Review Statistics of the early synthetic dye industry

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Abstract
From the invention of Perkin’s Mauve in 1856, to publication of the first edition of the Colour Index in 1924, more than 1200 synthetic organic colourants were introduced. Some achieved commercial success, while others were rarely used for reasons such as high cost, low fastness, and toxicity. This turbulent period of innovation was largely driven by demand of the textile industry; however, synthetic colourants were subsequently adopted in many other applications. An understanding of the most common materials and their properties is therefore important to the study of heritage collections and their preservation. The risk of light damage during exhibition of objects is often a concern due to the fugitive nature of many synthetic colourants.

To provide a foundation for focused research on synthetic dye identification and lightfastness, work was carried out to identify the most prominent of these colourants used in North America up to the year 1924 when the first edition of the Colour Index was published. Information was compiled and analysed from several sources including multiple editions of the Colour Index, and government documents related to the manufacture and trade of synthetic dyes that provide data from 1914 onwards. Cross-referencing between the information sources provided a summary of parameters for each colourant including the date of introduction, number of manufacturers, lightfastness, and quantity produced or imported in the United States.

A document published in 1916 by the US Department of Commerce listed 259 colours with Schultz number imported during the 1913–1914 fiscal year, in quantities above 10,000 lb (4536 kg). Adding domestic products to the list, and removing duplicates, gave 289 individual colours with Schultz number imported and/or produced in the US. In addition, there were some imports of unknown composition: 96 azo, 23 sulphur, and 68 unclassified. Further review of census data from 1917 through the 1920’s suggested that less than one quarter of the dyes listed in the Colour Index were imported or manufactured in significant amounts. The results of this analysis are presented as summary statistics, which are complemented by an open dataset publication to facilitate future research.

Keywords: Synthetic dyes, Identification, Lightfastness

Introduction
Early advances related to synthetic and semi-synthetic dyes were made by Barth (indigo carmine, 1743) [1], Woulfe (picric acid, 1771) [2], Scheele (murexide, 1776) [3], and Runge (aurin, 1834) [2, 4]; however, a commercial industry was not significant until William Perkin created mauveine in 1856. This was followed by a period of accelerated developments of new products, which peaked near the end of the 19th century. Early synthetic dyes are generally categorised according to chemical structure. The most abundant synthetic dyes belong to the azo class. However, other chemical classes, including triphenylmethane, azine, xanthene, nitro, oxazine, indigoid and anthraquinone have each in turn had an important impact on the industry. As colourants were introduced to the market, many were used to colour materials other than textiles: e.g. waxes and varnishes, writing and printing inks, paint pigments, and early plastics. As a result, large quantities of synthetic colourants are present throughout museum collections around the world. Detailed reviews of the early industry [2, 3, 5–9] and respective dye chemistry [10–14] are plentiful in the...
literature, and provide valuable context for current studies of heritage materials.

For many heritage objects, efforts are made to identify colourant materials for historical study, authentication and dating, and fastness evaluation. The large number of possible compounds makes it an overwhelming task to characterise them all, and in many cases reference materials are scarce. Analysis of these colourants is further complicated by the varied nomenclature used by manufacturers, where similar names were used for different dyes. The confusing letter codes (markings) after dye names, practice of mixing products, and mischaracterization of the product composition create additional layers of complexity. Norton [15] offers insight into some aspects of this confusing issue in a section titled “The Marks of Coal-Tar Colors”. As just one example of the complexity, Norton indicated that 300,000 lb of a dye named Cotton Black with various markings (unclassified by Schultz #) was imported into the United States in 1914. The first edition of the Colour Index (CI) contains several listings that relate to this product name [16]: Cotton Black from Wülfing, Dahl & Co. (CI# 994); Cotton Black B, 3B, BG BGN BGNX, BN, C from BASF (azo direct dyes with no CI#); Cotton Black E extra from BASF (CI# 581); Cotton Black G, 2G, 3G, PF extra, R, RN from BASF (azo direct dyes with no CI#); and Cotton Black RW extra from BASF (CI# 582). In some cases, a classified dye may also have a spectrum of possible compositions depending on the production method. An example is given by Crace-Calvert [17] when discussing the methyl and ethyl-rosanilines, and the production of various forms of Hofmann’s Violet:

...by varying the circumstances of experiment, instead of three of the hydrogen being replaced by ethyl, dyes may be obtained having two, or only one, replaced by ethyl; moreover, by substituting methyl iodide for ethyl iodide, corresponding methyl compounds may be prepared. In this way Hofmann violets are obtained of different shades, varying from RRR, the very red, which is principally a salt of monomethylated rosaniline $C_{38}H_{18}(CH_3)N_3$, to BBB, the bluest shade.

In the 1980s, Schweppe [18, 19] aimed to simplify the problem by providing a shortlist of 65 early synthetic organic dyes with notes to assist with their identification, while also highlighting a subset of 22 stated as the most common [20]. In the field of heritage science, this list has become a common reference despite the ambiguous selection criteria. In a review of the early synthetic dyes, Barnett [20] remarks that areas for further work include identifying the most common materials using 19th century trade literature, and compiling respective fastness data. The challenge, of course, is finding quantitative data regarding dye production or use. The Colour Index is an encyclopaedic resource of colourant data; however, information related to the degree of use is limited, and modern lightfastness data is unavailable for many of the earliest materials. Similarly, most trade books of the period simply outline the vast range of products available. It is likely that a significant number of the catalogued products were rarely used, and analysis could be prioritized to specific materials given the appropriate information.

This study investigates several trends in the synthetic dye industry using early 20th century literature: multiple editions of the CI [16, 21, 22], Norton’s census [15], and the annual Census of Dyes and Coal Tar Chemicals from the US Tariff Commission [23, 24]. The goal of the work is to provide a framework to better understand the most prominent early synthetic dyes, optimise methods for identification, and further develop lightfastness data for risk assessment tools. Findings are presented as summary statistics due to the large number of materials, while tabulated values are provided in a complementary dataset for further research work [25].

Data mining the colour index

Many reference texts were published with lists of dyes during the latter half of the 19th century, leading to the development of different classification systems [26]. The first widely adopted approach was Tabellarische über-sicht der Künstlichen Organischen Farbstoffe by Schultz and Julius [27], which was published in seven editions between 1888 and 1931. The fifth edition [28], retitled Farbstofftabellen, became a template for the first edition of the CI and resulted in a legal dispute between the two groups [26]. The CI employed a new numbering system, and provided a convenient table for cross-referencing with listings in Farbstofftabellen. The table is a valuable resource since it allows conversion from the 1914 Schultz number to the first CI number [16], and subsequently to the CI constitution number in current use [21]. This conversion was applied in the following section during a review of census data, where US dye imports and production quantities were published with the 1914 Schultz number prior to 1924.

