UV-VIS Spectrophotometric Study of Selected Water Colours Currently in Use in Two Primary Schools Gwale Local Government Area of Kano State

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Abstract- ***Ultraviolet-visible spectroscopy of twelve (12) common water colours available in two primary schools in Gwale Local Government area of Kano state Nigeria were examined, the results showed that the λmax range between 726 nm and 408 nm and this tend to shift to longer wavelength which according to literatures associate increase in λmax with increase in conjugation in molecular structure of an organic compound. The experimental results also showed that the Molar Extinction Coefficient of the colours range between 3.5 x 103 to 2.9 x 104 with water colours (WC) 12 having the highest value. The value obtained although within the acceptable level ≥ 1 × 104 for most of the dyes is low. This is indicative of the reason for water colours being used in primary education where substantivity of the colours are not required due to a number of reasons, implication for primary education are also examined. However the molar extinction value of WC 2 and 3 could be increased to meet up with the acceptable value if need be. The UV-Vis spectroscopy of the WC studied here did not reveal the chemical structure of the dyes, hence, there is the need to carry out IR and GC-MS or NMR spectroscopy of the colours in order to determine their chemical structures.***

Indexed Terms- Water Colours, Molar Extinction Coefficient and Ultraviolet-visible Spectroscopy

I. INTRODUCTION

Spectrophotometry is a technique used to measure how much a chemical substance absorbs light by measuring the intensity of light as a beam of light passes through sample solution. The basic principle is that each compound absorbs or transmits light over a certain range of wavelength (Sharma et al., 2021). Ultraviolet-visible spectroscopy is one of the most simplified and economical methods of examining analyte interactions with radiation where only the change in absorbance is measured as a function of wavelength. The technique is versatile and gives rapid response regarding quantitative information (Cole and John 2017)

The term molar extinction coefficient (ε) is a measure of how strongly a chemical species or substance absorbs light of a particular wavelength (Chang et al., 2018), it is an intrinsic property of chemical species that is dependent upon their chemical composition and structure. Thus it's a finger print of a compound as it can be used to differentiate between different molecules and to define the range of wavelength where light has its maximum depth of penetration in materials, that is, high extinction coefficient means high absorption cross section (Lynta and Laura 2017).

Dye may be defined as coloured substances, which are capable of application in aqueous solution or dispersion to a substrate, so that the substrate acquires a colour appearance (Bello et al., 2018). Generally all colours may be classified as animal, vegetable, mineral, synthetic or abstract. Animal and vegetable colouring matter are organic substances,, they are complex chemical materials containing carbon, hydrogen, and usually oxygen or nitrogen derived from the roots, seeds, fruits leaves, and barks of plants. While animal dyes usually come from worms and shells (O Neil et al., 2019). However mineral or "abstract" colours are usually permanent, examples include those of rocks, glasses, ceramics, enamels and jewels. Purely physical effects of refraction and dispersion of light produce abstract colours; no actual coloured substance is present. Examples are brilliant blue, green and violet of many insect wings, bird feather and some mineral colours as in opals (Rajaguru et al., 2018).

Water colour dyes were invented in China and did not arrive in Europe until the 13th century but they soon became popular. Old water colour recipes used to contain honey as it made the paint soft, by 18th synthetic water colours made of hydrocarbon organic compounds (dyes) have been wildly circulated around the world (Torres et al., 2018). It became a pack of resources for primary school introductory lessons to even a core subject (Creative Arts). Also to challenge pupils or students to get creative with a wide range of simple and complex tasks which includes power point, worksheet and teaching Ideas resource, water colour pack become teacher’s delight (Chang et al., 2018).

Water colours are water or alcohol soluble dyes commonly used in pre-primary, primary and junior secondary schools for drawing, writing and painting. There are many different types currently in use in primary schools and the most common are the tubes, tray, and bottles filled with liquid pigment. In addition, they can be purchased in the form of pencils, markers, and sheets (Lynta and Laura 2017).

