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Natural Dyes as pH indicator: a review

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ABSTRACT

This review emphasizes the significance of pH indicators in the field of analytical chemistry by employing extracts obtained from plants. The use of synthetic dye prepared industrially is known for its high energy receipt, which in a way contributes to environmental pollution. A pH indicator is a dye that might be synthetic or natural and has versatile applications. Efforts are being made to develop natural indicators by utilizing various flower and other plants extracts.. The study demonstrates the ability to use flower extracts as acid-base indicators in acid-base titrations. Natural indicators are readily available, easy to prepare, and yet showed promising results compared to synthetic indicators. The titration using flower extracts exhibits a clear color change at the specified points, which is consistent with the results obtained from standard indicators. Natural indicators are deemed highly valuable, cost-effective, straightforward, and precise for such titrations. also, it considered a green chemistry. The method employed in industrial processes for chemical reactions is defined by its focus on energy efficiency and its effort to minimize the utilization of hazardous or toxic solvents and reagents whenever feasible.

INTRODUCTION

Natural dyes: Natural dyes have applications in various sectors include but not limited to textile industry, pharmaceuticals, leather, foodstuffs and in cosmetics. Typically, natural dyes are derived from plants' roots, stems, leaves, flowers, fruits, as well as dried insects' bodies and minerals. Plant and animal-based colorants are considered safe because they are non-toxic, non-carcinogenic, and biodegradable. Natural dyes primarily come from four main sources: specialized plants, animal sources, plants rich in natural dye content, and animals used for natural dyeing (1).

Source OF Natural Dyes

1-plant dyes Most natural dyes are obtained from various parts of plants, including berries, flowers, leaves, and roots. Dyes can also be obtained from the outer and internal bark and heartwood of trees. Also, younger shoots seeds, fruits as other sources of natural pigments might be use. According to the literature approximately 1,000 sources of vegetable dyes that have been used worldwide until the early twentieth century. Some examples of these dye-yielding plants include the following :

- Madder (Turkey red) - from the roots of the madder plant
- Black logwood - extracted from the core of the logwood tree.
- Indigo (blue), is from leaves and stems of the indigo plant.
- Fustic (yellow) - Obtained from the timber of the fustic tree
- Catechu (brown) Derived from the resinous substance of the acacia tree
- Henna (orange-red) - from leaves of the henna plant

2-Animal dyes

Some small insects, for example the little cochineal (*Dactylopus coccus costa*), feed on red aloe vera berries and produce red animal pigments. These insects were collected by hand . Around 8,500 oysters were utilized to produce one gram of the dye, rendering it highly expensive and accessible only to royalty. The primary sources of animal-based dyes include:

- Sepia (brown) Derived from the secretions of various species of cuttlefish.
- Tyrian purple or crimson is obtained from the bodies of certain marine snails.
- Cochineal (red) - Cochineal red dye is derived from the bodies of cochineal insects.

Table 1:- Categories of some natural dyes.

Natural dye classification

Colours	Chemical classifications	Common names
Neutral	Vegetable, Tannins, Gallotannins, ellagitannins, and catechol tannins	Wattle, Myrobalan, Pomegranate, Sumach, Chestnut, Eucalyptus
Blue	Indigoid	Indigo
Purple and Black	Benzophyrone	Logwood
Red	Anthraquinone dye	Lac, Cochineal, Madder (Majithro)
Brown and Purple-Grey	Naphthoquinone dyes	Henna, Walnut, Alkanet, Pitti
Yellow and Brown	Flavone dye	Weld, Quercitron, Fustic, Osage, Chamomile, Tesu, Dolu, Marigold, Cutch

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3-Mineral dyes: (derived from coloured clays and earth oxides)

- Prussian blue is a blue pigment that is derived from a compound of iron and cyanide.
- Chrome red is a red pigment that is derived from a compound of chromium and lead.
- Chrome green is a green pigment that is derived from a compound of chromium and oxygen.
- Chrome yellow is a yellow pigment that is derived from a compound of chromic acid and lead.
- One of the oldest pigments that has been used since prehistoric times is ochre pigment made from iron ore (2)

Classifications of Natural Dyes Dyes are classified in several ways depending on their natural hue and chemical functional groups (structure).