The CI contains a large amount of information showing interesting trends when extracted and studied as a dataset. For example, a column of citations for each dye provides the approximate date of introduction for each compound. Using this information, the earliest date was tabulated for each dye, and a sorted list was used to generate a plot of cumulative dyes invented through time. The result in Fig. 1 shows a sigmoid curve with features characteristic of the stages of an evolving technology:
birth, development, maturity and stagnation. At a conference celebrating the centennial of Perkin's creation of mauveine, Lecher [5] described the stage up to ~ 1870 as the 'empirical period' when the structural theory was not yet established. This was followed by the 'rational period', as the Kekulé structure of benzene was developed in 1865 [29] and later accepted. When the industry entered this latter period, the introduction of new dyes accelerated as specific organic compounds were sought after. This is evident in Fig. 1, where the rate of dye introduction accelerates shortly after 1870, and peaks around 1889. Another moment of significance is observed at the year 1893, when 50% of this first wave of dyes was introduced.

Further information is added to this overview of the early synthetic dye industry by cross-referencing date of introduction with chemical classification. The stacked histogram in Fig. 2 highlights the distribution of dyes invented over time by chemical class, with a dominant peak generated by the azos around 1890 (cf. Fig. 1). A smaller peak at 1907 is due to the development of anthraquinone and sulphur dyes, which is followed by a cluster of indigoids around 1915. The introduction of triphenylmethane and xanthene dyes is scattered throughout the time period, along with the remainder of chemical classes grouped as 'other' to simplify the plot.

The CI provides occasional qualitative indications of popularity in the descriptive text for the listed dyes, but the information is sparse and of limited use. Another potential popularity indicator is the number of manufacturers, M, that offered each product. One would assume that compounds having many manufacturers would also experience significant commercial use. Those with one manufacturer may have had patent protection; however, this was likely circumvented or ignored using different methods of manufacture and varied rules by country. Gardener [30] provides a compilation of articles related to the British coal-tar industry, with the issue of patent protection highlighted throughout the text. In one paper, Bloxam [31] states “The whole of organic chemistry has been wondrously advanced by the desire of the maker of dyestuffs on the one hand to obtain monopolies of new colours, and on the other hand to avoid paying royalties under existing patents”. To illustrate the varied number of manufacturers, Fig. 3 shows a plot of the number of dyes having more than a given value of M – defined here as the manufacturers in exceedance, Me. The plot was constructed in this manner to quickly determine how many colourants would be required for future analysis (e.g. chemical and lightfastness) if we target those with more than some threshold number of manufacturers. Nearly all dyes had one or more manufacturers, while less than 50% had $M \geq 3$, and only ~ 10% are indicated with $M \geq 15$. The number of manufacturers is also used in the following section when plotting import and production quantities from US census data.

A final parameter investigated in the CI was the lightfastness rating for each colourant. The third edition [22] was reviewed for ISO and AATCC lightfastness values.

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**Fig. 1** Cumulative number of synthetic dyes invented by year, compared with the rate of dye invention. The dashed line represents the annual quantity of dyes invented, calculated as a moving rate of invention over five-year intervals (secondary y-axis).

**Fig. 2** Number of synthetic dyes invented by year and chemical class.
related to each of the 1,230 synthetic organic dyes listed in the first edition [16], using a conversion table in the second edition [21] for the two CI numbering systems. In total, 432 were found, or ~ 35% of the total list. Counts of dyes with half-step ratings (e.g. ISO 2–3) were split equally into adjacent bins of full step ISO values to plot a histogram of the quantity of dyes with each lightfastness. Figure 4 shows the resulting percentage of dyes having each ISO value, with a peak at ISO 3. This distribution is affected by the number of dyes with ISO ratings listed in the CI, which varies significantly by chemical class and application type. The distributions are also highlighted separately for the direct and vat dyes, showing peaks at the lower and higher ISO ratings respectively. Figure 5 gives a related plot in which the relationship between the ISO and AATCC lightfastness scales is evaluated using data from 237 of the dyes, where both measures were available.

Many of the earliest synthetic dyes were highly fugitive to light, which is well documented in literature of the period [32]. When Lauth discussed a new dye (Violet de Paris) in 1867, he gave some perspective on the shifting public opinion toward lightfastness:

_The violets obtained from methyl-aniline possess a richness and purity which leave nothing to be desired ... Nevertheless they were not adopted by manufacturers, who, indeed at the time above mentioned (1861), attached less importance to the beauty of a colour than to its permanence. In this latter respect the methyl-aniline violets do not excel, and consequently dyers would have nothing to do with them. Gradually, however, people have become accustomed to colours which fade on exposure to the solar rays. Indeed the public taste at the present day, in colours as in everything else, inclines rather to tinsel than to solid excellence._

In his 1896 Hofmann memorial lecture, Perkin [6] also points to the shift of public interest toward new...
vibrant colours at the expense of fastness. In a later review of the industry, Whittaker [33] comments on the unfortunate discovery of so many fugitive dyes during the early development of the industry:

“The basic dyes supply the next series of milestones. I have always felt that it was a tragedy that these dyes, of still unsurpassed brilliant hues coupled with extreme fugitiveness, were discovered so early in the development of synthetic dyes. Their lack of fastness retarded the use of the then so-called “Anilines” for years, and provided the old-time dyers with a strong justification for their hostility and conservatism. The other misfortune was that these brilliant hues found their way into the textile designers’ studios, and were repeatedly sent to the dyers for reproduction in a fastness for which there were no comparable dyes. For example, Malachite Green was discovered in 1878, but the dyer had to wait until 1920 for Caledon Jade Green, which first enabled him to give with confidence a Jade Green hue suitable for soft furnishings and washing fabrics. Meantime dyers were compelled to write thousands of letters regretting inability to dye the hues requested. The leading basic dyes appeared in the following sequence—Magenta (1858), Methyl Violet (1866), Methylene Blue (1876), Malachite Green (1878), Auramine 0 (1883), whilst Rhodamine B followed in 1887 and Rhodamine 6G in 1892.”

