madder took the same amount of dyestuff as to dye it (Cooper 1815, 437), possibly due to the type of prints being made. During the 1870-1890s, madder prints were dark, with vines, geometric, or stippled backgrounds (Figures 5, 6, 7, and 8). No figures have been found giving the amount of garancine used in printing. Only half as much alizarine was used to print as to dye the same amount of fabric (Badische n.d., 40).

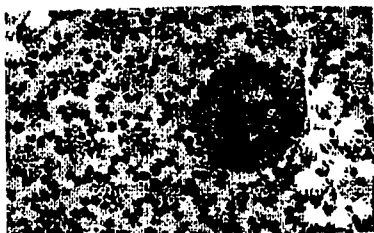
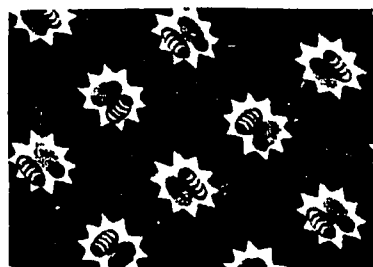


Figure 5. Madder Prints 1874
(Crookes 1874, 579)



(Crookes 1874, 647)

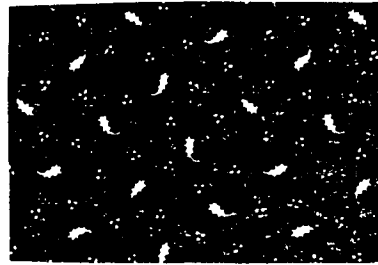
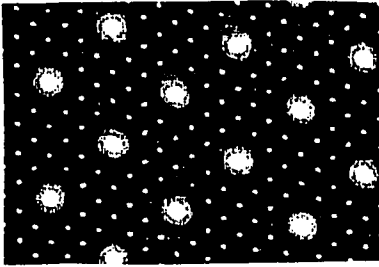


Figure 6. Cocheco Madder Prints 1883
(Affleck 1987, 8)

(Affleck 1987, 20)

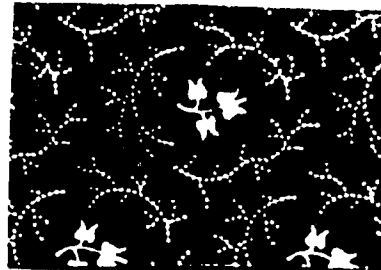
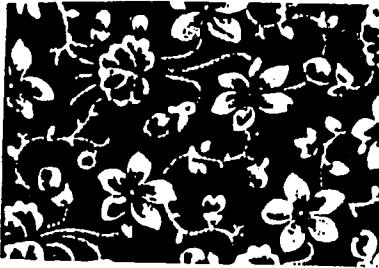


Figure 7. Cocheco Chocolate Prints 1884
(Cocheco Swatches #1179)

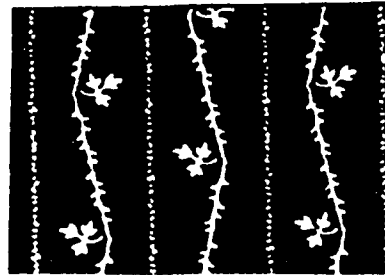
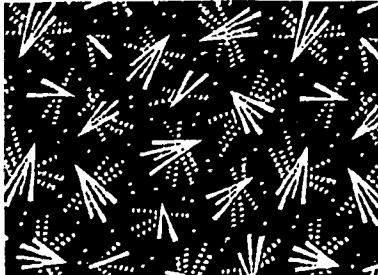


Figure 8. Cocheco Madder Style Prints 1885-1888
(Affleck 1987, 8) (Cocheco Swatch #5604)

Consumption at Cocheco Manufacturing

Like

Hamilton Manufacturing, Cocheco (Appendix B3) used a variety of madder products in an attempt to meet its print and dye needs (Table 2). Cocheco, founded in 1836 at Dover, Delaware, and known for its prints (Bezanson 1954, 265), used French madder, Turkish madder roots, several types of garancine including Turkish garancine, several types of

alizarine, Dutch madder, and French madder extract.

Unfortunately, no records have been found to show when Cocheco began using alizarine exclusively, but a letter suggests that it was after 1885.

Table 2. Madder Products and Substitutes Consumed at Cocheco Manufacturing (Cocheco mss. 5.11-5.15)

Year	Percentages of Total Amount ^a						Total Amount
	FrMd ^b	TkRt	Gar	TkGr	Aliz	MdEx	Pounds
1876 ^c	50.8	29.0	6.4	5.7	5.8	2.3	63,424
1877 ^d	58.1	26.3	.4	5.0	8.5	1.7	74,153
1878	98.8	-	-	-	1.2	-	2,006 ^e
1879	98.9	-	-	-	1.1	-	1,780
1880	n/a						
1881	8.7	-	-	-	84.9	6.4	12,443

^aI divided the individual dyestuff amounts inventoried by the total amount of madder-related dye consumed to get the percentages.

^bFrMd refers to French madder, TkRt to Turkish madder roots, Gar to garancine, TkGr to Turkish garancine, Aliz to alizarine, MdEx to madder extract.

^cIncludes two brands of alizarine and three types of garancine.

^dIncludes three brands of alizarine and two types of garancine.

^eDrug records no longer are available. 1878-81 records come from Cocheco's Color Shop.

In 1885, Howard Stockton, treasurer of Cocheco, wrote to Washington Anderton, the color superintendent, stating that Anderton would "be obliged" to use alizarine for printing chocolates (small designs on brown grounds, Fig. 7) on cotton (Cocheco mss. 1.5). Possibly, Anderton was still

relying on the five non-alizarine chocolate recipes listed in his 1873 notebooks. Stockton further warned Anderton that he was using "enormous quantities" of garancine. It was in 1885 that garancine was used for the last time at Hamilton. Stockton may have been aware of this development at Cocheco's competition, and was prompting Anderton to change also.

The available Cocheco dye records do not include 1885 when Anderton was accused of using so much garancine. Garancine accounted for less than six percent of Cocheco's madder related dye consumption between 1876 and 1881, as opposed to the weighted average of almost 40 percent at Hamilton between 1872 and 1885.

Other differences exist between the two companies. Hamilton used more than five times the total pounds of madder-related dyestuffs as Cocheco used (Table 3), yet Hamilton used one-third the madder extract, and had stopped using madder roots in 1873, four years earlier than Cocheco. It is impossible to say for certain why these differences exist. Hamilton was not known for its prints but Cocheco was. It may be that Cocheco did not care to change a successful product.

Table 3. A Comparison of Madder-Related Product Consumption in 1877 (Hamilton mss. 575-585 and Cocheco mss 5.14)

Company	Percentage of Total Amount ^a					Total Amount
	MdRts ^b	MdEx	FrMd	Gar	Aliz	Pounds
Hamilton	-	-	53.5	35.4	11.1	373,921
Cocheco	26.3	1.7	58.1	5.4	8.5	74,153

^aI divided the individual dyestuff amounts inventoried by the total amount of madder-related dye consumed to get the percentages.

^bMdRts refers to madder roots, MdEx to madder extract, FrMd to French madder, Gar to garancine, and Aliz to alizarine.

Consumption at Other Companies Existing records for Eddystone Manufacturing Company and Lancaster Mills show that alizarine was the only madder product consumed (Tables 4 and 5). Eddystone, a printwork founded in 1877, was a subsidiary of Bancroft and Sons and Simpson and Sons near Philadelphia. Lancaster was a woolen mill founded in 1843 in Massachusetts. About 400 pounds of madder were listed in the earliest Eddystone records, but were never listed as consumed. Due to its founding date, I hypothesize Lancaster probably used madder, and possibly garancine, but no record exists. Therefore, Lancaster may have used alizarine earlier than 1878, but that is the earliest date that can be confirmed.

In the years records are available, Eddystone used an average of 48,720 pounds of alizarine per year, and

Table 4. Alizarine Consumption at Eddystone Manufacturing
(Bancroft mss. 1560-1563)

Year	Pounds
1876	1,689
1877	3,565
1878-1882	n/a
1883	30,571
1884	44,938
1885	63,431
1886	58,284
1887	52,302
1888	51,453
1889	44,036
1890	44,746

Table 5. Alizarine Consumption at Lancaster Mills
(Lancaster mss. 56-58)

Year	Pounds
1878	15,999
1879	24,527
1880	23,910
1881	16,920
1882	22,354

Lancaster used an average of 20,742 pounds, compared to Hamilton, where an average of over 193,000 pounds of alizarine were used per year. These data make Eddystone and Lancaster comparatively smaller than Hamilton.

One author states that those companies using the most up-to-date dyestuffs could produce the greatest volume of print goods (Smith 1944, 64). If this is true, the advantages of synthetic dyestuffs may have helped Eddystone and Lancaster compete with such large firms as Hamilton.

Perhaps the smaller companies had the advantage of being more flexible. Madder, which was "set" by simmering, required large boilers in the dye houses. Alizarine was "set" by steaming (Appendix F). This difference would have rendered much of the equipment in large established companies obsolete. The 50 by 130 foot madder house at the largest company studied, Hamilton, housed three dung cisterns; 16 dye, soap, and bran cisterns; a grinding mill; 7 washing machines; and 8 boilers ranging from 22 to 36 feet long (Hamilton mss. Carton 19). A small company would not have had this much equipment nor the financial, and research, investment it represented.

Another important difference to consider in understanding the different patterns of alizarine consumption between Hamilton and Eddystone lies in the founding dates of the two companies. Hamilton was founded in 1825 when madder was without competition from alizarine; the company enjoyed a half century of economic success with madder. Eddystone was founded in 1877 when alizarine was available. The founders of Eddystone had used madder in their previous textile companies, but now favored alizarine (Bancroft mss. 1560).

Part Two

Price Factors

Whereas consumption figures at Hamilton Manufacturing

were used to illustrate Part One, prices from Amoskeag Manufacturing will be used in Part Two. Amoskeag Manufacturing, founded in Manchester, New Hampshire in 1822, spun, wove, dyed, and printed cottons and wools.

Payments of shipping discounts and gold premiums obscure the data on prices of dyestuffs at Hamilton, and the bookkeepers at Amoskeag used an accounting method which precludes identifying dye consumption by year. Relating amounts of dyestuff from one company with prices of dyestuffs from another company can be attempted due to German monopolistic price setting practices (Beer 1959, 118; O'Neill 1883a, 14). Evidence suggests Germany deliberately controlled alizarine prices from 1879 to 1883 (Table 6), and dye prices found in other company records are within pennies of each other for a given brand of alizarine at a given time (Adams mss. 481; Bancroft mss. 1886; Lancaster mss. 56; Parkhill mss. 4).

Price Relationships If alizarine replaced madder because of the costs involved there should be a clear relationship between the amounts of each dyestuff used and their relative prices. Amoskeag Manufacturing records provide a range of retail prices for the garancine and alizarine they used from 1870 to 1890, but only three retail madder prices are available. Conversely, while a complete list of wholesale madder prices for 1870 to 1890 is available (Bezanson 1954, 202), no comparable records exist

for garancine and alizarine. Wholesale and retail prices are not the same, yet in light of the sparseness of retail data, unfortunately, I must use the wholesale data for madder in Table 6. The following explanations are necessary to explain the price fluctuations.

Table 6. A Comparison of Madder, Garancine, and Alizarine Prices per Pound

Year	Madder ^a	Garancine ^b	Alizarine ^b
1870	.130	.50	
1871	.130	.30	
1872	.130	.29, .27	3.37
1873	.120	.19, .21, .23	
1874	.085	.18, .19, .20	1.30
1875	.085	.15, .17, .27	
1876	.077	10, .12, .15, .20	.57
1877	.073	.18, .19	.15, .25, .31
1878	.070	.14, .15	
1879	.079	.12, .13	1.05
1880	.088		1.05, 1.20
1881	.093		1.20, 1.60
1882	.094		1.14, 1.20, 1.60
1883	.091		1.16, 1.20, 1.60
1884	.085		.26, .29, .45, 1.20
1885	.086		.22, .23, .25, .26
1886	.082		.19, .20
1887	.082		n/a
1888	.082		.18, .19
1889	.082		.17, .18, .20
1890	.082		.16, .17, .18

^a(Wholesale--Bezanson 1954, 202).

