Indian Journal of History of Science (2022) 57:330–334
https://doi.org/10.1007/s43539-022-00059-9

HISTORICAL NOTE

Journey of natural pigments from ancient antiquity to present: Insights on sustainable development

Shrabana Sarkar[1] · Dilnawaz Khatun[1] · Bhramar Dutta[1] · Rajib Bandopadhyay[1]

Received: 12 February 2022 / Accepted: 16 September 2022 / Published online: 11 October 2022

Abstract
This review discusses the use of natural colours in artwork, textile, culture etc. throughout the historical time and their prospective future. The colourful artworks play an important role, as pigment makes paintings vibrant and portrays symbolic meaning of human cultures throughout the world. In primordial times, only natural pigments isolated from different sources (like plants, animals) and minerals were used. From late nineteenth century, the extensive use of synthetic colorants started, which were proved to be hazardous for the environment. In recent times, natural colorants from pigmented bacteria becomes a promising source of eco-friendly colours in terms of sustainable development.

Keywords Artwork · History · Natural colours · Textile

1 Introduction

Colours have important character to make differences in cultures all over the world. Human beings have intrinsic urge to leave footprints about their daily lifestyles, cultures in the form of artworks (Barnett et al., 2006). History of arts mainly focuses on thoughts of human for aesthetic purposes. It often describes the chronology of cultures during each evolution. The application of colours in arts plays an important role as it makes paintings vibrant and portrays symbolic meaning of human culture. Colours were heavily involved in architectural expansion of Greek and ancient Egypt, which proves the practices of symbolism. The use of ancient purple-dye in crafts of the Roman Kingdom proves the cultural importance of natural pigments in the aspect of production and application techniques of the natural dye (Yusuf et al., 2017). On the other hand, the use of colours also changes the impact of art in terms of visual senses of viewers'. The colour palette of ancient Egypt was more graceful than Stone Age. Likewise, the Renaissance colour palette was much more elegant in terms of new dimensions and portraiture than that of ancient Rome and Greece. As an example, it can be stated that, Chauvet paintings were monochromatic whereas paintings at Lascaux and Altamira were vivid and polychromatic because of different colours. Therefore, it can be concluded that evolution of colours played an important in role in symbolisation of cultures as well as better visualisation.

It has been found that first use of colours started long back in Paleolithic era (Stone Age). The chronological studies have shown that in Prehistoric era (cave paintings mainly) earth minerals or ochre were used as source of natural colours followed by plants and animals. For example, there were two types of red pigments, plant (madder) and animal originated. Until late sixteenth century, animal originated red dyes from kermes insect, cochineal insects, Polish and Armenian were most popular. The animal based lac red dye from insect (*Laccifer lacca*) was common in Persian carpets, while the Turkish carpets were dyed using madder plant (*Rubia tinctoria*) based red dye. Red dye was also extracted from bark juices of *Caesalpinia*, sandal tree as well as dragon's blood (Abdel-Kareem, 2012). Yellow dyes, only extracted from plants, were one of the largest groups of natural pigments. These days, most expensive natural source of yellow pigment is saffron, also previously cited in the Bible (Siva, 2007). Like red dye, blue dye was used to be extracted from both plants (Indigo and Woad) and animal (from Murex mollusc) (Abdel-Kareem, 2012).

The natural colours are eco-friendly, non-hazardous and also provides elegant coloration with number of hues.

✉ Rajib Bandopadhyay
rajibindia@gmail.com

[1] UGC-Center of Advanced Study, Department of Botany, The University of Burdwan, Golapbag, Bardhaman, West Bengal 713104, India