When reviewing the extensive list of materials in the first edition of the CI, it is natural to wonder which materials were used in significant quantities, and most likely prevalent in museum collections. The CI was developed as a catalogue of all colourants, but only provides occasional information about popularity using qualitative terms such as ‘used extensively for…”. It is possible that many of the colourants were never used in significant quantities, while others achieved varying degrees of popularity. Some colourants are known to have had a period of success prior to their replacement by a new dye with improved properties and/or simplified production methods. An example is found in the history of the earliest synthetic green dyes. Cherpin created the first of value called aldehyde green in 1862, which was later displaced by Perkins green, iodine green, and methyl green. The CI notes the prior popularity for many of these dyes, as well as their replacement and ultimate obsolescence. Although limited quantitative data exists regarding the use of earliest synthetic dyes, valuable information is available from United States census data starting in 1913–1914. The following section provides an overview of data collected from government documents of the period.

**US imports and domestic production**

A resource for assessing general dye popularity is the US census data published in the early 20th century, at a time when there was significant pressure to boost domestic production and compete with manufacturers in Europe. The outbreak of World War I in July 1914 led to a severe disruption of the dye industry due to the broad reliance on supplies from Germany. This included finished products, as well as the large number of intermediates for dye manufacture. The issue was often described as the ‘dyestuff famine’ or ‘dyestuff crisis’ [34, 35], and short-lived attempts were made to return to traditional methods using natural dyes [36] with limited success. Commenting on the state of the US dye industry, Hesse [34] made the following observations in November 1914:

*At or about the end of 1912, 76 different chemical dyes were made in this country; today 100 such are made – in two years a 33 per cent increase; the United States market probably has no fewer than 900 different chemical dyes, each of them in active use, some of them to a very small extent, others to a very large extent and, no doubt, many of each of these could be eliminated and their places taken by others now on the market.*

At approximately the same time, the mystery regarding US dye imports was addressed by a commercial agent named Thomas H. Norton at the US Department of Commerce (Fig. 6). With careful planning to avoid the pitfalls experienced by similar efforts in Britain, Norton successfully conducted a census of imports for the 1913–1914 fiscal year [15]. His report included a large table of import quantities above 10,000 lb. (4536 kg), dollar values, commercial dye name, and Schultz number where available. These quantities were evaluated in the present study by converting the Schultz numbers to those of the first CI edition. Figure 7a shows the quantities reported by Norton versus CI number, with markers at the top indicating many of the chemical classes. The top-ten imported dyes are noted with labels on the peaks, and outlined in Table 1. Further information is provided in Appendix: Table 2, and the accompanying dataset [25]. Norton also catalogued dyes without a Schultz number; however, these only amounted to ~16% of the total import quantity (see
Appendix: Table 3 for those above 100,000 lb). The results of Fig. 7a provide a useful indication of which dyes were predominantly used in the US when domestic manufacturing was still maturing.

A related development from Norton’s census was the US Revenue Act of 1916. This led to the formation of the Tariff Commission, and enacted measures to temporarily support the US dyestuff industry through trade policy. As a means of tracking progress, an annual report was published by the Tariff Commission starting in 1918 (with 1917 data) called the Census of Dyes and Coal-Tar Chemicals. The report continued for several decades, with each issue summarising quantitative data regarding dye production and imports by chemical classification number (i.e. Schultz prior to 1924, followed by early CI#). For the current study, a review of these data was undertaken by tabulating production amounts from 1917 through the 1920’s. Conversion to first edition CI number also allowed cross-referencing with data summarised in the previous section. Figure 7b and c show imports and domestic production data respectively for 1920, where the log-scale highlights the large quantities of some dyes. Unlike Norton’s census, subsequent publications list amounts below 10,000 lb (not shown here); however, some domestic production data was withheld to maintain manufacturer privacy. A small group, particularly sulphur dyes, included production amounts but were not characterised by Schultz number.

Figure 8a presents US imports for the 1914 fiscal year versus the number of manufacturers listed in the first edition of the CI for the respective dyes. A similar plot is given in Fig. 8b, showing peak annual production for the period of 1917-1924 versus number of manufacturers. There is significant scatter in these data; however, the plots indicate a trend of increasing dye quantities with number of manufacturers. In both plots, data points circled in red indicate one of the 65 dyes in the Schweppe list [18]. Bracketed numbers in the legends give the number of points plotted for each series. For example, Fig. 8a shows 259 materials imported into the US in quantities greater than 10,000 lb, of which 43 are described by Schweppe. Dyes imported in large quantities, and not in Schweppe’s list, may be worth further examination if the CI describes applications relevant to heritage objects.

Disruption to the dye industry during WWI contributed to the United States domestically producing many of the dyes that were previously imported in significant quantities. Figure 9 explores this trend with a plot of the production and imports of dyes in the United States during 1920 versus 1914 imports (Norton’s census) for the corresponding materials. By 1920, approximately one third were produced in the US in quantities significantly larger than the prior 1914 imports. Some continued to be imported (41%); however, these were typically at much lower quantities. A small number (6%) were both imported and produced in the US during 1920, with production dominant.

A broader assessment of census data from 1917 through the 1920’s suggests that less than one quarter of the colourants in the CI were produced or imported in the United States in significant quantities during the period. In comparison, Norton’s census listed 259 colours with Schultz number imported in quantities above 10,000 lb (~ 21% of the CI) during the 1913–1914 fiscal year. Adding the list of domestic products (tabulated by Norton without quantities), and removing duplicates, gave 289 compounds with unique Schultz number that were imported and/or produced in the US. There were also several imports of unknown composition in Norton’s census: 96 azo, 23 sulphur, and 68 unclassified. This likely included duplicate counts of similar compounds. See Appendix: Table 3 for the small subset of undefined dyes imported in amounts over 100,000 lb. The overall findings emphasize that a subset of the CI list is worth greater attention for further analysis. It is also important to note that some applications of concern to heritage collections may have used colourants in relatively small amounts that are overshadowed by these general statistics.
Conclusions

Statistics of the early synthetic dye industry were reviewed by extracting colourant data from the CI including date of introduction, number of manufacturers, chemical class, and lightfastness. These parameters were plotted to show trends with respect to the number of dyes introduced over time, the rate of introduction, and the types of colourants from the mid-19th century to 1924. The number of manufacturers was shown as a potential indicator of popularity with values ranging from zero to more than 60 per colourant. Lightfastness data with ISO and AATCC ratings were summarised by cross-referencing between multiple editions of the CI. This was used to highlight the relationship between ISO and AATCC rating systems, and also the distribution of ISO lightfastness for 432 colourants listed in the 1st edition of the CI.