^b(Retail--Amoskeag mss. E-2; G-3).

Patents as a Price Factor When the original German patent rights on alizarine expired in 1883 (Scientific American 1883, 72), prices dropped from well

over a dollar to less than a half dollar per pound. The German cartel of 1881, which fixed prices and allocated quantities of alizarine for manufacturers (Beer 1959, 118), was defied and new dye houses began production (O'Neill 1983a, 14).

While competition brought alizarine prices down, it by no means curtailed German alizarine production. Germany retained a large share of the market by bringing out new patented alizarine colors: by 1885, one company, Sehlbach, is known to have produced 13 shades of red varying from yellowish- to bluish-red (Appendix C, Table 8). In 1884, prices paid for alizarine at Amoskeag ranged from \$.26 for some brands to \$1.20 for others.

Prices per pound of dyestuff are meaningful only when compared to the amounts of fabric each can dye. Fifty pounds of madder, 13 pounds of garancine, or 2 pounds of alizarine were needed to dye 100 pounds of fabric. The averaged price of each dyestuff (taken from Table 6) was multiplied by these factors to get the relative prices (Table 7).

The last year that madder was consumed at Amoskeag was 1873, but if price was the reason for changing to garancine, the change should have occurred in 1871 when garancine was \$3.90 a pound as opposed to madder at \$6.50. While the lag may be due to inventory on hand, other companies carried amounts of madder, unconsumed, on their books for months

Table 7. A Comparison of Average Madder, Garancine, and Alizarine Prices to Dye 100 Pounds of Fabric

Year	Madder	Garancine	Alizarine
1870	\$6.50	\$6.50	n/a
1871	6.50	3.90	n/a
1872	6.50	3.64	\$6.74
1873	6.00	2.73	n/a
1874	4.25	2.47	2.60
1875	4.25	2.56	n/a
1876	3.85	1.82	1.14
1877	3.65	2.40	.47
1878	3.50	1.89	n/a
1879	3.95	1.56	2.10
1880	4.40	n/a	2.25

(Bancroft mss. 1560) or years (Amoskeag mss. E-2). Hamilton did not give up madder until 1879 when even alizarine was cheaper. Also, if cost was the deciding factor, alizarine at \$1.14 should have replaced garancine in 1876 when a comparable amount cost \$1.82. But, garancine was used through 1880 at Amoskeag when it cost \$1.56 a pound and was replaced in 1881 by alizarine costing \$2.25.

As discussed earlier, the unusually low prices of \$1.14 and .47 in 1876 and 1877 may have been for alizarine from less-than-reputable dye houses. Rampant price cutting is mentioned as a motivating factor in the formation of the German cartel of 1881 (O'Neill 1883a, 14). An additional explanation involves the various kinds of alizarine. Alizarine produced from garancine was less dependable than coal-tar alizarine.

Part Three

Other Factors

Because comparable costs of dyestuffs needed to dye a given amount of fabric do not provide conclusive evidence that price was the sole factor in the transition from madder to alizarine, other factors must be considered. Such factors as the methods used with each of these dyestuffs, demands for more color variety, and technological advances, and general economics seem to be contributing components.

Methods Dyers and printers needed years of experience to develop an "eye" and a "feel" for the variations inherent in madder. Variations due to sun, rain, and soil conditions affected the amount and dye strength of the dyestuff in the madder roots (Miller 1758, 33). Processing conditions also affected madder's dye strength (Miller 1758, 12). Processors could guarantee madder's grade (purity) by the amount of foreign material included with the ground roots but, given a known grade of madder, dyers still could not predict its potency. That was dependent not only on growing and processing factors, but also on the storage conditions after the madder was ground and sold. Moist storage conditions, or storing madder more than two years, reduced madder's dye strength. Therefore, when a dyer or printer developed a successful recipe which gave him good results with all the uncertainties of madder, he guarded the method carefully¹. The situation was much

different when the dyer used alizarine.

Alizarine, as a man-made compound, was more nearly pure than the comparable dyestuff found combined with organic substances in madder roots (Schuster 1970, 159). Synthetic alizarine gave more consistent results; there were no variations in it due to growing conditions.

Even though this purity made alizarine easier to use, manufacturers of patented alizarines also offered recipes to help new users achieve an acceptable dye job. Between 1878 and 1886, Pickhardt and Kuttroff of New York, who were agents for the German manufacturing company Badische Anilin und Soda Fabrik (BASF), and A. Klipstein, agent for Bindschedler and Busch of Switzerland (Ward 1911, 169) sent recipes for the use of their products to Cocheco (Cocheco mss. 1:14). Pickhardt and Kuttroff published a book of recipes for all BASF's alizarine colors (Badische n.d., 5) which included directions for using alizarine powder and paste, to print and dye wool and cotton. These recipes probably simplified and accelerated the transition from madder to alizarine by removing much of the guesswork associated with madder.

Desire for Variety Some authors claim that it was the novelty of alizarine's many shades (Appendix C, Table 8), not alizarine's favorable price or ease of use, that swayed users from madder to alizarine (Beer 1959, 4; Sansone 1887, 8; Peck and Earl 1877, 40). A quote taken from an

1886 Dry Goods Bulletin and Textile Manufacture affirms that variety was an important factor.

The more the merrier seems to be the motto as regards the number of colors, and the most showy shades are together in the most barbarous combinations (In Affleck 1987, 36).

Madder and its related products maintained their popularity based largely on the variety of colors they produced.

However, once the chemical composition of alizarine was understood, dyers could produce more color variations with it than with madder. Between 1875 and 1900, alizarine orange, blue, black, green, brown, violet, and garnet made obsolete the fewer colors provided by madder and garancine. As more patented alizarine appeared on the market, madder and garancine consumption decreased.

Manufacturers appealed to their customers' love of variety by constantly developing new designs--perhaps 2000 patterns per season (Peck and Earl 1877, 40). Cocheco does not seem to have produced quite as much variety. In the period from 1881 to 1890, Cocheco printed approximately 10,000 patterns, or about 1000 a year, and these came out continuously, not in two seasons (Cocheco Swatch Collection 1881-1890).

Generally, there were cycles in print fashions. Sometimes a design was good for two seasons, faded in popularity, then might reappear four or five seasons later. Other styles, such as one named the Dolly Varden², called an

"uncouth print," supposedly enjoyed only a few days "ephemeral popularity" (Adams mss. 481), yet Hamilton printed it in 1000-yard batches in April and May of 1872 (Hamilton mss. 124), and Cole (1900, 152) states that Dolly Varden was a popular print from 1865 to 1875. The public was very fickle and when a print design had passed its popularity peak, it was difficult to sell. Printers had to pay close attention to their selling agents who advised them, sometimes by letter twice a day, how much of which pattern to print (Adams mss. 481; Cranston mss. 384).

Alizarine's many colors made the variety of patterns even more popular with the public (Bancroft mss. 736). While red was popular in the 1870s, black, blue, and green were popular in 1889 (Bancroft mss. 718). Alizarine could provide these colors; madder could not. However, the data supplied in this research refers only to alizarine red.

Technological Advances In the 1860s, dissatisfaction with natural dyes was growing among dyers (Appendix E). The art of dyeing had not kept up with technological advances which sped up production in spinning, weaving, printing, and ginning cotton (Beer 1959, 3). Very little "speeding up" was possible with madder. Only so much could be done with its vegetable nature. Moisture, which accounted for forty to fifty-five percent of the weight in fresh madder roots, could be removed (Peckin and Everest 1918, 33). But even dried and ground madder contained up to

seventy percent bark, pith, and sugars (Matthews 1920, 497). Efforts to remove much of this waste matter continued for years after alizarine was discovered and, as late as 1877 it was hoped, by French madder growers especially, that these experiments would restore the old importance of madder (Hayes 1877, 227).

Not only was there no waste to synthetic alizarine, but it also was sold in convenient forms (powder and paste), and in different concentrations (5%, 10%, 20%, 40%, and 60%) (Badische n.d, 5; Ender 1970, 204; Slater 1882, 9). Other conveniences quickly followed the production of alizarine. Turkey Red oil, patented by Wurth in 1872 (Brunello 1968, 288) took the place of the rancid olive oil used with madder. A single compound, alizarine assistant, simplified and took the place of several more of the mordants used with madder (Herrick mss. 307).

General Economic Conditions The depression of 1873 saw the collapse of many small textile firms and the consolidation of several small firms into larger ones (Clark 1928, 155). This reorganization enabled men to amass larger amounts of capital than had been available in the first half of the 19th century (Beardsley 1964, 64). These funds facilitated the formation of new companies in which new methods were tried. This is not an uncommon occurrence. An economic historian states that for a variety of reasons, innovations were introduced with fairly uniform success in

periods of economic depressions (Strassman 1959, 196), and that financially strong firms eagerly sought innovations during depressions in the 19th century (Strassman 1959, 185). One of those innovations was alizarine, another was the use of chemists.

Conclusions

Duerr and Turnbull (1896), Sansone (1887), and Schaefer (1941b) suggested that alizarine replaced madder within the twenty year period following alizarine's discovery in 1868 and production in 1870. The transition from madder to alizarine, in the companies studied, was completed between 1877 and 1886 with smaller (Lancaster) or newer (Eddystone) companies completing the transition earlier than the older (Cocheco) and larger companies (Hamilton).

My findings seem to substantiate those of Feller (1966) who found the cost of equipment changeover to be a prohibiting factor in the adoption of new technology. Newer companies changed to alizarine before the older ones, perhaps due to the advantages of being able to take advantage of new technology without the expense of throwing out equipment used with the old technology. The management at Cocheco and Eddystone encouraged the use of alizarine; it is not known who instituted the change at the other companies studied.

This work also mirrors Smith's findings in the bleaching industry (1979) where he concluded that combining old and new technology into some sort of intermediate solution eased the transition and made the innovation more acceptable to textile workers. Garancine, which was chemically enhanced madder, served as a transition product between synthetic alizarine and madder.

The costs of madder, garancine, and alizarine all dropped in the period covered by this research, and costs do appear to be a factor influencing the change from madder to garancine. However, garancine was cheaper than alizarine when alizarine replaced garancine in at least one company studied, leading to the hypothesis that cost was only one quality of alizarine that endeared it to American dyers and printers.

Alizarine also represented a technological advance over madder, and technological advances were deemed necessary in order to make the coloring aspect of the textile industry as efficient as other facets in textile production. Alizarine provided more concentrated color power with less bulk, and gave more consistent results than did garancine or madder (Brunello 1968, 297).

The many alizarine shades and colors helped textile manufacturers satisfy the public desire for variety better than the limited colors of madder. Manufacturers provided alizarine recipes that eliminated much of the trial and

error associated with madder, and made achieving variety much easier for dyers and printers.

Alizarine use increased during depressed times in the late 1870s and 1880s. Innovations have a fairly good chance of being adopted as men search for new ways to reduce costs.

Thus, alizarine was found to replace madder due to a combination of alizarine's reduced costs as improved technology increased its ease of use. Alizarine also provided a greater variety of colors at a time when manufacturers and customers were receptive to new things.

Further Research

When World War I cut off American supplies of synthetic dyestuffs, a government fact-finding committee suggested returning to natural dyes, not realizing how impossible a task that would be. That ignorance would not have surfaced if histories of the many natural dyestuffs had been known. This information is now available at the level of home crafts (Goodwin 1982; Grae 1974; Kramer 1972; Krochmal and Krochmal 1974), but the history of natural dyestuffs in commercial use has not been documented.