Based on Structure Most commonly available natural colourants might be falling under this system of classification includes:-

- 1- Anthocyanidin
- 2- Di-hydropyrans

3- Flavones

4- Alpha naphthoquinones

5- Anthraquinones

6- Indigoids (3) . Green Chemistry: Green chemistry commence with the knowledge that production, processing, use, and The final disposal of chemical products may base harm if implemented incorrectly. Green chemistry can be defined as utilizing chemical science and manufacturing in an environmentally friendly manner, which ensures sustainability, security, minimal pollution, and reduced consumption of materials and energy, while also aiming to minimize or eliminate waste .Green chemistry is a pull on profits, it is about maximizing profits and encouraging , while, protecting human health and the environment (4) . Indicators: They are Dyes or pigments can be derived from various sources, such as fungi, algae, and plants. Anthocyanins, an organic pigment class, are found in most violet, blue, or red flowers and exhibit pH-dependent color changes. These compounds can function as acid-base indicators, where they are added to a specific solution to visually determine its pH through the observed color change. The color of the indicators changes due to the change in pH. Indicators applied for the titration process show color changes, which are describe as good at a given pH interval. pH indicators serve as chemical detectors for the presence of hydronium ions (H_3O^+) or hydrogen ions (H^+) in a solution (5) . pH indicators: also known as acid-base indicators or neutralizers, are substances that exhibit a color change in their solutions based on pH variations. Typically, they are weak acids or bases, and their conjugate acid or base forms display different colors due to variations in their absorption spectra. Indicators are derived from weak organic acids or bases with complex structures. A general acidic indicator is represented by the formula HIn , while a basic indicator is represented by $InOH$. The ionization of an acidic indicator in a solution is illustrated by an equilibrium reaction (6) $HIn \rightleftharpoons H^+ + In^-$ -Some Plant based pH indicators:

1-Tagetes erectus: It is a type of annual herbaceous plant found abundantly in India, South Africa, Zambia, China, Australia, and some other countries. Its height is approximately from 30-110 cm. The flowers of these plants are characterized by the fact that they are found in the form of small heads or a single type of inflorescences, and they can be easily grown through their seeds. It is a peels of yellow to red colors with different shades. Its flowering time is very long, extending from summer to autumn. The flowers are rich in carotenoids.

2-Bougainvillea glabra: It is a type of climbing shrub with a height of 10-12 feet and sometimes up to 30 feet, and it has thorny perpetual green stems. Its tiny flowers are white in color and the diameter of these flowers is about 0.2 cm. They are set in groups enclosed by colored paper such as bracts.

3- Caesalpinia pulcherrima: This bush grows in climates with little or no frost, its height reaches 3 meters. The plant will die still in cold season but will renaissance again in mid to late spring. This plant is known as evergreen. These flowers manufacture racemes up to 20 cm long. Each flower has five petals of different colors, yellow, red or orange. The fruits of this shrub have a pod-like structure 6-12 cm long. (7)



Figure (1): (Tagetes erectus , Bougainvillea glabra, Caesalpinia pulcherrima)

4-Bombax Malabaricum: A high flattened deciduous tree with buttercream at the base, Rakta shalmali, also known as silk cotton tree, Deokapas, Shimal, Tambdi-savaru, and Lal katyan, belongs to the genus Bombax and is part of the malvaceous family . It can grow up to 40m tall and have a girth of 6m, with a prominent trunk measuring (24-30m). The red color observed in this plant is attributed to the



Figure (2) :- Bombax Malabaricum

5- Beta vulgaris: Beetroot classified inter alia the 10 most powerful vegetables. Betalain beetroot tincture. Betalains are soluble in water. Nitrogenous dyes split into two type of categories: beta-cyanine red and betaxanthin yellow. Betacyanins appear red to violet-red in color and are sop up into Range 535-550 nm. It is generally yellow in color and is absorbed at 475-480 nm. The beetroot displays a dark crimson red pulp that has a sweet taste. They impart this color due to the presence of a group of chromophores. Beetroot roots were purchased, dried, crushed and used as a natural indicators (9) .