The analysis of CI data was followed by a review of United States census literature from 1914 through the 1920’s. In broad terms, census data suggested that less...
than a quarter of the colourants listed in the 1st edition of the CI were imported or produced in the US in significant amounts. Norton’s earlier census for 1913–1914 listed 259 colours with Schultz number imported to the US in quantities above 10,000 lb (~21% of the CI), and a total of 289 classified (Schultz #) compounds imported and/or produced. There were also several compounds of unknown composition in Norton’s census that made up ~16% of total imports: 96 azo, 23 sulphur, and 68 unclassified. Census data were further used to show the amounts of each colourant imported and produced in the US, which was then compared with the number of manufacturers. Comparisons were also made with the Schweppe list of synthetic dyes since it is frequently used as a reference for dye analysis. Several of the dyes on Schweppe’s list were imported or produced in significant quantities during the studied time period; however, the results highlight that many other products deserve further consideration.

Table 1  Top ten dyes imported into the United States in 1914

| Rank | Schultz # (1914) | CI # 1st ed. | CI # 2nd ed. | Generic Name | Class | ~Date Intro. | M | Imports lb x 10^3 |
|------|-----------------|-------------|-------------|-------------|-------|--------------|---|-----------------|
| 1    | 874             | 1177        | 73,000      | Vat Blue 1  | Indigoid | 1890         | 13 | 8507            |
| 2    | 720             | 978         | 53,185      | Sulphur Black 1 | Sulphur | 1896         | 23 | 5615            |
| 3    | 462             | 581         | 30,235      | Direct Black 38 | Trisazo | 1901         | 39 | 1238            |
| 4    | 333             | 401         | 22,590      | Direct Blue 2 | Disazo | 1890         | 32 | 606             |
| 5    | 842             | 1113        | 69,825      | Vat Blue 6    | Anthraquinone Vat | 1903 | 6  | 479             |
| 6    | 275             | 299         | 26,695 see also 26,750, 26,751 | Mordant Black 5 | Disazo | 1889         | 24 | 460             |
| 7    | 493             | 655         | 41,000; 41000B | Basic Yellow 2; Solvent Yellow 34 | Ketonimine | 1883 | 18 | 449             |
| 8    | 217             | 246         | 20,470      | Acid Black 1  | Disazo   | 1891         | 42 | 429             |
| 9    | 436             | 539         | 31,560      | Direct Black 9 | Trisazo | 1896         | 14 | 403             |
| 10   | 700             | 865         | 50,420      | Acid Black 2  | Azine | 1867         | 41 | 395             |

Schultz # (1914) is shown from source data, along with the conversions to first and second edition CI numbers. Approximate date of introduction and number of manufacturers are given from the 1st ed. of the CI.

Fig. 8  Imports and production of dyes in the United States versus the number of manufacturers listed in the Colour Index for each colourant: a imports during the 1914 fiscal year, b peak annual production reported during the period of 1917–1924.
To support research related to the history and preservation of heritage collections, a compilation of the tabulated values is provided as an open dataset [25]. In our ongoing work, this information provides a tool for selecting specific samples of interest for chemical analysis and lightfastness testing using a set of criteria: introduced 1870 and earlier (empirical period); produced or imported in large quantities (≥ 100,000 lb/yr); having a large number of manufacturers listed in the CI (M ≥ 15); or historically significant. Appendix: Table 2 provides a summary of colourants meeting these criteria, while the dataset [25] allows anyone to generate a custom list based on parameters of interest.

In parallel to the work described here, a list of available period samples was tabulated from trade books and dying texts (i.e. commercial name, and manufacturer where available). This was cross-referenced with the first edition of the Colour Index to verify the CI# where possible, and then pick the target samples of interest for analysis. At the present time, over 100 samples have been studied for the effects of light exposure with a custom fadometer, and chemical markers using gas chromatography-mass spectrometry (GC-MS). The goal is to provide an open database for researchers to explore the results, and build upon in future work. Finally, the samples with and without light damage are catalogued and stored for possible analysis with other analytical techniques.

**Appendix**

Table 2 gives a summary of dyes in the first edition of the CI [16] that meet one or more of the following criteria: (a) introduced 1870 or earlier; (b) imported or produced in quantities of 100,000 lb/yr or more (1914–1924); (c) having 15 or more manufacturers listed in the CI. Matches for each criterion are emphasised in bold and underlined for clarity. A question mark in the column of peak annual US production (1917–1924) indicates that the dye was produced in at least one reporting period; however, the quantity was withheld for manufacturer privacy. This list of dyes is also supplemented with some materials of known relevance or historical significance that are not already captured: e.g. the first sulphur dye (CI 933), and early dyes without CI number (aldehyde green, aldehyde blue). Additionally, cross-referencing with the Schweppe list [18] of important early synthetic dyes showed a near match for Mordant Red 3 (CI 1034): introduced ~ 1871, with nearly 82,000 lb imported to the US in 1914. The dye was added to the table in consideration of these factors.
Table 2  List of dyes fulfilling selection criteria based on date of introduction (≤ 1870), number of manufacturers (≥ 15), US imports and production (≥ 100,000 lb/yr), or other significance