Logwood would be particularly interesting to study because it was used extensively in dyeing socks and silks until after World War I. While other colors were sought in synthetic dyes, this natural black seemed to maintain its value.

It would be instructive to compare the madder to alizarine transition in America with that in Europe. England used one-third the madder grown and one-third the alizarine produced (O'Neill 1883b, 39), and France had a madder industry to protect. These transitions would be valuable individually and in comparison to each other.

The amount of yard goods produced jumped dramatically after alizarine was adopted around 1885. Having a better dyestuff does not explain this increase. Did the population increase substantially? Did real income per capita rise? Were people buying, using, and wearing more clothing than prior to 1885? Did the development of department stores and mail order enlarge the clothing market? Direct correlations between these factors and alizarine would be of interest.

Research Benefits

This research uncovered the previously unpublished intermediate role that garancine played in the transition from madder to alizarine. If transitions generally include an intermediate material or process, this information should be helpful in other situations where transitions are planned and of use to those people in charge of implementing innovations.

Endnotes

¹Joseph H. Walker agreed to pay \$300, or five months pay, if he divulged anything about the color processes at

Cocheco in 1866 (Cocheco mss. 5.8). R.H. Gibson wrote he feared he would be "Stigmatized as an unprincipled scoundrel for giving secrets of the trade to the world" when he published The American Dyer in 1873.

²Dolly Varden was a gaily dressed coquette in Barnaby Rudge, by Charles Dickens (1841) (Webster's 1983, 374).

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ARTICLE II

THE ROLE OF CHEMISTRY IN THE TRANSITION FROM
NATURAL MADDER TO SYNTHETIC ALIZARINE IN THE AMERICAN
TEXTILE INDUSTRY IN THE 19TH CENTURY

Introduction

A young dyer queried, "Can one be a reliable and expert dyer unless one possesses a considerable knowledge of chemistry?" (Wade's Jan. 15, 1887). He was answered, "Dyers, as a rule, are not scholarly men.... I think I am safe in affirming that the field of chemistry is one into which few of us have ever so much as peered." This statement reflects thinking common in the American textile industry in parts of the 19th century: rule of thumb methods were used, and if a chemist was employed, he had little formal schooling and was self taught (Beardsley 1964, 48; Bounds 1961, 29). However, attitudes were changing.

Between 1870 and 1890, the transition from the use of the natural dyestuff madder to synthetic alizarine in the American textile industry seemed closely associated with another transition: traditional dyers and color superintendents were supplemented by trained chemists. Two factors have been offered to explain this change. Men were needed who could (1) make good use of English and German research (Bruce 1987, 335; Beardsley 1964, 14), and (2) take

the "next step" (improved dyes) in the technological advances in cloth making (Beer 1959, 3; Mellor and Cardwell 1963, 265).

Perhaps an understanding of these factors will explain why the synthesis of alizarine itself was held to be a turning point in dye chemistry (Ihde 1964, 457). Because, as exciting a discovery as Perkin's first synthetic dye, aniline mauve, was in 1856 (Appendix G), it did not trigger the development of organic chemistry programs, nor did it add chemists to the American textile industry. However, in the decade after alizarine was synthesized in 1868, more than two dozen American colleges formed advanced chemistry programs (Bruce 1987, 335), and textile companies hired chemists (Bancroft mss. 494; Cocheco mss. 5.9). Events in the textile coloring industry and this chemical surge in America seemed to be running on parallel tracks.

American chemistry owed much of its pre-20th century development to European influences (Appendix H). American students attended German universities (Beardsley 1964, 14; Bruce 1987, 91; Ihde 1964, 270), American print technology was based on English and French developments (Brunello 1968, 211; Sansone 1887, 6), and American dyestuffs, both natural and synthetic, came from Europe (U.S. Department of State 1879, 140, 228, 384, 992). Yet, by 1900, many American colleges offered graduate chemical courses, American print goods were welcomed overseas (Clark 1928, 409); and in 1918,

America made its own synthetic dyestuffs (Matthews 1920).

Purpose

Chemists, and a knowledge of chemistry, were rare in the early American textile industry that today could not exist without this critical information base (Campbell and Hatton 1951; Dutton 1942; Forrestal 1977). I will show the role that alizarine played in the acceptance of chemists and chemistry in the American textile industry.

Questions

Three questions will be addressed. (A) Which factors are associated with the development of organic chemistry? (B) What effect did European textile dye technology have in America? (C) What part did dyes, especially alizarine, play in the transition to chemicals in the American textile industry?

Previous Research

In previous research, Rossiter (1975) and Marcus (1985) documented the evolution of chemistry in agriculture. Farmers, before their conversion to agricultural chemistry, employed practices which had outgrown their utility; late 19th century authors suggest there was a lack of standards and systematic methods and equipment (Marcus 1985, 6). Similar charges have been leveled at the 19th century American textile coloring industry (Mellor and Cardwell

1963, 273; Ward 1911, 174).

The transition in the bleaching industry, which underwent technological changes from natural "grassing" to chemical bleaching powder, includes some parallels with developments in the dyeing industry, which also changed from using natural materials to synthetic ones. Bleachers feared the new process would take their jobs, synthetic bleach was not expected to do as good a job in whitening the fabric, and early chemical compounds were unstable (Smith 1979). When the new bleach processes were made safe, and the old and new techniques integrated, chemical bleach replaced the time-consuming grassing. Change occurred when the old and new technologies could be combined to ease the transition (Smith 1979). No research has been found documenting a transitional dyestuff in the change from madder to alizarine.

Chemistry in America

Early Coloring Practices

Nineteenth century American textile colorists cloaked their dyestuff techniques in a great deal of secrecy (Haserick 1869, 1; Mellor and Cardwell 1963, 271) when they used natural dyestuffs such as madder. Mordants, temperatures, and timing were all critical components that required years of experience to handle successfully.

Color superintendents who worked with madder kept notebooks with samples and notes on the trials they had

conducted. One of these men was John Duxbury who worked at Bristol Print Works in 1835, and at Crocker and Richmond in Taunton, MA until 1841. Duxbury experimented with standard mixes for madder, and varied the setting techniques and mordants (Duxbury mss.). Samuel Dunster, color superintendent in various American printworks from 1835 to 1858, left 10 journals. He too, experimented with auxiliary ingredients and techniques using madder.

The experimentation done by men such as Dunster and Duxbury was intended to compensate for the problems inherent in madder. All natural dyestuffs vary in concentration and intensity of dye matter due to various growing conditions. Dyers judged their success by the colors they achieved. Once effective recipes using natural dyestuffs were developed, "efforts toward practical improvements were stifled" and dyers turned into "ultra conservatives" (Metz 1911, 177). It was under these conditions that in 1866, Joseph H. Walker had to agree to pay \$300, or five months' salary, if he divulged anything about the color processes he observed while working at Cocheco Print Works (Cocheco mss. 5.8). At least one dyer feared he would be "stigmatized as an unprincipled scoundrel" for giving secrets of the trade to the world when he published an American dye book (Gibson 1873, 3). In 1876, William Harley, color superintendent at Hamilton Manufacturing, was told he and the company chemist must have

"more harmonious relations" and that Harley's color books must be open for inspection by the chemist at all times (Hamilton mss. Carton 19). Harley could not tolerate the latter edict and quit. This secretiveness, so common to dyers and printers in 19th century America, changed as America recognized and adopted European textile chemical coloring practices.

Reliance on European Materials and Technology

Americans never grew madder in sufficient quantities to supply their own textile industry needs (Lopez 1988, 50). Yet, the pink, red, orange, purple, and chocolate colors obtained from madder made it one of the most important dyestuffs in 19th century American textile coloring (Parnell 1860, 105; Sansone 1887, 99). Holland supplied madder for dyeing wool and France supplied madder for dyeing and printing cotton (Journal of the Franklin Institute 1832, 353). When alizarine, the dyestuff in madder, was synthesized, it was imported principally from Germany.

Not only natural and synthetic dyestuffs, but also workmen, were imported from Europe. In 1823, the textile firm, Taunton Manufacturing, in Massachusetts brought hundreds of skilled workers from England and Scotland (Emery 1893, 641). Four years later, the Taunton management decided to "procure a practical superintendent for the print works from England" (Emery 1893, 647). Europeans

appreciated the higher wages paid in America (Schoellkopf 1895, 66), and workers, such as Anderton, were valued for the knowledge of chemical dyeing techniques they brought with them from Europe (Cocheco mss. 6).

One author suggests this lack of chemistry in America stemmed from an abundance of American natural resources (Bruce 1987, 142). The need for synthetics, and therefore chemists, was more acute in Europe where substitutes had to be found for dwindling natural materials. For example, severe deforestation in 17th century Europe led industries to seek alternate sources of fuel. Burning coal produced large amounts of coal-tar that in turn supplied the raw materials for chemical research from which dyestuffs were discovered (Ihde 1964, 454). These circumstances did not exist to the same degree in America, leading the editor of Dyestuffs to conclude America had no chemists (1915, 1).

American chemical students valued working with the masters at German universities (Beardsley 1964, 14). Technical chemical education was lacking through the 1860s at many American colleges that were designed to teach only the classics (Beardsley 1964, 18). In 1847, when Abbott Lawrence gave \$25,000 to Harvard to start a chemistry laboratory because he believed New England bleacheries and printworks needed skilled chemists, Harvard separated the chemistry students from their classical students with a fence. Chemistry students could neither take the same

classes, nor attend chapel with other Harvard students (Beardsley 1964, 7). Chemistry was seen as technical information, a vocation, while studying the classics made one a gentleman. Lawrence's views were ahead of their time, and the applied chemistry program did not survive. The cutting edge in chemistry was in Europe.

By the 18th century, chemistry had grown from the 4-elements of earth, air, fire, and water "known" since 450 B.C. as the building blocks of everything else (McKie 1952, 5) to more complicated schemes such as the Phlogiston Theory of Joseph Priestly in the 1770s (Gibbs 1967, 83). However, it was not until Antoine Lavoisier published his table of elements in 1789 that the foundations of modern chemistry were laid (McKie 1852, 274). While much of the early work went on in England and France, it was Germany that quickly assumed a lead role.

American students maintained, "No young man can be expected to know anything of chemistry unless he had studied with Liebig in Germany" (Bruce 1987, 23). Other German chemists were also popular instructors. Between 1850 and 1900, an estimated 800 Americans earned advanced chemistry degrees from German universities (Beardsley 1964, 14).

Further evidence of American reliance on European textile technology is found in the common practice of copying European print designs (Adams mss. 481). European designs were considered fashionable. American subscribers

received, and used, print patterns from French and English designers (Affleck 1987, 29)¹.

Thus, America imported natural and synthetic dyestuffs, workmen, print designs, and chemical education from Europe. However, America did have some indigenous chemical expertise.

Chemical Education in America

There had been chemists in America from early days when chemistry courses were taught by clergymen in "natural philosophy" programs at the College of Pennsylvania in 1756, William and Mary in 1774, and at Harvard in 1787 (Ihde 1964, 267). In the 19th century, American medical school programs included some chemical instruction. Samuel Luther Dana is an outstanding example of such an education.

Dana (1795-1868) earned his M.D. from Harvard in 1818 (Rossiter 1975, 32). By 1826, Dana, after settling in Waltham, Massachusetts and abandoning his medical career, was producing sulfuric acid and bleaching powder for the textile industry (Bruce 1987, 144). This type of one-man industrial research was not uncommon in the late 18th and early 19th centuries.