Water colour pans come in small containers that are also called cakes. They can be bought in half pans and full pan sizes. The great thing about the pans is that they are small, compact, and portable. The pigment is durable, which makes them a great long-term investment, one of the downsides of painting with pan pigment is that they do not dry as vibrantly as tube pigment (Patel et al., 2019).

Water colour bottles, are bottles filled with very concentrated pigment in liquid form. One of the best benefits of water colour bottles are their intense vibrancy for this reason, many people love creating colourful artwork with these liquid pigments. However, one of the disadvantages of water colour bottles is that they do not have the best light fastness properties (Chang et al., 2018 and Patel et al., 2019).

Water colour pencils are very unique because they combine the best qualities of water colour painting and drawing. These water colours are shaped like pencils but contain water-soluble pigment, which means you can use them in both a dry and wet format. Simply lay down pigment as if you were using coloured pencils, or, activate the pigment with a damp paint brush to create beautiful, loose water colour effects. Also, you do not need a lot of water to activate these pigments and due to their portable nature, these pencils are very convenient when painting outside the classroom. It should be noted that water colour pencils, like pans, will dry less vibrantly than tube paint or liquid water colours (Chang et al., 2018 and Patel et al., 2019).

Water colour markers are shaped just like regular markers, but what sets them apart is that they contain water-soluble ink. This pigment can be applied both in dry format or water can be added to dilute the pigment and create loose painterly effects. As well, the brush tips glide smoothly over the paper in a way that mimics a paint brush to give each brush stroke a painterly look. The tips, which are usually made of nylon are pliable and makes them great for user who desires the versatility to easily switch between drawing and painting. But, similar to water colour pencils, these markers don’t necessarily have the strong vibrancy or the long lasting light fastness (Masayoshi and Nakabara 2021).

Water colour sheets are exactly as they sound the booklet contains sheets of paper that have dry water colour pigment on them. The advantage of painting with water colour sheets is that they are lightweight and portable (Chang et al., 2018 and Patel et al., 2019).

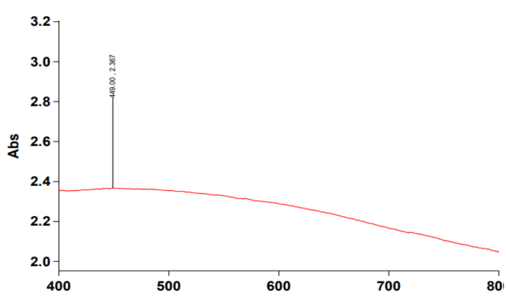
In water colours, the chemical structures of the dyes present were not disclosed due to commercial reasons. As a result, it was not easy for researchers to study the actual chemical reaction between the dye molecules and the substrates or to determine the factors affecting uv-vis absorption spectral shift. Therefore, the purpose of this study is to determine the molar extinction coefficient of the dyes and to examine the dyes shift in wavelength in twelve dyes of a water colour pans readily available and in use in selected primary schools, Gwale Local Government area of Kano State.

II. EXPERIMENTAL

Water colours containing dyes are standardized products for specific end-use and are not homogeneous chemical compounds. They often have impurities and may contain a large amount of shading components, most of which can interfere seriously the UV-VIS spectra analysis. Therefore, separation and purification were done in order to obtain the pure state of dyes for accurate analysis (Patel et al., 2019). The spectrophotometric properties of the water colour dyes (WC 1 – 12) were examined using procedure given by Navarro and Sanz (2019). The sample concentrations were adjusted so that the absorption intensities of the components were roughly the same. The water colours sample solutions were prepared and each solution was then scanned from 400-800 nm by Spectrum Version UV-visible spectrophotometer at NARICT, Zaria.