Mauveine, the first synthetic dye was accidentally produced by Perkin in Germany in the year 1856 and this initiation led to rapid decline of natural pigments within a century (Siva, 2007). The preference for natural pigment increased at the time of green movement in late 1960s, after realisation about harmful, detrimental, allergic, and carcinogenic effects of synthetic colorants (Sarkar et al., 2017). The extraction of natural colours from raw materials saved time and extra expense for their art (Kanungo et al., 2020). The most advantageous properties of natural dyes are their non-allergic, non-toxic, bio-friendly nature unlike synthetic azo dyes. They can be classified in two types; adjective yes (require mordants) and substantive dyes (does not require mordants). The common mordants that are used for stabilisation of colourants are iron and tin. The variation in types and amount of mordants in either same (polygenetic type natural dye) or different dyes can create wide range of new colours (Křížová, 2015). The shades created by natural colorants are also shimmering, soft and comfortable to human eyes. Many plants, from which dyestuffs can be extracted, thrive on wasteland. Therefore, wasteland utilisation is an additional merit of natural dyes. Using of natural pigments are appropriate to protect the traditional art made up of natural pigments from ancient textile, museum painting now being restored and conserved by the archaeological departments (Křížová, 2015). The application of natural pigments from ancient antiquity towards future has been described in time scale in Fig. 11.

2 Natural palette of the cave artists in prehistoric era

In very beginning artists used natural objects present in surroundings to make colourful paintings. When the primitive people took shelter in the cave to save themselves from natural disasters, they used to paint on the wall of caves about their lifestyles. They mainly used water soluble colouring agents which were easily accessible; therefore, colour palette of cave artists in Prehistoric era was natural. The geometrical designs in the Blombos Cave, South Africa (about 70,000 years old), Avignon in France (more than 30,000 years old), were painted by different coloured ochre (red, black, yellow), earth pigments etc. (Barnett et al., 2006). Other than this, different plant derived and earth stone based fundamental colours were used in cave paintings during 30,000–12,000 BCE (before Christ). As an example, the crushed berries were used as source of mud colour to paint on rocks (Siva, 2007). The chemical analysis of cave paintings done by Palaeolithic artists at Lascaux (France) and Altamira (Spain) confirms the types of major colours which were mostly mineral based natural pigments like manganese oxides and iron. Earth brown (goethite), yellow (haematite and goethite), black (manganese), warm shades of red (iron-rich ochre) were proven to be predominant part of rock paintings found in first discovered Altamira cave (Spain, 34,000–15,000 BCE) (Robb, 2020). The remnants from excavation at Harappa and Mohenjo-Daro (Indus Valley Civilization), paintings in Ajanta caves, are evidences for use of plant based natural dyes like Madder (root of *Rubia tinctorum*), Henna (leaves of *Lawsonia inermis*), Indigo (leaves of *Indigofera* spp.) etc. (Yusuf et al., 2017). Three fundamental dyes which were largely found in cave

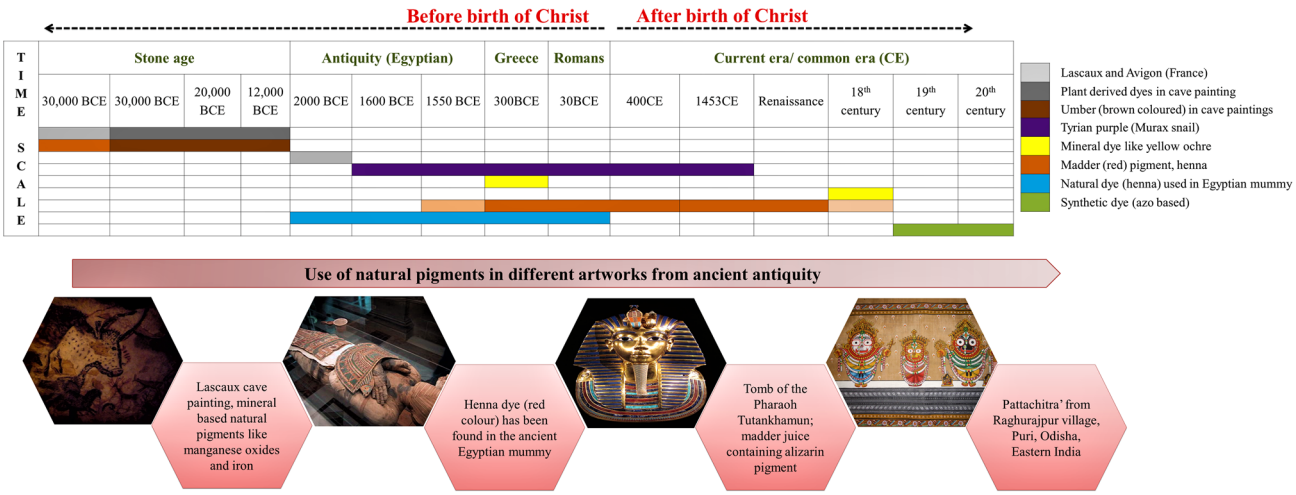

Fig. 1 Historical time scale of natural colour in artworks and culture

paintings were red, black and yellow, along with different intermediate shades. Astonishingly, there was no trace of white colour which is now one of the common pigments used by artists. At Lascaux, natural colour of the rock was used as a pale background, whereas, in some Prehistoric paintings of Africa white colour was found to be used (Lambourne and Strivens, 1999).