Dana furthered the work of self-taught American Edward Bancroft, who had found that while not all of the ingredients in the Turkey Red process were important, something in cow dung was a critical mordant (Bancroft 1813,

271). In 1832, Dana discovered that sodium phosphate was the active component of dung, and that it could be extracted from bones. Samuel Dunster's journal of 1843 contains a dung substitute: pounded bones were dissolved in nitric acid, drained in a leaded colander and flushed with hot water (Dunster mss. 3). Dung substitutes could have eliminated the use of tons of excrement in the dye industry (National Cyclopedia 1898, 167). Yet, dung continued to appear in dyers' recipes (Herrick mss. 307.3) and dye books (Bird 1882, 171; Duerr and Turnbull 1896, 39).

Merrimack Manufacturing, a textile company of forward-thinkers at Lowell, Massachusetts, hired Dana in 1834 (Youmans 1896, 312). Dana's discoveries of phosphate and a continuous bleaching process gave Merrimack a competitive edge in calico printing and were "not always published promptly" (Youmans 1896, 312). Dana died in 1868, the year alizarine was synthesized, and before the importance of dye chemistry was widely recognized by the America textile industry. This may help explain why his phosphate discovery was not better known.

Two Ph.D. granting chemical research facilities were established in American colleges: at Harvard in 1863 and at what would become the University of Illinois, in 1867 (Beardsley 1964, 9, 44). This meager commitment to chemistry cannot be considered an overwhelming response to the new technology opened by Perkin's discovery in 1856, but

it does signal an awakening of chemical interest in academia. To illustrate the relative importance of research in American colleges, note that teaching was considered the most important faculty responsibility and most highly regarded function by the administration in presidential inauguration speeches at both Cornell in 1868 and Harvard in 1869 (Bruce 1987, 336).

Coincidentally, only two years after the discovery of alizarine in 1868, Yale began its Ph.D. program in chemistry, quickly followed by the University of Pennsylvania in 1871 and Harvard in 1872. In 1875, research was mentioned as being more important than teaching for the first time by a college president, at Johns Hopkins University (Bruce 1987, 336). By 1876, Johns Hopkins and two dozen other institutions of higher learning had developed graduate degree chemistry programs (Bruce 1987, 335). Harvard granted the first American Ph.D. in chemistry to Frank Austin Gooch in 1877 (Ihde 1964, 270).

Chemistry in American Textile Firms

The growing interest in chemistry in America was reflected in the textile industry's hiring practices where company priorities are revealed in the positions of the men given recognition. When Crocker and Richmond Print Works started to produce calico in 1823, the names of their color superintendent and senior mechanic were noted (Emery 1893,

645). This practice implied the importance of men who kept the machinery running. Securing the best managers and chemists was first found to be a priority when A.C. Houghton reorganized the Arnold Print Works some time after 1876 (Stone 1930, 126). Several factors are thought to have contributed to this change of attitude, at least at the managerial level, toward the acceptance of chemists in American textile companies in the late 19th century.

When Eddystone Manufacturing Company was founded in 1877 (Bancroft mss. 686), the new synthetic alizarine, not the old stand-by madder, was used (Bancroft mss. 410). Records from Lancaster Mills show that only alizarine, not madder, was used in 1878 (Lancaster mss. 55) and possibly earlier. Why was the synthetic dyestuff preferred in these two companies when madder had proven its worth for centuries?

Alizarine had to be mordanted just as madder did, but alizarine did have several advantages. Alizarine could be manufactured as a nearly pure substance in any concentration desired. Ground madder contained two to four percent dyestuff; the rest was waste material (Ender 1970, 204; Schuster 1970, 196). Alizarine gave consistent results, whereas madder colors varied according to various growing conditions which produced the roots.

The use of alizarine is also thought by 20th century writers (Brunello 1968, 275; Mellor and Cardwell 1963, 265;

Roggersdorf 1965, 26) to have filled a gap in the textile industry created when all other facets of production, except dyestuffs, had been improved (Appendix E). While the public clearly appreciated the variety in color provided by the first synthetic dyes, the anilines were not durable, so the textile industry did not give up valuable madder when aniline dyes were discovered. Men with chemical training also were more commonly found in the textile industry after the discovery of alizarine.

From Color Superintendents to Chemists Bancroft and Sons hired William J. Greenhalgh to be their color foreman in 1874. Samuel Bancroft (1840-1915), a son who had ended his schooling at 16, "dusted off" his 18 year-old chemistry books to coach Greenhalgh, who had had no prior chemical education (Bounds 1961, 29). There is no record of Samuel tutoring any of his previous employees in chemistry. Nor was Bancroft the only American textile company adding chemistry to their production in the 1870s.

Washington Anderton, an Englishman, brought his chemistry notebooks with him from England when he was hired by Cocheco Manufacturing in 1878. His notes from two 5-month classes held in 1873 include information on elements, formulas, and methods of analyzing unknown compounds. Only bleaching powder made from arsenite of soda seems directly related to dye chemistry. However, the notebooks Anderton kept while he worked at Radcliffe Printing in England from

1873 to 1878 contain recipes and experiments on garancine and alizarine, as well as madder (Cocheco mss. 6).

In 1878, Anderton came to America, and Cocheco, as a color-mixer, for the equivalent of 8 pounds sterling a week and \$250 moving expenses. In 1882, the year Anderton became color superintendent, he feared Cocheco was going to bring in someone else because they were placing ads for a chemist in European papers (Cocheco mss. 1.9). This suggests he had been hired in the same way, and probably for the same reason; practical European dye chemistry came to America in the heads of its textile workers. Such information was also transported in American heads.

An American, Spencer Borden, a member of the family managing the American Print Works in Fall River, Rhode Island, had spent several years studying dye chemistry in France and England. Borden brought information about madder extracts back to America (Shepard 1872, 87). Some authors had high hopes that madder extracts developed in 1867 would solve the printers' need for a more efficient dyestuff than traditional madder² (Shepard 1872, Crace-Calvert 1876). Unfortunately, I was "several generations too late to get any information" Borden might have left concerning his studies, or use of madder extracts (Hope G. Borden, letter to the author, March 2, 1987).

The alizarine technology fostered by American textile management was promoted in the trade journals also. The

Textile Manufacturer began publication in 1875, The Textile Recorder in 1883, and the Journal of the Society of Dyers and Colourists in 1884. While these were all English journals, the first ran a regular column on American notes of interest, and the latter listed American members, starting with the first issue (1884, 20). These journals included many articles on synthetic dye formula and reactions. For example, Textile Manufacturer (1875a, 273) printed a regular section called "The Colourist", written by Antoine Sansone, active in the print industry in Manchester, England. He aided dyers and printers through articles on testing chemical compositions and reactions, and through recipes using madder and alizarine. The same journal later published tests to help dyers determine whether cotton fabric had been dyed with madder or alizarine (1875b, 372). "Textile Colouring", a section in the Textile Recorder, was written by Charles O'Neill, a faculty member in the Manchester Technical School.

In the late 1880s, American dyers were encouraged to become more knowledgeable about chemistry. "True, a man may be a good dyer and know nothing about chemistry, but if two men are equal and one follows lectures and reads chemistry, he has all the chances to outstrip the other man" (Wade's Feb. 19, 1887). Wade's Fibre and Fabric was an American publication devoted primarily to wool weaving and dyeing, but it ran a regular weekly column on the print cloth market

in Fall River, Massachusetts, (authored by Senator Robert Howard, secretary of the spinners' union) and occasional articles on dyeing and printing cotton fabric.

From Madder to Alizarine Like the transition from color superintendents to chemists, which occurred over time, the transition from madder to alizarine did not occur simultaneously in all American textile companies. Madder was replaced in 1873 at Amoskeag by garancine (Amoskeag mss. E-2; G-3). The same change occurred at Hamilton in 1879 (Hamilton mss. 574). Garancine served as an intermediate product overlapping the use of both madder and alizarine. While garancine was made from madder, it had been chemically altered with sulphuric acid and may have helped ease the adoption of the synthetic dye. The following incidents reveal some of the problems in the transition.

In 1885, Anderton was chided for using "enormous quantities of garancine" by the Cocheco management (Cocheco mss. 1.24). Although Anderton had worked with alizarine in England before he came to Cocheco, he must have been reluctant to give up garancine. Perhaps the quality of alizarine, a decade earlier, had not suited him. When asked about ordering alizarine, Anderton said he wanted to be able to buy it in small quantities as needed (Cocheco mss. 1.24). In 1886, Anderton received letters from Cocheco's selling agent complaining his colors were "horrible", "almost washed out", "too weak", "too strong",

and "anything but right" (Cocheco mss. 1.15) suggesting he had trouble with the transition from garancine to alizarine. Garancine was not used after 1879 at Amoskeag, nor after 1885 at Hamilton. No records have been found showing when Cocheco gave up all natural madder products and used only synthetic alizarine.

Not reluctance, but possibly ignorance, led the bookkeeper at Amoskeag to incorrectly list alizarine as a type of "aniline" until 1885 when it was listed separately at the end of the aniline inventory. Alizarine was given an inventory page of its own in 1888 (Amoskeag mss. E-2; G-3). The slowness to adopt new technology demonstrated by Anderton and the bookkeeper was also reflected in some of the experimentation being done.

The 20th century view of alizarine's value rested in the "greater tranquility and fewer inconveniences" with which it could be used (Brunello 1968, 297). Supposedly, 19th century dyers and printers in the textile industry were eager for the convenience offered by alizarine (Beardsley 1964, 64). Alizarine was touted for its purity, strength, uniformity, brilliance, and fastness (Textile Colorist 1918, 231) as late as 1918 by Americans planning to synthesize it during the World War I dye shortage. This efficiency is not reflected in practices found in the few surviving 19th century notebooks.

Anderton, who experimented with extract of madder, garancine, and patented alizarines in 1875, rated the color of products from different suppliers as "good" or "not quite equal to type". In 1876, his experiments seemed designed to determine the true strength of alizarine and he found the concentration rarely matched the advertised percentage (Cocheco mss. 6). The alizarine sold as 10 percent ranged from 10.5 to 11.3 percent and the 20 percent alizarine was found to be 18.4 to 19.3 percent. Thomas Stafford of Amoskeag also noticed a discrepancy between expected and realized alizarine concentrations. To get a medium red shade, Stafford needed to use seven gallons of 10 percent, or six and three-fourths gallons of 20 percent alizarine (Amoskeag mss. I-2).

There are also anomalies between the notebooks of Rufus Herrick, who experimented with alizarine at Merrimack from 1875 to 1889 and those of Samuel Dunster, who experimented with madder from 1830 to 1858. In 1852, Dunster stated that cow dung was the "old-fashioned way" (Dunster mss. 9), and that dunging was not used during his stay with Philip Allen and Sons from 1848 to 1852 (Dunster mss. 8). Dunster mentioned dung substitute, or salts, several times (Dunster mss. 3; 8; 9). Yet, Herrick still used dung in trials he conducted with alizarine in 1882 (Herrick mss. 307.3). It is hard to understand how Herrick, who worked at Merrimack, where Dana did his dung-phosphate research, was seemingly

less aware of dung substitute than Dunster, who was outside the company.

While alizarine was a synthetic dyestuff, in some ways it had to be treated the same as natural madder. Like Dunster, Herrick, in 1884, experimented with soaping, steaming, and chroming. However, not all the experiments being conducted seem appropriate. Herrick experimented with the affect of chalk on alizarine dyeing. Chalk was used to offset the deficiencies in some madder due to the soil in which it was grown. Herrick tried alizarine with, and without, blood and albumen in 1875 (Herrick mss. 307). Blood and albumen were also considered useful ingredients when dyeing with madder. Cotton did not "take" dye as easily as wool did, and it was thought cotton needed to be "animalized" to correct this problem (Schaefer 1941, 1410). In 1884, a commercial "cotton animalizer" appeared in Amoskeag inventories (Amoskeag mss. E-2). In 1927, a Bancroft employee remembers using chalk and albumen with alizarine "in the old days" (Bancroft 1927, 9).