| Cl# [1st ed.] [16] | Cl Constitution # [21] | Cl Generic Name [21] | Chemical Class [16] | Approx. Date of Introduction [16] | Manufacturers [16] | US imports, Lb x 10^6 [13-14] [15] | US imports, Lb x 10^6 [13-20] | US imports, Lb x 10^6 [15-20] | Peak US Production, Lb x 10^6 [15-20] [21-24] | Schweppe Listed [18] |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 2               | 10005           | Mordant Green 4 | Nitroso         | 1875            | 17             | -               | -               | Y               | -               | -               | N               |
| 5               | 10020           | Acid Green 1    | Nitroso         | 1885            | 19             | 0.500           | 45.9            | N               | -               | -               | Y               |
| 7               | 10305           | Nitro           | Nitro           | 1850            | 12             | -               | -               | Y               | -               | -               | N               |
| 8               | 10310           | Nitro           | Nitro           | 1869            | 1              | -               | -               | N               | -               | -               | N               |
| 9               | 10315           | Acid Yellow 24  | Nitro           | 1856            | 24             | -               | -               | Y               | -               | -               | Y               |
| 10              | 10316           | Acid Yellow 1; Food Yellow 1 | Nitro | 1879 | 43 | 250 | - | 44.5 | Y |
| 15              | 11000           | Solvent Yellow 1 | Monomazo        | 1863            | 20             | -               | -               | 52.3            | N               | -               | N               |
| 16              | 13015           | Acid Yellow 9   | Monomazo        | 1877            | 22             | 36.0            | 8.38            | 7.3             | N               | -               | Y               |
| 17              | 11160; 37210    | Solvent Yellow 3; Azoic Diazo Component 4 | Monomazo | 1877 | 19 | - | - | 48.1 | N |
| 19              | 11200           | Solvent Yellow 2 | Monomazo        | 1876            | 16             | -               | -               | 101             | N               | -               | N               |
| 20              | 11270; 112708   | Basic Orange 2; Solvent Orange 3 | Monomazo | 1875 | 51 | 63.3 | - | 986 | Y |
| 21              | 11320; 113208   | Basic Orange 1; Solvent Orange 4 | Monomazo | 1877 | 31 | 106 | 3.31 | 211 | N |
| 23              | 11920           | Solvent Orange 1 | Monomazo        | 1876            | 20             | -               | -               | 117             | N               | -               | N               |
| 24              | 12055           | Solvent Yellow 14 | Monomazo       | 1883            | 36             | -               | -               | 117             | N               | -               | N               |
| 26              | 15970           | Solvent Yellow 12 | Monomazo       | 1878            | 28             | 11.4            | 96.6            | Y               | -               | -               | N               |
| 27              | 16230           | Acid Orange 10; Food Orange 4 | Monomazo | 1878 | 24 | 48.5 | 10.3 | 124 | Y |
| 28              | 16100           | Acid Orange 14  | Monomazo        | 1878            | 19             | -               | -               | Y               | -               | -               | N               |
| 30              | 17200           | Acid Red 33; Food Red 12 | Monomazo | 1890 | 15 | - | - | 30.7 | Y |
| 31              | 18050           | Acid Red 1      | Monomazo        | 1902            | 26             | -               | 7.03            | 218             | Y               | -               | Y               |
| 36              | 14025           | Mordant Yellow 1 | Monomazo        | 1887            | 29             | 145             | -               | 2233            | Y               | -               | N               |
| 40              | 14030           | Mordant Yellow 1 | Monomazo        | 1885            | 39             | 96.5            | 1.20            | 386             | N               | -               | N               |
| 53              | 16580           | Acid Violet 3   | Monomazo        | 1891            | 16             | 47.1            | 11.8            | 173             | N               | -               | Y               |
| 56              | 16600           | Acid Violet 6   | Monomazo        | 1890            | 5              | -               | -               | 108             | N               | -               | N               |
| 57              | 18055           | Acid Violet 7   | Monomazo        | 1902            | 18             | 36.0            | 0.100           | 143             | Y               | -               | N               |
| 63              | 16010; 16011    | Acid Orange 16  | Monomazo        | 1879            | 15             | 21.5            | -               | ?               | N               | -               | N               |
| 69              | 12120           | Pigment Red 3   | Monomazo        | 1905            | 17             | 49.7            | -               | ?               | N               | -               | N               |
| 73              | 12140           | Solvent Orange 7 | Monomazo        | 1883            | 24             | -               | 2.21            | 171             | N               | -               | N               |
| 78              | 16020           | Acid Orange 17  | Monomazo        | 1879            | 23             | -               | 0.500           | 18.9            | N               | -               | N               |
| 79              | 16150           | Acid Red 26     | Monomazo        | 1878            | 40             | 21.0            | 1.92            | 1285            | Y               | -               | N               |
| 81              | 12020           | Solvent Brown 5 | Monomazo        | 1878            | 18             | -               | -               | ?               | N               | -               | N               |
| 82              | 12170           | Solvent Red 4; Pigment Red 40 | Monomazo | 1902 | 20 | - | 0.500 | ? | N |
| 88              | 16180           | Acid Red 17     | Monomazo        | 1878            | 41             | 24.7            | 16.5            | 224             | Y               | -               | N               |
| 89              | 16250           | Acid Red 44     | Monomazo        | 1883            | 12             | -               | 0.351           | -               | Y               | -               | Y               |
| 101             | see 11270, 11330, 11335 | Monomazo        | 1898            | 12             | -               | -               | 474             | N               | -               | N               |
| 135             | 12210           | Basic Blue 16   | Monomazo        | 1886            | 16             | 15.4            | 0.055           | Y               | -               | N               |
| 138             | 13065           | Acid Yellow 36  | Monozzo         | 1879            | 35             | 285             | 23.8            | 629             | Y               | -               | N               |
| 142             | 13025           | Acid Orange 52  | Monozzo         | 1875            | 15             | -               | -               | 7               | -               | -               | N               |
| 143             | 13080           | Acid Orange 5   | Monozzo         | 1876            | 36             | 11.2            | 12.0            | Y               | -               | -               | N               |
| 145             | 13090           | Acid Orange 1   | Monozzo         | 1880            | 22             | 39.3            | 10.4            | -               | Y               | -               | N               |
| 146             | 13096           | Monozzo         | 1880            | 31             | 90.5            | 20.1            | 138             | N               | -               | N               |
Table 2 (continued)