3 History of natural dye in era of Egyptian–Romanian culture

The colour palette of ancient Egypt was more graceful than that of Stone Age. The Egyptians were cognisant as they outshined in weaving for inscription, the garments of Gods along with bandages for the dead persons. The plant as well as mineral based dyes were widely used in ancient textile of Egypt (Yusuf et al., 2017). A cloth fragment, found in the tomb of the Pharaoh Tutankhamun, was dyed using madder juice containing alizarin (red) pigment (Sharma & Jain, 2013; Yusuf et al., 2017). Different natural dyes were in practice like purple colour (archil), derived from some marine algae originated on the rocks of Mediterranean Sea; red colour (alkanet) extracted from root of *Rubia tinctorum* and *Alkanna tinctoria*; indigo from the leaves of *Indigofera* spp. (Yusuf et al., 2017). Malachite, probably the oldest known green pigment, was first discovered in ancient Egyptian paintings (Barnett et al., 2006). The oldest probable record of use of henna (*Lawsonia inermis*) dye (red colour) had been found in the ancient Egyptian mummy which helped to preserve it for thousand years like the cave arts of Prehistoric era. At present time, to decorate human body and colouring the hair, henna dye is being used in many warm countries like India (Abdel-Kareem, 2012). According to the study done by Keerthika et al. (2015), other than henna, another natural dye isolated from *Eclipta prostrata*, which is cheap and safe as compared to synthetic dye can be used as hair dye. The Egyptian blue (mixture of round limestone sand and a copper-containing mineral), probably first discovered around 3000 BC appears fresh till date on wall paintings of that time (Barnett et al., 2006). Therefore, it can be said that in spite of using technology, natural pigments are still better over synthetic artificial colours. The red ochre (iron rich soil), probably one of the oldest red pigments, is still in fashion.

The yellow pigment (safflower) had been found in central Asian Mediterranean region (Abdel-Kareem, 2012). Painted and dyed fabric of ancient Egypt became more frequent during later eras like Islamic and Coptic periods (Ahmed et al., 2017). New kingdom (18th dynasty) (1550 BCE) used cloths woven with coloured threads more often (Ahmed, 2009). To the ancient Egyptian artists purity of colour was very important and they mixed colours to vary hues according to dynasty. The Egyptians used different colours in art which were largely symbolic. Most of the ancient Egyptian paintings were made in the tomb or on the wall of temples (Chiavari et al., 1995). They had developed mineral based six colours, blue (copper carbonate Egyptian blue: azurite), green (malachite: copper ochre), yellow (hydrated iron oxide as yellow ochre), red (red ochre: anhydrous iron oxide) along with black (charcoal) and white (gypsum and calce); each of them had their own significance (Chiavari, et al., 1995; Singer, 2016). From different spectroscopic analysis it had been found that Egyptian crafts and arts dyed with natural colours were traded by imaginative craft-men (Yusuf et al., 2017).

In the era of late Roman Civilisation (midtenth century BCE) Romanesque churches (St. John Abbey) were decorated with paintings dominated by mineral based natural colours (red, white, yellow ochres). Animal based dye, Tyrian purple (from Murex snail) was considered as the probable oldest dye known to mankind used by Phoenicians dating back to 1600 BCE and continued until 1453 CE (Common Era) by Romans and Greeks (Zasada-Kłodzińska et al., 2020). The palettes of the Renaissance Baroque and Rococo were natural like that of cave artists but it was much more elegant in terms of new dimensions and portraiture than artworks of ancient Rome and Greece. For example, Chauvet paintings (~40,000 years back) were monochromatic whereas paintings at Lascaux and Altamira (both of ~20,000 years back) were vivid and polychromatic because of the use of different elegant colours (Von Petzinger and Nowell, 2014).