Herrick compared equivalent types of alizarine from seven dye manufacturers. He also compared dry and wet garancine with the reddest patented alizarine in 1885 (Herrick mss. 307). Herrick compared the patented yellow-red alizarines from different manufacturers in 1887. From these results, Herrick combined various amounts of Sehlbach's most yellow-red alizarine with various amounts of

Pickhardt and Kuttroff's most blue-red alizarine (Herrick mss. 307.4). This is a curious exercise in that German companies were constantly producing new alizarine shades. Possibly Herrick was hoping to develop a new color and gain fame for himself.

Meanwhile, Bancroft and Sons also experimented to find the most pleasing shades in patented alizarines and chose their dealer accordingly. Alizarine brands were tested to determine their durability to soaping (Bancroft mss. 703; 715). By 1886, Bancroft believed the public had been spoiled by alizarine and no longer would buy any of the old natural red colors (Bancroft mss. 736).

Herrick's trials comparing alizarine results when using ingredients associated with madder seem especially unnecessary in light of the alizarine recipes available. In order to advance their dyestuff, BASF had to prove that alizarine was better than aniline dyes. They had to counter the prejudice generated by early fugitive aniline colors that synthetic dyes were not "fast" (Roggersdorf 1965, 39). To make it easier for dyers and printers to be successful, dye manufacturers provided recipes (Cocheco mss. 1.5; 1.14, 4.2, 6; Badische n.d., 5).

These alizarine recipes replaced such recommendations as use "plenty of madder" (Dunster mss. 5) and "a little bit of everything" (Dunster mss. 3), and possibly sped the acceptance of synthetic dyes in the textile industry. With

these recipes, the message was clear, the old "bucket and scoop methods" were not appropriate to use with alizarine (Ward 1911, 174).

On the other hand, O'Neill in The Textile Recorder, stated that recipes would never appear in that journal for the "art of using recipes is acquired only by long practice and great knowledge of apparently quite unnecessary subsidiary matter" (O'Neill 1883, 39). The Textile Manufacturer had no such qualms and published recipes regularly.

Another explanation for Herrick's seemingly out-dated experiments is possible. While 20th century literature, 19th century periodicals, and 19th textile managers seemingly recognized alizarine's theoretically superior qualities, the practical men in the dye and printworks were more involved with physical reality and may have needed more time to adjust.

Strassman, an economic historian, reported that people need a period of time to adjust to totally new technology. For example, American carpenters and blacksmiths are thought to have trained themselves to be machine builders and inventors between 1786 and 1813, after which time American machine inventions experienced a sudden spurt (Strassman 1959, 83). Once men like Herrick and Anderton became used to the new dye technology represented by alizarine, it was easier to accept the other synthetic dyestuffs that quickly

followed.

Herrick experimented with paranitraniline, a red dye which was used cold (Reoch 1916, 238), in 1885. It was sometimes called "Ice Red" in contrast to madder that had to be simmered, and alizarine that had to be steamed to "set" the color. Herrick found that the first ice red did not withstand soaping (Herrick mss. 307.3). Within a month the sales agents sent an improved formula, suggesting the manufacturer's chemist was quite adept at manipulating his formula. The old-timer at Bancroft remembered in 1927 that alizarine was replaced by Para Red some time after 1890 (Bancroft 1927, 9). Other synthetic red dyestuffs followed in such quick succession that today madder and garancine rarely appear in dye lists, and only rarely is alizarine found.

Conclusions

America expressed little need for chemistry in the 18th and early 19th centuries. College programs offered a few theoretical chemistry courses, but were generally opposed to research. In the textile industry, color superintendents developed skills using natural materials, and dyeing was more of an art than a science (Abrahams 1976, 17).

Since America imported almost all its dyestuffs, workmen, and dye technology from Europe, there was little need for the American textile industry to develop its own

dye chemistry research programs. But depressed economic conditions in business, technological improvements in the dye industry, and chemical programs in universities coalesced in the mid-1870s making it advantageous for the textile industry to adopt chemists and their dyestuffs.

The American dye and print company records studied suggest the transition from natural madder to synthetic alizarine worked its way down from the top where management encouraged both the use of alizarine and chemists. Trade journals presented arguments in favor of chemists and about 1885, or 15 years after alizarine red production began, chemists were hired in addition to color superintendents and alizarine replaced madder in many facilities. Some of the auxiliary ingredients used with madder were used with alizarine and the use of these familiar substances may have made the synthetic dye more acceptable.

Although aniline dyes were the first synthetic dyes in the textile industry, not until durable alizarine replaced the valuable madder did dyers and printers give up the large part of their natural dyes. Garancine, a chemically treated madder product, helped ease the transition. Once men were accustomed to non-natural dyestuffs, new ones seem to have been accepted readily.

As the market for prints increased, alizarine facilitated printing larger amounts of fabric. Alizarine, with its purity and predictable dye strength, gave dyers and

printers a better chance to reproduce colors they wanted consistently .

Further Research

Unfortunately, the durability so important in madder, garancine, and alizarine are lacking in today's red dyes and researchers work to find ways to control "bleeding" (Crews 1989, 2). Future researchers may need to work not with ways to control bleeding, but to produce synthetic red dyes which are as permanent as the old natural madder dye.

Endnotes

¹ American Print Works "borrowed" freely from European designs as revealed in this communication, "Please express English swatches" sent from an American color superintendent to his agent (Adams mss. 481). But, according to Affleck (1987, 29), when one American company chose a European design to print, the others respected the first companies' priority and did not use that same design themselves. Other sources suggest that not all men followed this concept. In 1869, Cranston's selling agent sent a print from Simpson and Sons, and another from Cocheco Print Works in 1870, to be copied by Cranston's color superintendent (Cranston mss. 384). In 1885, Cocheco received a Wamsutta print from their selling agent to copy (Cocheco mss. 1:24).

² Hamilton Manufacturing stopped using madder extracts in 1878 when all madder was replaced by garancine. Cocheco

continued to use madder extracts at least through 1881 (Cocheco mss. 5.15). There is no record of any madder extract being used at the other companies studied.

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GENERAL SUMMARY

Although the red dyestuff madder found in the roots of several plants had been used throughout much of the world for at least 5000 years, within 20 years after alizarine (chemically identical to the main dyestuff in madder) was discovered in coal-tar, madder use declined and almost entirely ceased in American textile coloring companies. This research sought to determine why the transition from madder to alizarine occurred.

This research began with 1870 when quantities of alizarine were available, and ended with 1890 when writers (Duerr and Turnbull 1896; Schaefer 1941a, 1403) claimed alizarine had replaced madder. I tried to test the accuracy of the accepted 20 year transition period.

Research into other innovations in the textile industry, such as chlorine bleach (Smith 1979), the Perrotine press (Capey 1930), and the Draper loom (Feller 1966) suggested that changes occurred slowly because workers were reluctant to give up old methods, because new methods initially did not work as well, because the equipment to use new methods was expensive, and because workers had to adjust to the new technology. This research sought to test whether similar problems and adjustments were necessary in the transition from madder to alizarine.

Brunello (1968) suggested the change from madder to alizarine was based on the cheaper price of alizarine. This

research documented all available prices and made comparisons between actual use and price to determine whether the transition was based on prices.

Lastly, other events and factors in society were explored to test their impact on the transition. Two economic depressions, a general increase in awareness of chemistry, tariff changes, a public desire for greater variety in colors, and textile events in Europe were all possible contributors.

Data from records of 10 American dye or print works, located in museums and historic societies in Delaware, Rhode Island, Massachusetts, and New Hampshire, formed the basis of information to answer the research questions. While records from only two companies (Amoskeag Manufacturing and Hamilton Manufacturing) were complete for the entire 1870 to 1890 period, the spotty data from the other companies supported the general data making conclusions more broadly based.

The research data and findings were divided into two broad categories: economic and chemical. Each section dealt with the transition from madder to alizarine, but while the emphasis was different, the findings were similar.

Use of madder gradually declined during the first third of the research period 1870-1890 and garancine took madder's place. This chemically treated madder product was mentioned frequently in the literature, along with all the many other

madder products, as a primarily French attempt to improve madder's concentration. However, the importance of garancine became evident in the company records I studied where it occupied the main role for the middle third of the research period. Only in the last third of the period did alizarine gradually become important until it completely replaced the other madder dyestuffs in the late 1880s.

Garancine acted as an intermediate product bridging the use of natural madder and synthetic alizarine. It may have given workers a way to ease into the use of synthetics and reactions they had not previously experienced. Available recipes show dyers and printers used many of the same mordants and auxiliary products with garancine and alizarine as they had with madder. Familiar procedures also acted as an aid in the transition.

Price was not the sole reason for alizarine's adoption. Findings show that had price been the determinant, the transition from madder to garancine would have occurred in 1871, several years sooner than it actually did at Amoskeag, and the transition from garancine to alizarine, which occurred in 1886, should have occurred later if based on price.

That the transitions did not happen as predicted by price alone leads to the notion that other factors were instrumental in the transition. Economic depressions during the mid-1870s and mid-1880s contributed to the

reorganization of textile firms, when men tried new technology. Alizarine was a new dyestuff and chemistry had not been widely used in the American textile industry before 1875. Both were found to meet textile manufacturers needs better than natural madder.

Together, alizarine and chemistry helped textile producers standardize their work. The purity, known concentration, and consistency of alizarine made its use more efficient and dependable than the use of madder in producing large quantities of fabric. Work stoppages due to weather, water, and equipment problems decreased and weeks without dye work stabilized.

Alizarine was not the first synthetic dyestuff to be discovered, but as a substitute for madder which was of critical importance to the print industry, it is credited as being the turning point in the transition from natural dyestuffs to synthetics (Ihde 1964, 457). Its acceptance opened the door for the great variety of synthetic dyes which followed.

Today madder is known, and grown, only by the home craftsperson who wants to keep history alive. Alizarine too, has been replaced by a succession of new synthetics. Documenting the use of madder, garancine, and alizarine in the American coloring industry preserves an important link in textile history.

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APPENDIX A

MADDER IN HISTORIC TEXTILES

From its probable beginnings in northern India, madder use spread to Egypt, Persia, Greece, and Rome (Peckin and Everest 1918, 23). Madder has been identified in a fragment of cloth sticking to a silver vase (Mehta 1970, 1; Robinson 1969, 17) unearthed from 3rd millenia B.C. ruins at Mohenjo-Daro (Wheeler 1968, 85). Madder is suspected to be the dyestuff in Pliny's 1st century account of Egyptian dyeing, in which fabric dipped into one dyebath came out many different colors (Parnell 1860, 13). In the 3rd century (telephone conversation March 7, 1989, Temple Beth Shalom, Sun City, AZ), laws in the Mishna regulated madder growing for Jews (Schaefer 1941a, 1399). Madder has been identified in a 5th century shroud, 6th and 7th century clavi, and 8th to 10th century Coptic kelims (Schweppe 1976, 29).

Madder moved along trade routes into Europe. From Egypt, the Muslims took madder to North Africa and into Spain around the 9th century (Crookes 1874, 228). In the 8th century, Charlemagne ordered madder to be cultivated in farm gardens covering what is now France, Belgium, Holland, Italy, and northern Spain (Brunello 1968, 130). Madder was grown (perhaps on a commercial scale) in Holland by the 10th century (Laycock 1918, 223). Madder shows up in 10th and 11th century Anglo-Scandinavian textiles (Taylor 1983b,

157), and 15th to 17th century European tapestries (Hofenk de Graaff and Roelefs 1976, 32). Madder was used to dye French military breeches (Schuster 1970, 197), and some British Red Coats (Abrahams 1976, 16).