| 148 | 14270 | Acid Orange 6 | Monoazo | 1875 | 28 | - | - | ? | Y |
| 150 | 14600 | Acid Orange 20 | Monoazo | 1876 | 24 | - | 1.32 | 29.0 | Y |
| 151 | 15510 | Acid Orange 7 | Monoazo | 1876 | 58 | 128 | 2.30 | 850 | Y |
| 161 | 15575 | Acid Orange 8 | Monoazo | 1887 | 20 | 90.2 | - | 88.8 | N |
| 163 | 15850 | Pigment Red 57 | Monoazo | 1903 | 4 | 101 | 22.6 | 68.4 | N |
| 165 | 15585 | Pigment Red 53 | Monoazo | 1902 | 5 | - | 30.8 | 161 | N |
| 170 | 16500 | Mordant Black 9 | Monoazo | 1902 | 6 | 285 | 2.80 | ? | N |
| 176 | 15620 | Acid Red 88 | Monoazo | 1877 | 62 | 46.4 | - | 434 | Y |
| 179 | 14720 | Acid Red 14; Food Red 3 | Monoazo | 1883 | 44 | 231 | 15.1 | 527 | N |
| 180 | 14835 | Acid Red 12 | Monoazo | ? | 10 | 20.1 | - | 206 | N |
| 182 | 16045 | Acid Red 13 | Monoazo | 1878 | 26 | - | - | ? | Y |
| 184 | 16185 | Acid Red 27; Food Red 9 | Monoazo | 1878 | 40 | 85.5 | 9.86 | 294 | Y |
| 185 | 16255 | Acid Red 18 | Monoazo | 1878 | 32 | 30.0 | - | 289 | Y |
| 189 | 15630 | Pigment Red 49 | Monoazo | 1899 | 8 | 282 | 0.220 | 353 | N |
| 193 | 15640 | Acid Red 10 | Monoazo | 1882 | 9 | 209 | - | ? | N |
| 195 | 14095 | Mordant Yellow 3 | Monoazo | 1890 | 23 | 124 | 15.9 | 94.2 | N |
| 202 | 15705 | Mordant Black 17 | Monoazo | 1903 | 29 | 243 | 19.2 | 1523 | N |
| 203 | 14645 | Mordant Black 11 | Monoazo | 1904 | 11 | 130 | 87.2 | 303 | N |
| 204 | 15710 | Mordant Black 1 | Monoazo | 1904 | 12 | 96.6 | 87.3 | 587 | N |
| 208 | 13390 | Acid Blue 92 | Monoazo | 1897 | 11 | 45.0 | 8.62 | 554 | N |
| 216 | 16105 | Mordant Red 9; Pigment Red 60 | Monoazo | ? | 13 | - | 1.75 | 107 | N |
| 234 | 20170 | Acid Orange 24 | Disazo | 1881 | 20 | 13.2 | 5.24 | 169 | N |
| 241 | 20350 | Acid Black 17 | Disazo | 1891 | 5 | 291 | - | ? | N |
| 246 | 20470 | Acid Black 1 | Disazo | 1891 | 42 | 429 | 6.67 | 2609 | Y |
| 248 | 26100 | Solvent Red 23 | Disazo | 1879 | 24 | - | - | ? | N |
| 252 | 27290 | Acid Red 73 | Disazo | 1882 | 19 | 123 | 3.06 | 158 | Y |
| 258 | 26105 | Solvent Red 24 | Disazo | ? | 23 | - | - | 41.4 | N |
| 262 | 27200; see also 27201 | Acid Red 115 | Disazo | 1879 | 15 | 13.2 | 0.550 | 51.8 | Y |
| 280 | 26905 | Acid Red 66 | Disazo | 1879 | 17 | 36.6 | 2.34 | 74.2 | N |
| 289 | 26400 | Acid Blue 120 | Disazo | 1892 | 19 | 146 | 114 | 481 | N |
| 299 | 26695; see also 26750 and 26751 | Mordant Black 5 | Disazo | 1889 | 24 | 460 | 13.7 | 223 | N |
| 307 | 26370 | Acid Black 24 | Disazo | 1902 | 10 | 69.6 | 2.40 | 150 | N |
| 308 | 26300 | Acid Black 7 | Disazo | 1888 | 18 | 152 | - | 43.0 | N |
| 311 | 27740 | Acid Red 3 | Disazo | 1885 | 12 | 168 | - | ? | N |
| 317 | 27725 | Direct Blue 132 | Disazo | 1893 | 1 | 306 | 17.3 | ? | N |
| 326 | see 29150-29230 | | Disazo | 1900 | 7 | 36.7 | 19.9 | 188 | N |
| 331 | 21000 | Basic Brown 1 | Disazo | 1863 | 47 | 27.6 | 0.114 | 334 | Y |
| 332 | 21010 | Basic Brown 4 | Disazo | 1878 | 37 | 171 | - | 673 | N |
| 364 | 24890 | Direct Yellow 4 | Disazo | 1886 | 19 | 277 | 0.250 | 91.2 | Y |
| 365 | 24895 | Direct Yellow 12 | Disazo | 1886 | 31 | 148 | 23.8 | 308 | N |
| 370 | 22120 | Direct Red 28 | Disazo | 1884 | 41 | 12.0 | 10.1 | 1503 | Y |
| 375 | 22145 | Direct Red 10 | Disazo | 1886 | 25 | 39.7 | - | 243 | N |
| 376 | 22150 | Direct Red 17 | Disazo | 1891 | 17 | 46.1 | 6.20 | ? | N |
| 394 | 22570 | Direct Violet 1 | Disazo | 1889 | 29 | 13.1 | - | 92.5 | N |
| 401 | 22590 | Direct Blue 2 | Disazo | 1890 | 32 | 606 | 71.2 | 905 | N |
| 406 | 22610 | Direct Blue 6 | Disazo | 1890 | 48 | 19.0 | 1.10 | 1790 | N |
| 410 | 22250 | Direct Yellow 1 | Disazo | 1884 | 26 | - | - | 54.3 | N |
| 415 | 22130 | Direct Orange 8 | Disazo | 1887 | 16 | - | 1.20 | 96.5 | N |
| Nr. | Code   | Type            | Solvent | Lambda (nm) | E (cm⁻¹) | S (cm³/mol) | T (°C) |
|-----|--------|-----------------|---------|-------------|----------|-------------|--------|
| 419 | 22310  | Direct Red 1    | Diazo   | 1889        | 35       | 47.7        | 14.1   |
| 420 | 22311  | Direct Brown 2  | Diazo   | 1889        | 32       | 53.7        | -      |
| 446 | 23370  | Direct Orange 10| Diazo   | 1886        | 20       | 19.9        | -      |
| 448 | 23500  | Direct Red 2    | Diazo   | 1884        | 42       | 342         | 10.5   |
| 461 | 23520  | Direct Violet 21| Diazo   | 1885        | 16       | -           | -      |
| 472 | 23710  | Direct Blue 21  | Diazo   | 1890        | 20       | -           | 92.2   |
| 477 | 23850  | Direct Blue 14  | Diazo   | 1890        | 30       | -           | 1.10   |
| 478 | 23880  | Direct Orange 7 | Diazo   | 1888        | 21       | 55.6        | 3.81   |
| 495 | 24100  | Direct Red 7    | Diazo   | 1885        | 26       | 47.7        | 4.30   |
| 502 | 24140  | Direct Blue 8   | Diazo   | 1885        | 29       | 78.3        | 3.07   |
| 512 | 24280  | Direct Blue 22  | Diazo   | 1894        | 9        | 15.2        | 1.46   |
| 518 | 24410  | Direct Blue 1   | Diazo   | 1891        | 23       | 117         | 48.9   |
| 520 | 24400  | Direct Blue 15  | Diazo   | 1890        | 35       | 12.9        | 7.51   |
| 539 | 31560  | Direct Black 9  | Triazo  | 1896        | 14       | 403         | 38.0   |
| 553 | 31820  | Direct Black 7  | Triazo  | 1896        | 2        | 146         | -      |
| 575 | 31940  | Direct Black 5  | Triazo  | 1893        | 3        | 144         | -      |
| 576 | 31955  | Direct Blue 30  | Triazo  | 1890        | 2        | 100         | 0.300  |
| 581 | 30235  | Direct Black 38 | Triazo  | 1901        | 39       | 1238        | -      |
| 582 | 30245  | Direct Black 4  | Triazo  | 1901        | 24       | 249         | -      |
| 593 | 30295  | Direct Green 6  | Triazo  | 1891        | 43       | 76.6        | 33.3   |
| 594 | 30315  | Direct Green 8  | Triazo  | 1891        | 31       | -           | 11.6   |
| 596 | 30045  | Direct Brown 1  | Triazo  | 1890        | 16       | 17          | -      |
| 598 | 30140  | Direct Brown 6  | Triazo  | 1888        | 15       | 48.7        | -      |
| 606 | 35005  | Direct Brown 44 | Polyazo | 1887        | 7        | 41.9        | 17.7   |
| 620 | 40000  | Direct Yellow 11| Stilbene| 1883        | 35       | 222         | 0.841  |
| 621 | 40015; 40002| Direct Orange 15| Stilbene| 1888        | 22       | 24.7        | -      |
| 622 | 40006  | Direct Yellow 6 | Stilbene| 1886        | 16       | 85.1        | -      |
| 636 | 18820  | Acid Yellow 11  | Pyrazolone| 1892       | 11       | 33.5        | 56.6   |
| 640 | 19140  | Acid Yellow 23; Food Yellow 4 | Pyrazolone| 1884       | 25       | 266         | 133    |
| 655 | 41000; 41000| Basic Yellow 2; Solvent Yellow 34 | Ketonimine| 1883       | 18       | 449         | 127    |
| 657 | 42000; 42000| Basic Green 4; Solvent Green 1 | Triphenylmethane| 1878       | 32       | 179         | 2.04   |
| 662 | 42040  | Basic Green 6   | Triphenylmethane| 1879       | 24       | 73.9        | 3.30   |
| 670 | 42095  | Acid Green 5; Food Green 2 | Triphenylmethane| 1879       | 18       | 71.4        | 12.2   |
| 677 | 42510; 42510| Basic Violet 14; Solvent Red 41 | Triphenylmethane| 1856       | 36       | 87.1        | 2.09   |
| 679 | 42530  | Triphenylmethane| Triphenylmethane| 1863       | 12       | -           | 1.05   |
| 680 | 42535; 42535| Basic Violet 1; Solvent Violet 8 | Triphenylmethane| 1864       | 35       | 255         | 3.23   |
| 683 | 42536  | Basic Violet 13 | Triphenylmethane| 1866       | 17       | 22.4        | 0.095  |
| 684 | 42585  | Basic Blue 20   | Triphenylmethane| 1871       | 5        | -           | -      |
| 685 | 42590  | Triphenylmethane| Triphenylmethane| 1866       | 4        | -           | -      |
| 686 | 42556  | Triphenylmethane| Triphenylmethane| 1866       | 0        | -           | -      |
| 687 | 42515  | Triphenylmethane| Triphenylmethane| 1860       | 2        | -           | -      |
| 688 | 42760  | Solvent Blue 23 | Triphenylmethane| 1866       | 5        | -           | -      |
| 689 | 42775  | Solvent Blue 3  | Triphenylmethane| 1861       | 21       | 50.6        | -      |
| 692 | 42685  | Acid Violet 19  | Triphenylmethane| 1877       | 22       | 19.1        | 4.85   |
| 698 | 42650  | Acid Violet 17  | Triphenylmethane| 1890       | 21       | 154         | 45.2   |
| 703 | 42765  | Acid Blue 119   | Triphenylmethane| 1862       | 15       | -           | -      |
| 704 | 42750  | Acid Blue 110   | Triphenylmethane| 1862       | 29       | 287         | 65.4   |
| 705 | 42770  | Acid Blue 48    | Triphenylmethane| 1862       | 16       | 31.5        | 1.82   |
| 706 | 42780  | Acid Blue 93    | Triphenylmethane| 1862       | 18       | 45.0        | 2.15   |