III. RESULTS AND DISCUSSION

The results of the UV-VIS spectroscopy of the water colours is presented in Figures 1 – 12 and Table 1 showing the colour and the spectroscopic properties of the dyes (WC 1 – 12)



Figures 1: Water colour 1

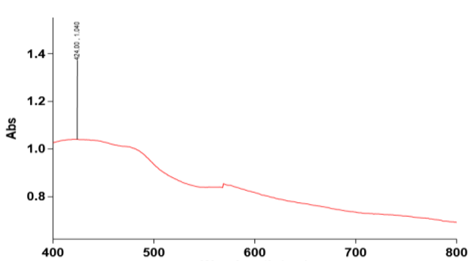


Figure 2: Water colour 2

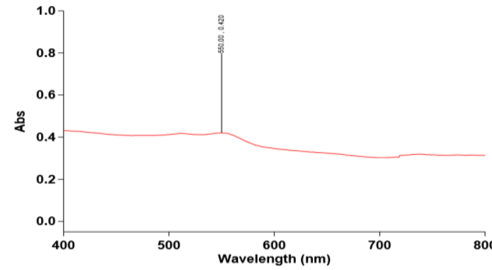


Figure 3: Water colour 3

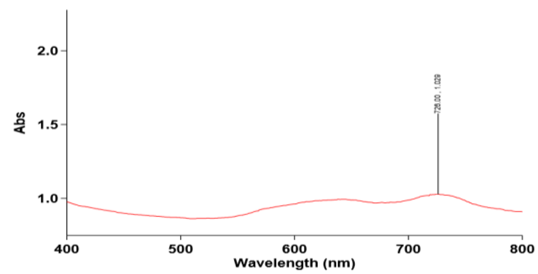


Figure 4: Water colour 4

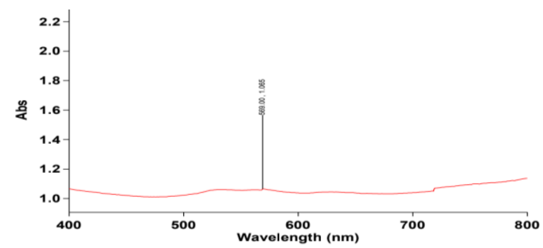


Figure 5: Water colour 5

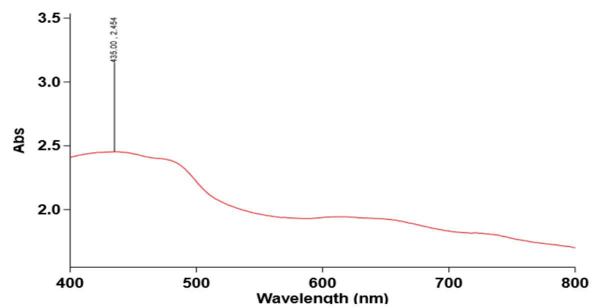


Figure 6: Water colour 6

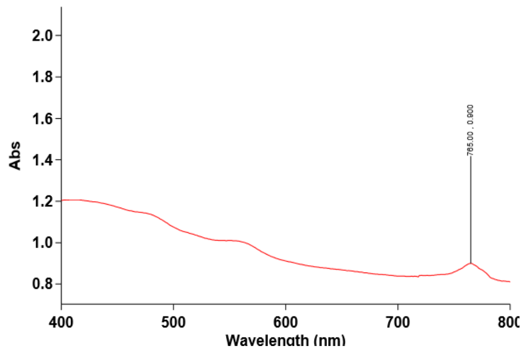


Figure 7: Water colour 7

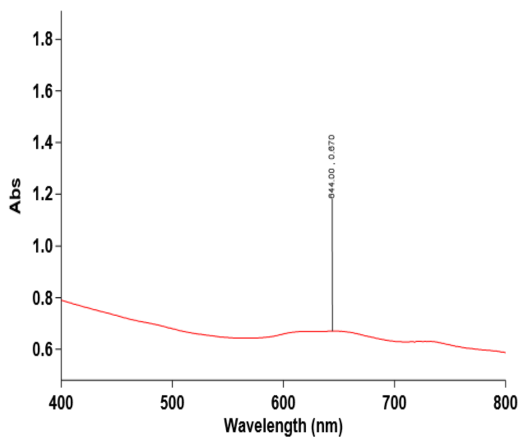


Figure 8: Water colour 8

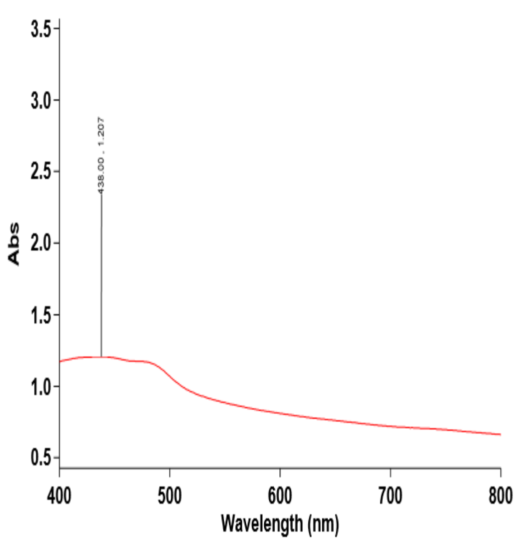


Figure 9: Water colour 9

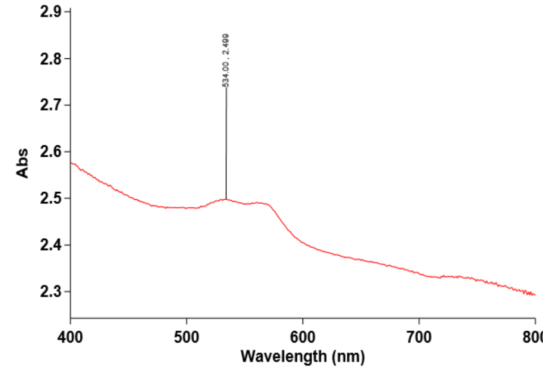


Figure 10: Water colour 10

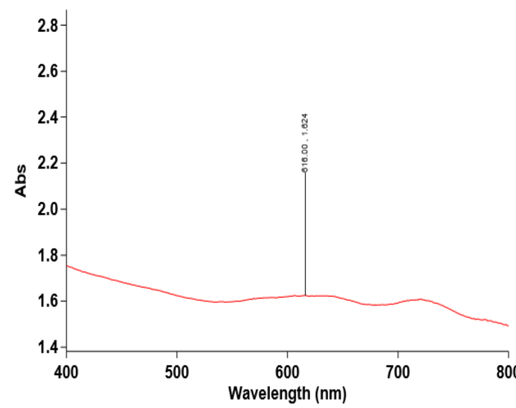


Figure 11: Water colour 11

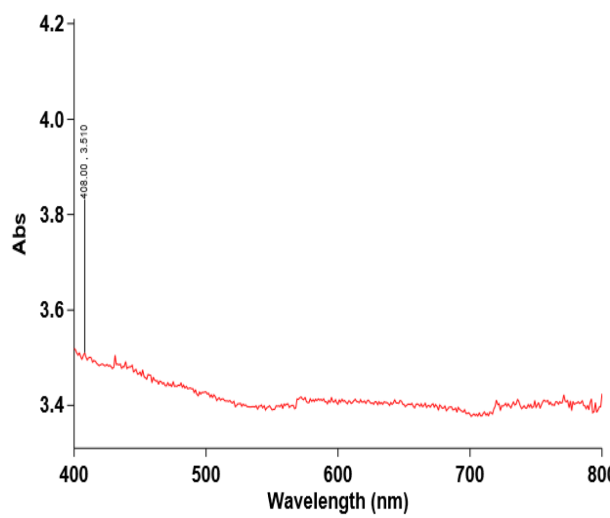


Figure 12: Water colour 12

Table 1: UV-VIS Spectroscopic Properties of Water Colours

Colour Water	Colour	Wavelength(nm)	Conc g dm^{-3}	Absorbance	Molar Extinction Coefficient
WC 1	White	449	1.2 x 10^{-4}	2.367	1.9 x 10^{4}
WC 2	Orange	424	1.2 x 10^{-4}	1.040	8.6 x 10^{3}
WC 3	Red	550	1.2 x 10^{-4}	0.420	3.5 x 10^{3}
WC 4	Dark blue	726	1.2 x 10^{-4}	3.029	2.5 x 10^{4}
WC 5	Purple	569	5.0 x 10^{-5}	1.065	2.1 x 10^{4}
WC 6	Light green	435	1.2 x 10^{-4}	2.454	2.0 x 10^{4}
WC 7	Brown	765	3.2 x 10^{-5}	0.900	2.8 x 10^{4}
WC 8	Dark green	644	3.0 x 10^{-5}	.670	2.2 x 10^{4}
WC 9	Yellow	438	1.2 x 10^{-4}	1.207	1.0 x 10^{4}
WC10	Pink	534	1.2 x 10^{-4}	2.499	2.0 x 10^{4}
WC11	Light blue	616	7.5 x 10^{-5}	1.624	2.1 x 10^{4}
WC 12	Black	408	1.2 x 10^{-4}	3.510	2.9 x 10^{4}