The most common technique for detecting madder in old textiles is thin layer chromatography (TLC). Preparation and analysis time is minimal, making TLC preferable to infra-red spectroscopy or gas chromatography (Hofenk de Graaff and Roelefs 1976, 32). Other methods include paper chromatography, spectrophotometric analysis, ultraviolet and infrared spectroscopy, and x-ray diffusion (Nelson and Johnson 1988, 13). Samples of the spectra generated by the alizarine¹, pseudopurpurin, purpurin, munjistin, and 15 other compounds known to be in madder are compared with minute samples taken from historic textiles. These tests discriminate among cultivated madder, wild madder, and lady's bedstraw that all appear as a similar color to the naked eye (Taylor 1983b, 158), and can show researchers which type of madder was used (Taylor 1983a, 117).

¹I deliberately do not refer to the main dyestuff in madder roots as alizarine, in my articles, to avoid confusion with the synthetic alizarine. However, the name for synthetic alizarine comes from alizarine in madder.

APPENDIX B1

CONTACT LETTER

Textiles and Clothing
140 LeBaron
Iowa State University
Ames, IA 50011

February 12, 1987

Curator
Museum
City, State

Dear Curator:

For my dissertation in Historic Textiles, I am investigating the transition from the use of natural madder to synthetic alizarine as a dyestuff in American textile companies. I have chosen the period 1870 to 1890.

Does your museum hold company correspondence, color superintendents' journals, or inventories for printworks, dyeworks, or textile manufacturers for this period? I am not able to use swatch books unless they are labeled with the dyestuff used.

Thank you very much for your help.

Sincerely,

Judith Lopez

APPENDIX B2

SOURCES CONTACTED

- # Baker Library, Harvard University Graduate School of Business Administration, Boston, MA
 - * Mrs. Jefferson Borden, 4th, Providence, RI
 - * Cranston Print Works Company, Cranston, RI
 - * Essex Institute, Salem, MA
 - * Fall River Historical Society, Fall River, MA
 - * Goldie Paley Design Center, Philadelphia College of Textiles and Science, Philadelphia, PA
 - # Hagley Library, Wilmington, DE
 - # Manchester Historic Association, Manchester, NH
 - + # Museum of American Textile History, North Andover, MA
 - + Old Colony Historical Society, Taunton, MA
 - * Old Sturbridge Village, Sturbridge, MA
 - + Rhode Island Historical Society, Providence, RI
 - + * Rhode Island School of Art and Design, Providence, RI
 - # * Winterthur Library, Wilmington, DE
-
- * Had no company records available, or pertinent, to this research.
 - + Sources visited during June, 1987.
 - # Sources visited during September and October, 1988.

APPENDIX B3

COMPANIES STUDIED

Company records for the related firms of Bancroft and Sons, Simpson and Sons, and Eddystone Manufacturing Company are located in the Hagley Library, Wilmington, Delaware. Joseph Bancroft began a cotton weaving business along the Brandywine River in Wilmington in 1831. His sons, William (1835-1928) and Samuel (1840-1915), who started at menial tasks at age seven, were made partners in the company in 1865 when the firm added bleaching and finishing to its operations. The copyletter books left by Samuel Bancroft are of particular value for this research.

Simpson and Sons, a printworks, began in 1845 in Pennsylvania. In 1877, Eddystone Manufacturing Company, a subsidiary, was formed as a partnership between Bancroft and Simpson. Bancroft dyed and finished the cloth; Simpson printed and sold it (Bounds 1961).

The Baker Library, Harvard Business School, Boston, Massachusetts holds the extensive Hamilton Manufacturing Company manuscripts. Hamilton was founded in Lowell, Massachusetts in 1825 by Samuel Batchelder (Van Slyck 1879, 67). Hamilton Manufacturing wove and colored a wide variety of cotton and wool fabrics. The Baker also holds fragmentary company records for several other firms: Lancaster Mills, founded by Thomas Bigelow in 1843 at

Clinton, MA; Thorndike Company; and Parkhill Manufacturing were used in this research.

The Museum of American Textile History (M.A.T.H.), North Andover, Massachusetts is the depository for the Cocheco Manufacturing Company papers. Cocheco, which was incorporated in Dover, Delaware in 1836, employed several color superintendents who left journals of their work. In 1875, John Bracewell was Cocheco's color superintendent. Bracewell remained at his post until 1882 when Washington Anderton replaced him. Letters to Bracewell and Anderton from Cocheco's selling agents, Lawrence and Company, and from the company treasurer, Howard Stockton, are of particular interest. The swatch book collection at M.A.T.H. is extensive and several fabrics were chosen to illustrate points in this research.

M.A.T.H. also holds fragmentary records of other American textile companies. Papers used in this research include the records of Adams Print Works, Cranston Print Works, Merrimack Manufacturing, and the Rufus Herrick papers from Merrimack.

Although Thomas Stafford worked under Anderton at Cocheco from 1881 until 1884, his main association was with the Amoskeag Manufacturing Company. Amoskeag was developed in 1822 by Samuel Slater from a small cotton mill. The company records, held at the Manchester Historic Association in New Hampshire, state that Stafford came to Amoskeag from

England in 1879 and worked at Amoskeag until his death in 1917.

The Rhode Island Historical Society in Providence holds the ten-volume collection of journals kept by Samuel Dunster. While his work precedes the time period researched, his madder trials are valuable points of reference for comparison to alizarine. Likewise, the John Duxbury journals held at Old Colony Historical Society in Taunton, MA, provide helpful early samples of color superintendent work.

<u>Companies Studied</u>	<u>Available Records*</u>
Adams Print Works	1869-1874
Amoskeag Manufacturing Company	1870-1890
Bancroft and Sons	1870-1890
Cocheco Manufacturing Company	1876-1881
Cranston Print Works Company	1869-1870
Eddystone Manufacturing Company	1876-1888
Hamilton Manufacturing Company	1870-1890
Lancaster Mills	1878-1888
Merrimack Manufacturing Company	1882-1889
Parkhill Manufacturing Company	1880-1882
Simpson and Sons	1871-1889
Thorndike Company	1889

*Partial accounts in a variety of forms.

APPENDIX C

MADDER, MADDER PRODUCTS, AND SUBSTITUTES

A discussion of madder, its products, and its substitutes is necessary to help differentiate the many substances. The original dyestuff, madder root from Turkey, was purchased in dried bundles (Journal of the Franklin Institute 1832, 353). It was sold unground in the 19th century due to an unscrupulous practice in the 18th century of adding filler materials to ground madder (Knecht, Rawson, and Loewenthal 1919, 836). Madder roots and Turkish madder roots refer to the same thing since madder from other sources was sold in powder form. The bundles of roots, which were ground by the user, could produce all the madder colors, including Turkey Red.

Both Dutch and French madder were sold as a ground powder in casks. One hundred parts of madder roots equaled 45 to 60 parts of dried powder, with the powder having twice the dyeing power of fresh roots (Peckin and Everest 1918, 33). Dutch madder, rubia tinctorium, was used particularly for dyeing wool and cheaper types of cotton. It gave a terra cotta shade in contrast to French madder, rubia peregrina, that was used to dye fine cottons pink and bluish reds. Both Dutch and French ground madder contained bark and pith of the root, neither of which had coloring power.

The French experimented with processes to remove some of this waste material. In fleur de garance, or flowers of madder, ground madder was washed with water and sulphuric acid. The fine-grained paste weighed half as much as the original madder, and gave twice the dyeing power. Julian is credited with developing this process in 1875 (Textile Manufacturer 1875, 97). Unless textile companies made their own flowers of madder, I hypothesize that this French invention was not used in the American textile industry between 1870 and 1890. None appears as such in the drug inventories studied.

In garancine, a paste of madder was treated with sulphuric acid. This not only eliminated much of the waste materials in madder, but also released additional coloring material by breaking some of the chemical bonds in madder. One hundred parts of madder gave 30 to 40 parts garancine with four to five times the dyeing power of madder (Ure 1878, 171). It was a scientific wonder in 1827 when discovered by Robiquet and Caventon, and was in general use by 1838 (Scientific American 1851, 107). Garancine was used extensively in American print works through the 1880s.

Garanceux was made by the same process as garancine, except that previously-used madder was substituted for the madder paste. One-third more dye could be extracted from material which otherwise would have been thrown away (Matthews 1920, 497). This product does not appear in

available American records during the research period.

Emil Kopp produced extract of madder in 1867 by boiling garancine in a weak solution of alum. The coloring material was precipitated with sulphuric acid, filtered and washed (Shepard 1872, 80). Madder extract was applied to cloth as a paste, a one-step operation that greatly aided printers who previously had had to apply a mordant, then to dip the fabric in a madder bath. However, the residual alumina in madder extract prevented printers from getting good purples from this product (Shephard 1872, 80).

To produce commercial alizarine, garancine was heated to 392 degrees Farenheit, destroying madder's secondary dyestuff, purpurin, which gave an unwanted yellow cast when madder baths were allowed to boil. Thus, early commercial alizarine gave excellent madder-purples, but could not provide madder-orange shades. Scientific American (1874, 72) reported later that Messrs. Lucius and Bruning had synthesized purpurin making it possible to attain all the colors of madder with commercial alizarine.

In 1868, Carl Graebe and Carl Liebermann developed a process requiring boric acid and multiple operations, to make synthetic or artificial alizarine from coal-tar. It was chemically identical to the principal dyestuff in madder roots (Crace-Calvert 1876, 44). Henrik Caro and Carl Glaser of Badische Aniline und Soda Fabrik were responsible for the commercialization of the Graebe and Liebermann formula

(Schuster 1970, 198). William Henry Perkin devised a cheaper alizarine formula, using sulphuric acid, which made alizarine commercially feasible in 1869 (Scientific American 1878, 106).

Although synthetic alizarine was initially produced by Perkin and by German companies, Germany quickly assumed the lead, and by 1875 a dozen companies (Hayes 1875, 184) were producing various brands of slightly different red shades. Hamilton Manufacturing left a list of suppliers and their comparable brands (Table 8). The brands were given identifying initials by which they were ordered. It is not known what all the initials stood for, but according to a writer for BASF, V meant shades tending towards violet and R were those with a yellow brown cast (Ender 1970, 202). Contrary to the suppliers' information, dye users, such as Hamilton, claim brands XD and RS4 were the most yellowish-red; V and RB were pure reds; brands ID, BBB, and VD were the most bluish-red.

While the brands in Table 8 and Table 9 are not identical, two general conclusions can be drawn from existing data: different brands of alizarine cost different prices, probably due to their varying qualities, and

Table 8. A Comparison of Patented Alizarine by
Supplier (Hamilton mss. 580)

Shade of Red	Suppliers			
	Sehlbach	Lutz and Movius	Riker & Co.	Pikhardt & Kittroff
Most Yellow	ID		BBB	VD
	IABD			
	IA		BB	
	I		B	RS
Most Red	IAG	3F		
	VE			
	VD			
	V			RB
	SX	4F	S	RY
	RR		SS	
Most Blue	X		SSS	
	XGD	5F		
	XD			RS4

alizarine cost less the longer it was on the market (Table 9). Exceptions are the increase in price in VD alizarine from .45 to 1.05 and in RB alizarine from 1.05 to 1.20 in 1881. This is due to the German price fixing cartel established to abolish disastrous underselling practices before 1881 (O'Neill 1883, 14). The drop in prices after 1884 is due to the expiration of Badische's original alizarine patent.