Table 2 (continued)
|   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|
| 707 | 42755 | Acid Blue 22 | Triphenylmethane | 1862 | 81 | 86.5 | 6.72 | 98.8 | N |
| 712 | 42051 | Acid Blue 3 | Triphenylmethane | 1888 | 14 | 129 | 45.5 | ? | N |
| 724 | 43800 | Triphenylmethane | 1834 | 3 | 1.46 | ? | N |
| 725 | 43875 | Triphenylmethane | 1835 | 0 | - | - | - | N |
| 728 | 44040 | Basic Blue 11 | Triphenylmethane | 1882 | 10 | 110 | 0.007 | ? | Y |
| 736 | 44095 | Acid Blue S7 | Triphenylmethane | 1895 | 3 | 174 | 4.18 | ? | N |
| 737 | 44090 | Acid Green 50 | Triphenylmethane | 1883 | 16 | 44.9 | 342 | 376 | N |
| 749 | 45170 | Basic Violet 10 | Xanthene | 1887 | 20 | 58.3 | 20.3 | ? | Y |
| 766 | 45350 | Acid Yellow 73 | Xanthene | 1871 | 17 | 0.725 | 2.4 | Y |
| 768 | 45380 | Acid Red 87 | Xanthene | 1871 | 23 | 94.5 | 0.209 | 161 | Y |
| 771 | 45430 | Acid Red 91 | Xanthene | 1875 | 17 | 17.5 | ? | - | N |
| 773 | 45430 | Acid Red 51; Food Red 14 | Xanthene | 1876 | 17 | - | - | 7.3 | Y |
| 793 | 46045 | Basic Orange 15 | Acridine | 1863 | 21 | 155 | 126 | 123 | N |
| 801 | 47005 | Acid Yellow 3 | Quinoline | 1882 | 16 | 15.3 | 76.5 | 51.2 | Y |
| 806 | Quinoline | 1856 | 7 | - | - | - | N |
| 812 | 49000 | Direct Yellow 59 | Thiazole | 1887 | 26 | 56.2 | 33.1 | 271 | N |
| 813 | 19540 | Direct Yellow 9 | Thiazole | 1887 | 15 | 29.9 | 22.6 | 3.5 | N |
| 814 | 19550 | Direct Yellow 28 | Thiazole | 1887 | 23 | 125 | 25.9 | 230 | N |
| 821 | 49700 | Indophenol | 1883 | 1 | - | - | 137 | N |
| 841 | 50240 | Basic Red 2 | Azine | 1859 | 35 | 59.9 | 2.61 | 150 | Y |
| 846 | 50245 | Azine | 1856 | 7 | 0.057 | - | Y |
| 857 | 50275 | Basic Red 6 | Azine | 1858 | 1 | - | - | - | N |
| 860 | 50400 | Solvent Blue 7 | Azine | 1863 | 28 | 25.3 | - | 436 | N |
| 861 | 50420 | Acid Black 2 | Azine | 1867 | 39 | 218.8 | - | 104 | N |
| 864 | 50415; 50415B | Solvent Black 5; Solvent Black 7 | Azine | 1897 | 44 | 187 | 0.220 | 310 | N |
| 865 | 50420 | Acid Black 2 | Azine | 1867 | 41 | 295 | 0.250 | 743 | Y |
| 870 | 50440 | Oxidation Base 1; Pigment Black 1 | Aniline Black | 1836 | 1 | - | - | - | N |
| 875 | see 76000 | Oxidation Base 10 | Aniline Black | 1888 | 15 | 33.7 | 0.300 | 168 | N |
| 883 | 51030 | Mordant Blue 10 | Oxazine | 1881 | 42 | - | 73.3 | 426 | N |
| 909 | 51175 | Basic Blue 5 | Oxazine | 1879 | 26 | 32.5 | 12.9 | 58.3 | N |
| 922 | 52015 | Basic Blue 5 | Thiazine | 1876 | 22 | 186 | 10.2 | 377 | Y |
| 933 | 33210; 53000 | Sulphide | 1873 | 8 | 1.5 | - | N |
| 969 | 53630 | Vat Blue 43 | Sulphide | 1908 | 3 | 233 | 141 | - | - |
| 978 | 53185 | Sulphur Black 1 | Sulphide | 1896 | 23 | 5615 | - | 16305 | N |
| 1016 | 55005 | Hydroxyketone | 1823 | 1 | - | - | - | N |
| 1019 | 57010 | Mordant Black 37 | Hydroxyketone | 1861 | 3 | 198 | 14.5 | - | N |
| 1027 | 58000 | Mordant Red 11; Pigment Red 83 (lake) | Anthraquinone | 1868 | 10 | 202 | 348 | ? | Y |
| 1034 | 58005 | Mordant Red 3 | Anthraquinone | 1871 | 6 | 81.9 | 34.2 | ? | Y |
| 1035 | 58200 | Mordant Brown 42 | Anthraquinone | 1877 | 14 | 110 | 16.7 | 157 | N |
| 1043 | 58220 | Anthraquinone | 1865 | 0 | - | - | - | N |
| 1052 | 58600 | Anthraquinone | 1833 | 1 | - | - | 0 | N |
| 1054 | 63010 | Acid Blue 45 | Anthraquinone | 1897 | 12 | 55.4 | 309 | N |
| 1062 | 58605 | Mordant Blue 32 | Anthraquinone | 1891 | 4 | 108 | 234 | 56.5 | N |
| 1066 | 67410 | Anthraquinone | 1877 | 6 | 319 | 8.50 | 0 | N |
| 1067 | 67415 | Mordant Blue 27 | Anthraquinone | 1891 | 6 | 112 | 38.8 | 0 | N |
| 1069 | 67425 | Anthraquinone | 1890 | 1 | 230 | - | 0 | N |
| 1070 | 67430 | Anthraquinone | 1890 | 1 | 260 | 2.00 | 0 | N |
| 1071 | Anthraquinone | 1888 | 2 | 135 | 23.2 | 0 | N |
| 1107 | Anthraquinone Vat | 1901 | 0 | 187 | 9.68 | 7 | N |
| 1113 | 69825 | Vat Blue 6 | Anthraquinone Vat | 1903 | 6 | 479 | 367 | ? | N |
| 1177 | 72000 | Vat Yellow 1 | Indigo | 1890 | 13 | 8507 | - | 28347 | N |
| 1180 | 73015 | Acid Blue 74; Food Blue 1 | Indigo | 1890 | 12 | 19.3 | 4.53 | 1877 | Y |
| 1184 | 73065 | Vat Blue 5 | Indigo | 1907 | 8 | 16.9 | 299 | ? | N |
| 1222 | 73620 | Indigo | 1906 | 1 | 19.8 | 190 | 0 | N |
| - | - | Aldehyde Green [14] | Triphenylmethane | 1862 | - | - | - | N |
| - | - | Aldehyde Blue [17] | Triphenylmethane | 1861 | - | - | - | N |