Table 1 gives the peak wavelengths, concentration, absorbance and the molar extinction coefficients of various water colours. The result showed that the λmax range between 726 nm and 408 nm also it tend to shift to longer wavelength (Bathochromic shift). This probably due to increase in conjugation in the molecular structure of the water colours samples equally the action of auxochromes might amplify the absorption intensity observed in samples white and black. The result is in agreement with the works of Patel et al., 2019, Jooneck et al., 2017, Yinon et al., 2019 and Colthup et al., 2021 which stated that with larger conjugated systems, the absorption peak wavelengths tend to be shifted toward the long wavelength region and the absorption peaks tend to be larger.

Water colours are dyes which tend to have large conjugated systems, these conjugated systems have a large influence on peak wavelengths and absorption intensities, and therefore in Table 1, their peak wavelengths tend to be shifted toward the long wavelength region, with peaks appearing in the visible region (400 to 700 nm). This is why they are recognized as colours.

Incidentally, the colour that we see is the colour that is not absorbed by the substance (which is called the complementary colour) (Potera, 2020).

According to Masayoshi and Nakabara (2021), absorption in the ultraviolet and visible regions is related to the transition of electrons. Transition refers to the switching of an electron from one state of motion to another. The state of motion of the π electrons in the conjugated system changes more easily than that of the σ electrons that form the molecular frameworks. If a photon collides with a π electron, that π electron readily changes to a different state of motion. This istrue even if the photon has only a small amount of energy. The π electrons in relatively large conjugated systems are more easily affected by low-energy