4 Natural dye in handcrafts, culture and heritage

Apart from historical artworks, use of natural pigments is still being practiced today. One of the examples is renowned traditional handicraft '*Pattachitra*' from Raghurajpur village of Puri, Odisha of Eastern India. It is a fashion of handmade painting started in fifth century BCE. In old days, natural canvas making was in practice, where the '*Patta*' was made by white cotton cloths only but the choice has been expanded now to meet the market demands for traditional handicrafts. Cotton cloth is soaked in the solution of tamarind seed and dried over sunlight. By using wood apple gum, artisans fix these layers until the canvas becomes ready for painting. Ultimately, they apply chalk paste as a primer to mask pores. Then it is scrubbed with the help of a stone to smoothen that canvas. Previously only two colours like black (burning lamp and coconut shell) and white (conch-shell powder) were used for painting but later other different natural colours like blood red (*hingula* and *geru*), yellow (from a kind

of stone, *haritala*), green (leaves) (Kanungo et al., 2020) and permutation of those five colours were used for more elegant appearances. Red is primarily used for the background. In addition to this, even natural objects like dried coconut shells are used as natural colour pellet. Other different gorgeous exotic artefacts like, candle stand, hanging bird wind chimes, Lord Jagannath wall hanging, tortoise for good luck, bangle and vermilion box, polling necklace for fashion, *patta* work on tussar sari, are also made for trading purpose (Kanungo et al., 2020). Black chalk (black clay) is used in terracotta and paintings, as a part of heritage (Yusuf et al., 2017). Another example of application of natural colour in traditional art is by Warli, the biggest Maharashtra tribe found on the northern outer edge of Mumbai. They practice various forms of arts expressing their livelihood, religious, social and folk life by using natural colours and wooden sticks (Patil, 2017).

The history of handmade paper in India started far back in the third century BCE. The natural mineral based dyes (red ochre and lead, zinc white, ultramarine, yellow ochre) were used to paint on paper (Sharma & Jain, 2013) which imparts insecticidal property to the papers (Yusuf et al., 2017). On the other hand, ancient (Dynasty 618–907, great Chinese era) Chinese handmade Lajian paper was made by using turmeric dyes (rhizome of *Curcuma longa* L.) in addition with Minium to get orange-red appearance on it. The kaolinite was used probably as a coating pigment. Growth of moulds due to humidity on the paper can be effectively prevented by the addition of wax coating on the surface of it (Luo et al., 2019). The other natural pigments like, pink (avocado skins) and yellow (pomegranate skins) had also been used. According to a recent finding, dye from babul bark has applications in handmade paper industry for its aesthetic sense and eco-friendliness in place of synthetic hazardous azo dyes to nullify toxic effects (Sharma & Jain, 2013).

At present, the natural colours are largely used for aesthetic purposes to avoid toxic effects of synthetic dyes. The natural mineral pigments (benign colouring agent) are used to make pigmented decorative candles in powder format because they can be easily dispersed in melted wax by capillary action. Hence, it helps to eliminate wicking effect which is necessary for normal burning of candle (Jobelius and Paulsen, 2013). Different plant-based pigments are also used to decorate candles (Venil et al., 2013). Madder root imparts a nice light peach shade whereas alkanet root shows burgundy red shade. Mixing of annatto seeds in the wax, changes its colour to warm yellow (https://www.thesprucecrafts.com/infuse-natural-colors-in-candles; Accessed on March 30, 2022). *Spirulina* gives a nice green shade, while peppermint imparts a very light green tone to candle along with mild fragrance.