Once the chemical pattern was understood, alizarine could be made to produce other colors beside madder red. In 1875, alizarine orange was discovered, alizarine blue in 1878, alizarine black in 1887, and alizarine green in 1888 (Ward 1911, 172). American patents for each product were

Table 9. A Comparison of Patented Alizarine Prices per Pound (Amoskeag mss. E-2; Bancroft mss. 1563; Hamilton mss. 591; Lancaster mss. 56)

Year	R	RS	VD	O	RN	V	RB
1878			.35				
1879			.45				1.05
1880							1.05
1881							1.20
1882 ^a							
1883	1.05	1.60	1.05	1.60			
1884	.94	1.44	.94	1.05			
1885 ^a							
1886	.20	.20		.36			
1887 ^a							
1888		.20			.19		
1889					.18	.20	
1890					.17	.18	

^aNo prices available.

taken out a few years after their European discovery by their original inventors (Table 10). An interesting fact about these alizarine colors should be noted. As these new colors were developed, the formula grew farther and farther away from the original alizarine chemical structure but the name alizarine was maintained for its propaganda value as an indicator of high quality (Ender 1970, 205).

As a further indication of the perceived superiority of European chemistry, note the American contributions to the patent list. As prolific an inventor as he was, A. Paraf has not been found in any of the dye publications used in this research. .

Table 10. American Patents for Madder Products and Substitutes (Doyle 1926, 8; United States Patent Office Index 1790-1873 1874, 895).

Year	Number	Inventor	Residence	Invention
1868	74,935	A. Paraf	Boston	Madder extract
1869	86,939	A. Paraf	New York	Madder extract
1869	95,039	A. Paraf	New York	Madder extract
1869	95,465	C. Graebe and C. Liebermann	Germany	Alizarine
1869	97,597	Bronner and Gutzkow	Germany	Alizarine
1870	99,904	J. Hunter	Philadelphia	Madder extract
1870	101,735	J. Hunter	Philadelphia	Madder extract
1870	104,259	T. Bristol	Rhode Island	Oleizarine
1871	110,995	A. Paraf	New York	Madder extract
1871	111,142	A. Paraf	New York	Madder extract
1871	113,918	A. Paraf	New York	Oil-izarine(sic)
1871	113,919	A. Paraf	New York	Rubidide
1871	120,392	A. Paraf	New York	Alizaride
1871	120,393	A. Paraf	New York	Madder process
1872	127,426	W. Perkin	England	Alizarine
1873	147,010	A. Kellor	New Jersey	Turkey Red process
1874	153,536	H. Caro, C. Graebe, and C. Liebermann	Germany	Alizarine
1877	186,032	H. Caro	Germany	Alizarine orange
1877	188,061	F. de LaLande	France	Purpurine
1877	188,217	J. Wolff and R. Betley	England	Alizarine
1882	258,530	H. Brunck	Germany	Alizarine blue
1887	368,054	R. Bohn	Germany	Alizarine black
1889	399,479	R. Bohn	Germany	Alizarine green

APPENDIX D

RELATED ECONOMIC CONSIDERATIONS

Wage cuts and economic depressions occurred in 1873-1878 and in 1882-1886 throughout America (Mohl 1985, 147-151). One proposed textile workers' strike in 1875 was beaten before it started by an announcement that should the walkout occur, "the services of all (strike) participants would no longer be required" (Merrimack mss. 401). Walkouts and strikes were also rumored throughout the 1880s (Wade's July 16, 1887). Textile workers in Fall River, Massachusetts were particularly hard hit.

Three-fifths of the most common type of print cloth, 64 x 64, tabby, 4.5 yards to the pound, was produced in Fall River, Massachusetts (Wade's Aug. 5, 1885). Their 40,000 looms used 203,750 bales of cotton yearly and wove at an average rate of a mile of fabric a minute (Wade's Nov. 20, 1886). A typical week's output at Fall River was 175,000 pieces each 28 yards long. Unfortunately, this many yards could not all be sold. Over-production plagued the industry. Table 11 shows the number of pieces on hand December 31 at the end of each business year.

Table 11. Over-Stock in Print Cloth in Fall River,
Massachusetts (Wade's Jan. 1, 1887)

Year	Surplus 28-yard Pieces
1880	1,067,000
1881	1,064,000
1882	844,000
1883	836,000
1884	1,141,000
1885	475,000
1886	207,000

In 1875-1877 foreign shipments of prints more than doubled, leading one author to state that people in England, the British colonies, China, and India preferred American patterns to any others available to them (Clark 1928, 413). Print cloth manufacturers were aware of this market, and did little to curtail their production. Each company seemed to expect that by producing many yards of fabric, the little profit on each yard would add up to the larger profits they wanted. This is a common failing in highly competitive markets.

The high prices paid for goods after the Civil War, when people restocked items which were unavailable or which had worn out (Smith 1944, 50), gave textile manufacturers a false sense of prosperity. Five new print cloth companies were formed in 1865 and another in 1868 (Smith 1944, 50).

However, there was a finite market for cotton prints (Clark 1928, 414) and when supplies had been replenished, demand diminished. Prices for enough cotton to weave one

yard of fabric dropped from .047 in 1870 to .026 in 1890. Wholesale prices for finished cotton prints dropped from .12 in 1870 to .063 in 1890. My computation shows that the percentage that manufacturers of prints paid for just one of their raw materials actually rose from 38 percent of the end cost to 41 percent (Table 12). The remaining 59 to 62 percent, a matter of a few cents, had to cover wages, dyes, equipment, all other expenses, and profits.

Table 12. A Comparison Among Prices of Raw Cotton per Pound, per Yard of Finished Prints, and the Percentage of Cotton's Price in the Prints' Price

Year	Cotton ^a	Cochecho Prints ^b	Percentage
1870	.047	.124	38
1871	.041	.116	35
1872	.050	.120	42
1873	.044	.115	38
1874	.038	.098	39
1875	.034	.087	39
1876	.028	.069	41
1877	.027	.068	40
1878	.025	.062	40
1879	.026	.063	41
1880	.028	.069	41
1881	.025	.070	36
1882	.028	.065	43
1883	.024	.065	37
1884	.024	.060	40
1885	.024	.060	40
1886	.022	.060	37
1887	.024	.060	40
1888	.024	.060	40
1889	.025	.060	42
1890	.026	.063	41

^aCosts per pound of cotton (Bezanson 1954, 92) were divided by 4.5 yards per pound (Bancroft mss. 701) to get the cost of cotton to make one yard of fabric.

^bPer yard of fabric (Bezanson 1954, 265).

In a continued effort to increase profit margins, textile companies reduced spinners' and weavers' pay (Table 13). Workers' problems worsened when print cloth companies attempted to save money on the cotton they provided their spinners and weavers. Cotton was available in different grades, some of which were easier to work with than others. If a bad batch was inadvertently purchased in good times, it was shoved to the back of the warehouse and not used. In bad times, this stored stock was brought out, much to the dismay of spinners and weavers who were paid on quantities produced. "Bad" cotton included short staple or brittle fibers. If this type of material was forced on the workers during the summer months, their problem was compounded. Cotton absorbs moisture in humid seasons, swells and breaks as it is worked (Wade's July 24, 1886).

Table 13. A Comparison of Spinners' and Weavers' Wages
(Wade's Nov. 27, 1886)

Year	Spinner's pay (per 100 hanks of thread)	Weaver's pay (per 45 yards of fabric)
1873	.0475	.300
1886	.0298	.182

Wage conditions in the madder house where print cloth was turned into prints seem equally bad by present day standards. Data from the Hamilton records for 1872 (a good year!) show low wages and layoffs were common (Hamilton mss. 219). From February 27 to March 25, names of 25 people are

listed as working in the Hamilton madder house. The first name on the payroll, McTague, who possibly was the foreman, earned \$60 for 24 days work. The majority of the rest of the workers earned between \$1 and \$2 a day. One name, possibly that of a child, earned .60 a day.

The work day began at dawn and ended at sunset. Extra pay was granted if the lamps had to be lit (Cocheco mss. 1.1). Many men, and the child, worked the equivalent of 1 and 1/4 workdays a day. The foreman did not.

From July 29 to August 31, 1872, there were 45 names on the madder house payroll. In September, there were 41 names, but 11 of those did not work the full month. In November, there were three fewer employees, and in December, everyone had Christmas day off, but only the foreman was paid. In June, only 36 names were listed, and of those 11 were newly hired people who worked 1 and 1/2 weeks or less. Only 18 men worked for the whole pay period.

Records at Hamilton Manufacturing show that of the 80 weeks in the months of June from 1870 through 1890, no madder, garancine, or alizarine was used during 31 weeks. Since it is unlikely men would be paid for days when no dye was used, I hypothesize they were laid-off. Yet, in the 20 year period, no dyestuffs were used in the madder house at Hamilton for only 17 weeks during the months of December, 1870-1890. This suggests that dyers had no time off (paid or otherwise) at Christmas for at least three years. No

madder dye was used during 15 weeks in the months of May and during 14 weeks in the months of November, 1870-1890 (Table 14). On the other hand, no work was lost in August and September, and there was only 1 week lost in March during the 20 year research period.

I can only speculate why some months were more vulnerable to closings than others. Before mills converted to steam power, the amount and condition of the river water was a problem. One sales agent advised his producer, in October, that it was better to delay delivery than to risk loss of reputation through poor color due to water conditions (Adams mss. 481). In another case, alizarine crystallized when it froze, in February, and could not be used (Bancroft mss. 703). Fires were a constant hazard (Cocheco mss. 3.3). Coal shortages were a problem after conversion to steam power (Wade's 1887). These last two problems would not be restricted to any particular month or season as some form of heat was needed always to set both madder and alizarine.

While June and December were the months with the most "vacation" weeks, 1877 and 1878 were the worst years for Hamilton's madder employees with 11 and 14 weeks, out of 52

Table 14. Non-dye Weeks in the Hamilton Madder House by Month, 1870-1890 (Hamilton mss. 575-585)

Month	Number of Weeks
January	3
February	5
March	1
April	4
May	15
June	31
July	3
August	0
September	0
October	4
November	14
December	17
Total	96

weeks, off respectively (Table 15). Despite the national depression, workers experienced no weeks off during 1871, 1873, and 1874 at Hamilton. Workers were not so fortunate during the 1882-1886 depression. There was no work for 8 or 9 weeks each in 1882, 1883, and 1884. By 1887, with 100 percent alizarine use, Hamilton was able to stabilize its work with 2 weeks off in June and 1 in December.

Possibly the ease in using alizarine and in getting good results encouraged additional companies to enter the textile coloring business. Even though the wholesale price per yard of prints dropped from 12 cents to 6 cents between 1870 and 1890 (Table 12), successively higher value was

Table 15. Non-dye Weeks in the Hamilton Madder House by
Year, 1870-1890 (Hamilton mss. 575-585)

Year	Number of Weeks
1870	1
1871	0
1872	5
1873	0
1874	0
1875	2
1876	5
1877	11
1878	12
1879	4
1880	5
1881	6
1882	9
1883	8
1884	8
1885	3
1886	5
1887	3
1888	3
1889	3
1890	3
Total	96

produced (Table 16). Alizarine is a likely factor
explaining this phenomenon.

Table 16. Dye Companies and the Value of Their Products
(Ward 1911, 174)

Year	Number of Companies	Output
1870	292	\$18,374,503
1880	191	26,223,981
1890	248	38,450,800

APPENDIX E

IMPROVEMENTS IN TEXTILE EQUIPMENT AND PROCESSES

I believe the modernization of the textile industry began in 1743 when John Kay developed the flying shuttle which made the weaving of wide widths of fabric faster. This increased the demands on hand spinners. Help came to them in 1764, when James Hargreaves' spinning jenny enabled one operator to spin as much weft thread as 20 women had earlier, and in 1769, when Richard Arkwright developed the water-frame which spun fibers strong enough to be used for warp threads. In 1779, Samuel Crompton combined Hargreaves' and Arkwright's inventions into the "mule" on which thread suitable for either warp or weft could be spun quickly (Clow and Clow 1952, 167).