Underlined bold values indicate matches to the selection criteria

*CII#870 may also be CII# 871 (from Schultz # 922 in source data); CII# 969 may also be CII# 970 or 971 (from Schultz # 748 in source data)
Table 3 US dye imports in 1914 [15] exceeding 100,000 lb, without Schultz number

| Product Name                  | Import Qty. | Category          |
|-------------------------------|-------------|-------------------|
| Benzo Fast Black L.           | 100         | Unidentified azo  |
| Oxy Diamine Black (V. M.)     | 147         | Unidentified azo  |
| Oxy Diaminogen (V. M.)        | 139         | Unidentified azo  |
| Cotton Black (V. M.)          | 300         | Unidentified azo  |
| Lake Red (V. M.)              | 349         | Unidentified azo  |
| Zambesi Black (V. M.)         | 629         | Unidentified azo  |
| Wool Black (V. M.)            | 119         | Unidentified      |
| Amine Black (V. M.)           | 146         | Unidentified      |
| Black (V. M.)                 | 139         | Unidentified      |

V.M. indicates ’various markings’ (e.g. 2B, BB etc)

For further comparison, Table 3 provides a supplementary list of ambiguous dyes that were listed in Norton’s 1914 census [15] with import quantities above 100,000 lb. Six dyes were categorised as unidentified azo materials, while the remaining three were of unknown chemical class.

Abbreviation
CI: Colour Index.

Authors’ contributions
EH compiled the dataset used in this study, and drafted the manuscript. JP provided significant input through edits and revisions. Both authors worked on the interpretation of data, and the selection criteria for targeted analysis of colourants in future work. All authors read and approved the final manuscript.

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Availability of data and materials
The dataset generated and analysed during the current study is available in the Harvard Dataverse repository, https://doi.org/10.7910/DVN/BK2CBX [25].

Competing interests
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