5 Conclusion and future possibilities of natural colours in art-crafts

In late centuries, biological research had found pigmented bacteria as a source of natural colour for different purposes (Halder et al., 2020); like prodigiosin and violacein in colouring candles and papers (Venil et al., 2013). Compared to other groups of organisms, bacteria can produce variety of pigments like zeaxanthin, prodigiosin, pyocyanin blue from *Flavobacterium* spp., *Serratia* sp., *Pseudomonas aeruginosa* respectively (Heer and Sharma, 2017). Natural bacterial pigments are also presently being used as therapeutic agent because of being antioxidant, non-toxic and biodegradable (Numan et al., 2018). It has also been reported that bacterial pigments have application as food additive, antitumoral, antifungal agents, photosensitiser in different aspect (Narsing Rao et al., 2017). In addition to environment friendly nature, it is also inexpensive and easy to extract. Still extensive research work needs to make it an alternative source to meet on growing market demand as replacement of harmful synthetic dyes. Moreover, natural pigments are being utilised in different perspective fields like textile (Venil et al., 2014), food (Narsing Rao et al., 2017), pharmaceutical (Numan et al., 2018) etc. in a sustainable way (Venil et al., 2020). Bacterial pigments are being utilised for their potential applications in textile, food, painting, cosmetics, pharmaceuticals, plastics etc. hence, it becomes one of the key bio-products of present day with enormous implications subjugated expectantly in a sustainable environment (Venil et al., 2014).

The arts of ancient era have lasted till date with antique appearances of authentic natural colours used by those artists without any decay. Due to the antibacterial and insect repellent nature of natural dyes, artwork could be preserved for thousand years as cave arts or ancient Egyptian mummies of Prehistoric era. Like synthetic colours, natural pigments can also provide vivid and polychromatic appearances. The natural pigments are environment friendly, inexpensive and easy to extract. In contrast synthetic pigments are hazardous to the environment. Owing to the sustainability of natural pigments over synthetic dyes, they can be used in different sectors to build the bio-economy of a country.

Acknowledgements Authors are thankful to UGC-Centre of Advanced Study, Department of Botany, The University of Burdwan for providing necessary research facilities. Shrabana Sarkar is thankful to Swami Vivekananda Merit-cum-Means Non NET fellowship for financial assistance. Bhramar Dutta is grateful to Department of Science and Technology (DST), New Delhi, for providing fellowship under PURSE Phase II programme.

References

Abdel-Kareem, O. (2012). History of dyes used in different historical periods of Egypt. *Research Journal of Textile and Apparel, 16*, 79.

Ahmed, H. E. (2009). History of natural dyes in North Africa 'Egypt.' In T. Bechtold & R. Mussak (Eds.), *Handbook of natural colorants.* Wiley.

Ahmed, H. E., Ibrahim, F. T., Ibrahim, E., Adel, B. S., & Yassin, Z. (2017). Identification of natural dyes in rare Coptic textile using HPLC-DAD and mass spectroscopy in museum of Faculty of Arts, Alexandria University, Egypt. *Dyes and Pigments, 145*, 486–492. https://doi.org/10.1016/j.dyepig.2017.06.035

Barnett, J. R., Miller, S., & Pearce, E. (2006). Colour and art: A brief history of pigments. *Optics and Laser Technology, 38*, 445–453. https://doi.org/10.1016/j.optlastec.2005.06.005

Chiavari, G. D., Fabbri, G. C., & Galletti, R. M. (1995). Use of analytical pyrolysis to characterize Egyptian painting layers. *Chromatographia, 40*, 594–600.

Halder, U., Banerjee, A., Biswas, R., Sharma, A., Pal, S., Adhikary, A., & Bandopadhyay, R. (2020). Production of prodigiosin by a drug-resistant Serratia rubidaea HB01 isolated from sewage. *Environmental Sustainability*, *3*, 279–287. https://doi.org/10.1007/s42398-020-00115-z

Heer, K., & Sharma, S. (2017). Microbial pigments as a natural color: a review. *International Journal of Pharmaceutical Science and Research*, *8*, 1913–1922.

Heer, K., & Somesh, S. (2017). Microbial pigments as a natural color: A review. *International Journal of Pharmaceutical Sciences and Research, 8*, 1913–1922.

Jobelius, S. L., and Paulsen, B. T. (2013). U.S. Patent No. 8,485,814. Washington, DC: U.S. Patent and Trademark Office.

Kanungo, P., Narayan, S., & Pritam, B. (2020). Socio-economic condition, welfare schemes, and occupational structure of 'pattachitra' artisans in Odisha, India. *Creative Industries Journal*. https://doi.org/10.1080/17510694.2020.1775029

Keerthika, A., Shukla, A. K., & Khandelwal, V. (2015). *Eclipta prostrata* (L.) L(.Asteraceae)–An eco-friendly natural hair dye. *Current Science, 109*, 1011.