Figure (3):- - Beta vulgaris

6- Clitoria ternatea L. flower: An everlasting herbaceous plant with immortal and obtuse leaves. It is widely cultivated in Asia, but it was also introduced to Africa, Australia and America. As these plants grow in damp soil, one of the common traits about this plant is its liveliness. Some cultivars of this plant produce white flowers. The fruits are 5-7 cm long and are edible when soft. Butterfly pea, also known as blue pea or cordofan-pea, is a plant that belongs to the Fabaceae family. It is known for containing flavonoids and anthocyanins (10)



Figure (4) :- *Clitoria ternatea* L. flower

7- *Jasminum sambac*: A tiny evergreen shrub, sambac is commonly cultivated all over the world for its beautiful and aromatic flower. It reaches a height of 3m (1.6 to 9.8 ft). *Jasminum sambac* is a plant native to southern Asia, including countries such as India, Bangladesh, Pakistan, Bhutan, Myanmar, Sri Lanka, and some others. It is characterized by glossy, dark green leaves that are pointed and oval in shape. The leaves are arranged in opposite pairs of three. The leaves of *Jasminum sambac* are shiny and have a dark green color. it has intense fragranced white, waxy flowers.



Figure (5) :- *Jasminum sambac*

8-*Lilium candidum* Flowers: This plant reaches a height of 1.2 m (3 ft 11 in) by 2 m (6 ft 7 in), it is a plant of the lily family also known as Madonna lily. The plant appears in late spring and bears some aromatic flowers in the summer. It is widely cultivated in the Middle East and Europe, including France, Italy and Ukraine, and in North Africa (11) .



Figure (6):- *Lilium candidum* Flowers:-

9-*Thespesia populnea*: An evergreen tree with heart-shaped leaves Cup-shaped yellow flowers. Each flower has a maroon eye that turns purple. Yet they are dense while they are young aged. belongs to the family Malvaceae.



Figure(7) :- *Thespesia populnea*

10-*Nerium odorum* (Sol.):very poisonous plant, It contains a strong heart toxin, and one must be ware of it. It is an evergreen shrub with a height of 4 meters. It is said that the whole plant has anti-cancer properties and has many benefits, including a heart tonic, diaphoretic, diuretic, emetic, expectorant, in the treatment of scabies, reducing swelling, and others. As the plant belongs to the family Apocynaceae



Figure (8) :- *Nerium odorum* (Sol)

11-*Thunbergia alata* (Bojer):It is flourishing most of the year, except in the depths of winter. Neither bellicose and not powerful. The flowers look very attractive. Known as Black Eyed Susan Vine, it belongs to the Acanthaceae family.



Figure (9) :- *Thunbergia alata* (Bojer)

12-Helianthus annus (L.):A plant with coare stems and yearly roots. The leaves are alternate (the lower one may be conflicting). This plant belongs to the Asteraceae family. It reaches a height of 3 meters. flowers are usually red to purple, and seldomly yellow (12) .



Figure (10) :-Helianthus annus (L.)

13- Roselle (Hibiscus sabdariffa L): grassy shrub up to 2.4 meters high. The leaves are alternate. The stems and leaves of the sepals are acidic and like to wild berries (Vaccinium spp.). They are utilized to make juice, wine, jam, tea and syrup. It is widely cultivated in tropical Africa, Asia, Australia and Central America. It has many benefits, including antiseptic, diuretic, and antioxidant (13) (14) (15) .



Figure (11) :- Roselle (Hibiscus sabdariffa L)

14- Catharanthus rosea : Semi-woody evergreen perennial plant, commonly grown as an annual in flower beds. It can reach a peak of (0.6-0.9 m) regularly recognized as Madagascar periwinkle or rose periwinkle. Madagascar periwinkle includes a hypothetical abundance of poisonous alkaloids. Jasminum sambac has a long history of traditional use in managing various health conditions. It has been employed for centuries to address issues such as diabetes, high blood pressure, asthma, constipation, and menstrual problems and it is useful for many uses. Madagascar Periwinkle produces unwanted facet consequences (16).



Figure (12) :- *Catharanthus rosea*

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