The Jacquard loom attachment made production of patterned weaves easier and faster a few years after its introduction in 1803. When Edmund Cartwright powered looms by adding James Watt's steam engine to them in 1785 (Hills 1970, 151; Walton 1912, 88), one operator could attend several looms at once. Improvements in bleaching, a critical step preliminary to coloring textiles, also occurred in 1785 (Smith 1979). These increased spinning and weaving capacities put extra demands on fiber producers. Eli Whitney, credited with invention of the cotton gin of 1793, answered this need when the gin was used to make large

quantities of almost seedless cotton available with less labor and time.

Traditional hand-carved wooden blocks used to print individual design motifs were replaced in 1763 by Edward Nixon's copper plates, which in turn were supplanted by Thomas Bell's copper rollers in 1785 (Clow and Clow 1952, 167; Bagnall 1893, 290). With roller printing, 25 times as many yards of cloth could be colored as by using blocks, but the calico industry continued to rely most heavily on a 5000 year old natural dyestuff, madder (Robinson 1969, 17).

When the main dyestuff in madder, alizarine, was synthesized in 1869, it filled a technological gap in the textile industry, but it also had significance in the chemistry field.

An amusing and instructive clue to the importance of alizarine in the chemical world is revealed in the first meeting between the discoverers of alizarine and its commercial promoter. Baeyer, director of the two young theorists Graebe and Liebermann who found alizarine, supposedly said he was astonished to meet Henrik Caro at Badische Aniline und Soda Fabrik. Baeyer is quoted as claiming he "never laid eyes on a technician before" (Roggersdorf 1965, 27). Useful work between organic chemistry and technology allegedly dates from that meeting (Schoellkopf 1911, 181; Schuster 1970, 199).

APPENDIX F

POWER SOURCES

The change from waterwheels to steam engines as a source of power is another factor possibly contributing to the transition from madder to alizarine. In 1870, steam provided only 25 percent of the motive power in New England textile firms; by 1890, steam supplied 51 percent of the power (Smith 1944, 40). Having steam power on the premises as motive power would have been more conducive to using the alizarine process which used steam as a setting agent than having to transform water to steam.

Hunter, in the first volume of his trilogy on industrial power, Waterpower, thoroughly documents the development of early American industries along rivers that provided a more efficient source of power than human or animal power (Hunter 1979). The Canal and Lock Company, founded by Francis Lowell and his associates in northern Massachusetts, established, maintained, and controlled the extensive water system needed to run textile companies, including Lowell and Merrimack Manufacturing (Appleton 1858; Hunter 1979, 204-291). Water, although plentiful and inexpensive, had its disadvantages. In 1878, a company had to close while a water wheel was replaced (Bancroft mss. 687), and an inconsistent flow interrupted operations.

The advantages of steam are chronicled in Hunter's Steampower (1988). Samuel Slater, in Rhode Island, changed his textile companies over to steam power beginning in 1828, almost 40 years before Lowell in Massachusetts did (Hunter 1979, 289), largely as a result of Charles T. James's advice (Hunter 1988, 106). James suggested that steam provided greater regularity of motion than did water wheels and that regularity was necessary to get the smooth texture needed to work with the new, finer cottons. Steam, too, had its disadvantages. In 1887, coal shortages threatened to cause mill closures at Fall River, Massachusetts. The 37 mills there used 150,000 tons of coal annually (Wade's Jan. 22, 1887).

APPENDIX G

EARLY "SYNTHETIC" DYES

Purists might argue that Perkin did not discover the first synthetic dyestuff. In 1300, archil, or phenol orcinol, was produced from lichens. It gave a purple-red color (Farrar 1974, 149). In 1740, saxe blue was derived from indigo and sulfuric acid (Farrar 1974, 50). In 1760, Hellot distilled indigo in the presence of quick lime and got aniline almost 100 years before Perkin (Brunello 1968, 228). In 1818, murexide, a purple-pink made from uric acid and nitric acid was produced. In 1840 this product used uric acid made from Peruvian guano (Mellor and Cardwell 1963, 275). Alizarine itself was produced in 1824 by heating madder with strong sulfuric acid (Crace-Calvert 1876, 24).

However, in each of the instances above, at least one natural ingredient was involved. Perkin discovered the first dyestuff made solely from non-naturally occurring materials.

APPENDIX H

EUROPEAN DYE CHEMISTRY

France

In the 1820s, France was the world leader in chemistry (Ihde 1964, 180) especially in textile chemistry. Jean-Baptiste Colbert (1619-1683), Minister of Finance under Louis XIV, instituted reforms and controls in the production and quality of French textiles in 1672. Colbert developed the office of Director of State for the Dyeing Industries, which regulated dyers and the appearance and durability of their products. It was Colbert who tried to introduce madder cultivation in Avignon in 1666 (Peckin and Everest 1918, 23). The crop was not successful, largely due to European lack of knowledge about raising madder.

In 1766, Pierre Joseph Macquer (1718-1784), Director of State for the Dyeing Industries, wrote the Dictionnaire de la Chimie. This work compiled the chemical findings then known. A second edition was published in 1778.

Macquer was succeeded as Director by Claude Louis Berthollet (1748-1822) in 1784 (Clow and Clow 1952, 203). In 1785, Berthollet was instrumental in recognizing and advancing chlorine as a bleaching agent in the textile industry.

The presence of the office and these men demonstrate the early importance France placed on having chemists

involved with its extensive, and valuable, textile industry. Other French researchers were also active on behalf of the textile industry.

Charles Francois DuFay de Cisternay, in a work published in 1737, demonstrated that cotton and wool absorbed dyes differently due to their inherent properties and that dyes attached to fibers chemically rather than mechanically (Brunello 1968, 226). Eugene Chevreul (1786-1889), the long-lived director of Gobelins, published his work on the composition of colors in 1864. His arrangement, perfected by Oswald, of 14,400 different gradually shaded tints, is still in use today (Brunello 1968, 270). Jean Antoine Chaptal (1756-1832), Minister of the Interior under Napoleon, and credited as being the last of the great masters of the art of dyeing (Brunello 1968, 261), perfected the Turkey Red formula in 1785. Jean Hellot (1685-1765) experimented from 1740 to 1750, until he concluded that mordants worked chemically, rather than by physical or mechanical means, as earlier believed (Brunello 1968, 231). By 1760, Hellot had discovered aniline (by distilling indigo in quick lime) almost 100 years before Perkin, but aniline's value as a dyestuff was not recognized at the time (Brunello 1968, 228).

It must be remembered that France was a major producer of madder, with thousands of acres of madder under cultivation. With this natural market to protect, it is not

surprising that French chemistry was not looking for, and did not recognize, synthetic dyestuffs.

By the beginning of the nineteenth century, dyers had achieved considerable mastery of their craft...in practice, a large part of their work consisted of ringing the changes on one very satisfactory dye-madder-with a variety of mordants (Farrar 1974, 149).

French dyestuff research went into improving madder's concentration of color power by developing products such as garancine and madder extracts. The situation was different in England.

England

The coal fields of Manchester supplied materials for gas works and coke production where quantities of coal-tar were generated. This coal-tar was termed a "serious industrial nuisance" (Ihde 1964, 454) and an "extremely unwelcome troublesome by-product" (Moore 1939, 298). Five gallons of it sold for one cent (Farrar 1974, 151). August von Hofmann, who had worked with coal-tar in Germany since 1835, was asked to come to England to develop research there.

Hofmann (1818-1892), director of the Royal College of Chemistry in London in 1845, encouraged his students to investigate coal-tar (Ihde 1964, 266). Peter Greis (1829-1888), recognized for his work in the azo group of coal-tar dyes, was one of Hofmann's students (Ihde 1964, 456). His best known student, however, was William Henry Perkin.

Perkin (1838-1907) accidentally discovered the first synthetic dyestuff, aniline mauve, while attempting to get quinine from coal-tar (Mellor and Cardwell 1963, 276). The 18-year old student realized the value of his colorful substance to the dye industry and dropped out of college. His father financed Perkin's dye manufactory, and his older brother managed the business. The Perkin dye company was very successful; in 1874, Perkin sold his business and lived on the proceeds until his death in 1907. The novelty of Perkin's aniline mauve in 1856, Freres' aniline magenta in 1859, and Hofmann's aniline violet in 1862 quickly made them commercial successes (Ihde 1964, 456).

"Notwithstanding their beauty,...the new dyes still had a few shortcomings" (Roggersdorf 1965, 12). An indication of the problem is revealed in the expression, "as fleeting as an aniline dye" (Brunello 1968, 281), coined in the 1860s. While the majority of synthetic dyes found between 1856 and 1866 were not as sun or water resistant as madder, durability did not matter to a populace who wanted brilliant variety in their colors.

Hofmann sought to establish the theoretical and structural components of aniline dyes systematically (Ihde 1964, 266) rather than to rely on the chance discovery of new dye colors (Beer 1959, 28). However, English textile industrialists were so conservative that they did not adopt Perkin's aniline mauve until after the French fashion

industry made it popular (Edelstein 1956, 600), and were unlikely to appreciate systematic knowledge. Hofmann returned to Germany in 1865, and his departure, combined with Perkin's retirement in 1874, are thought by some authors to explain why England lost her supremacy in synthetic dyes to Germany (Edelstein 1956, 603; Read 1958, 6).

The English government also was slow to reward men who made notable contributions to its textile industry (Beer 1959, 32). Perkin was knighted for his discovery 50 years after the fact. If government support was lacking in England, it certainly was not lacking in Germany.

Germany

The rulers of independent German states founded scientific research facilities in the 1840s (Bruce 1987, 7) which drew American students desiring advanced chemical degrees. After unification in the 1870s, the German government financially backed its synthetic dye manufacturers (Textile Manufacturer 1880, 12). This German interest in dye chemistry gave scientists in that country an advantage over those in England.

While France and England, two early contenders for supremacy in textile chemistry, fell behind, German synthetic dye works developed size and strength between the 1860s and 1880s. The Cassella company began in 1812 with

vegetable dyes and turned to aniline dyes by 1867. This firm published Dyestuffs, a journal for the synthetic dye industry, in America beginning in 1897. Badische Anilin und Soda-Fabrik (BASF) was founded in 1861 and incorporated in 1865. Mirroring the changing need for chemists, BASF employed five chemists in 1870 and 61 in 1884 (Roggersdorf 1965, 13). Adolf Baeyer began manufacturing aniline in 1861 and synthesized indigo in 1880 (Ihde 1864, 457). Meister, Lucius, and Bruning started in 1862, when a chemist and two merchants joined forces. The company became Farbewerke Höchst in 1868.

These German firms prepared an organized search to find a madder substitute and, since Perkin had shown dyestuffs were to be found in coal-tar, Germans looked there, too. They chose madder because of its age-old popularity and the large amounts of madder consumed, and likely to be consumed, in the European and American textile industries (Beer 1959, 118). If Germany could find a colorful and durable synthetic dye to replace madder, Germany would have a share of the lucrative dyestuff market then going to Holland and France.

Carl Graebe and Carl Liebermann, working in Baeyer's laboratories, furthered work done by Dumas and Laurent in 1832 on anthracene (Crace-Calvert 1876, 44), and succeeded in synthesizing alizarine from coal-tar in 1868 (Von Meyer 1888, 518). With skillful BASF development and promotion,

Graebe and Liebermann replaced the "hard core", "almost traditional", "cheap and reliable" natural dyestuff madder (Mellor and Cardwell 1963, 278).

To demonstrate the success of German efforts: by 1874, one German synthetic dye company easily produced 1000 tons of alizarine compared to Perkin's maximum output of slightly over 400 tons of alizarine a year (Beer 1959, 118; Paine 1958, 35). By 1881, German companies formed a cartel to regulate alizarine by fixing its price and allocating percentages to each producer and consumer (Beer 1959, 118). After alizarine was discovered, at least in Germany, it could no longer be said, as in the 1850s, that chemistry was an unremunerative trade for eccentrics (Roggersdorf 1965, 13).