Křížová, H. (2015). Natural dyes: Their past, present, future and sustainability. In *Recent developments in fibrous material science*. Kosmas Publishing.

Lambourne, R., & Strivens, T. A. (1999). *Paint and surface coatings: theory and practice*. Netherlands: Elsevier.

Lambourne, R., & Thomas, A. S. (1999). *Paint and surface coatings: Theory and practice*. Elsevier.

Luo, Y. J. C., Cheng, Y., & Huang, Y. (2019). Analyzing ancient Chinese handmade Lajian paper exhibiting an orange-red color. *Heritage Science, 7*, 1–8. https://doi.org/10.1186/s40494-019-0306-6

Narsing Rao, M. P., Xiao, M., & Li, W. J. (2017). Fungal and bacterial pigments: Secondary metabolites with wide applications. *Frontiers in Microbiology, 8*, 1113.

Numan, M., Bashir, S., Mumtaz, R., Tayyab, S., Rehman, N. U., Khan, A. L., & Al-Harrasi, A. (2018). Therapeutic applications of bacterial pigments: A review of current status and future opportunities. *3 Biotech, 8*(4), 1–15.

Patil, D. K. (2017). Warli art: Diversification of traditional painting creating future, hope & happiness. *International Journal of Home Science, 3*, 451–456.

Robb, J. (2020). Art (pre) history: Ritual, narrative and visual culture in Neolithic and Bronze age Europe. *Journal of Archaeological Method and Theory, 27*, 454–480. https://doi.org/10.1007/s10816-020-09471-w

Sarkar, S., Banerjee, A., Halder, U., Biswas, R., & Bandopadhyay, R. (2017). Degradation of synthetic azo dyes of textile industry: A sustainable approach using microbial enzymes. *Water Conservation Science and Engineering, 2*, 121–131. https://doi.org/10.1007/s41101-017-0031-5

Sharma, A. K., & Jain, R. K. (2013). Application of natural dyes: An emerging environment-friendly solution to handmade paper industry. In R. Kuhad & A. Singh (Eds.), *Biotechnology for environmental management and resource recovery* (pp. 279–288). Springer.

Singer, G. G. (2016). Color in Ancient Egypt. *Erişim Tarihi, 20*.

Siva, R. (2007). Status of natural dyes and dye-yielding plants in India. *Current Science, 92*, 916–925.

Urmi, H., Aparna, B., Raju, B., Akash, S., Sudeshna, P., Anjushri, A., & Rajib, B. (2020). Production of prodigiosin by a drug-resistant *Serratia rubidaea* HB01 isolated from sewage. *Environmental Sustainability, 3*, 279–287.

Venil, C. K., Aruldass, C. A., Dufossé, L., Zakaria, Z. A., & Ahmad, W. A. (2014). Current perspective on bacterial pigments: Emerging sustainable compounds with coloring and biological properties for the industry—An incisive evaluation. *RSC Advances, 4*, 39523–39529.

Venil, C. K., Dufossé, L., & Renuka Devi, P. (2020). Bacterial pigments: Sustainable compounds with market potential for pharma and food industry. *Frontiers in Sustainable Food Systems, 4*, 100.

Venil, C. K., Zakaria, Z. A., & Ahmad, W. A. (2013). Bacterial pigments and their applications. *Process Biochemistry, 48*, 1065–1079. https://doi.org/10.1016/j.procbio.2013.06.006

Petzinger Von, G., & Nowell, A. (2014). A place in time: Situating Chauvet within the long chronology of symbolic behavioral development. *Journal of Human Evolution, 74*, 37–54.

Yusuf, M., Shabbir, M., & Mohammad, F. (2017). Natural colorants: Historical, processing and sustainable prospects. *Natural Products Bioprospecting, 7*, 123–145. https://doi.org/10.1007/s13659-017-0119-9

Zasada-Kłodzińska, D., Basiul, E., Buszewski, B., & Szumski, M. (2020). Analysis of natural dyes from historical objects by high performance liquid chromatography and electromigration techniques. *Critical Reviews in Analytical Chemistry*. https://doi.org/10.1080/10408347.2020.1743640