photons. Transition expresses the way that the energy of photons is absorbed by electrons. If a photon has a relatively small amount of energy, the value of hc / λ (h is Planck constsant, c Velocity of light and λ Wavelength) for that photon is relatively small, and therefore the value of λ relatively large λ is observed as the absorption wavelength and so, if there is a conjugated system, peaks tend to appear in regions where λ is large, that is, the long wavelength region (Color Additive Status List 2017).

IV. MOLAR EXTINCTION COEFFICIENT

Table 1gives the molar extinction coefficient of the colours, which range from 3.5 x 103 to 2.9 x 104 with WC 12 having the highest value while WC 3 the lowest. According to Patel et al., (2019) for commercial colouring material the molar extinction coefficient should be greater than or equal to 10000 (≥ 1 × 104) for it to be accepted as a colouring material that can fixed on a substrate. In Table 1 WC 1,4,5,6,7,8,9,10,11 and 12 are within acceptable range while WC 2 and 3 values fell short of the required level.

The molar extinction coefficient is a measurement of how strongly a substance absorbs light and its ability to stain or be absorb on to a substrate which may be cellulosic, concrete, plastic and so on, It is known that extinction coefficient values do not vary much from solvent to solvent unlike the wavelength. The larger its value, the greater the absorption and its affinity for the substrate, equally for a substance to act as a colouring material certain constitutional conditions must be met, namely; It must have a suitable colour, must be able to fix itself or capable of being fixed to the substrate and when fixed, it must be fast to light, washing perspiration, rubbing, gas fumes and other agencies likely to cause dissolution from the substrate dye degradation (Anguilar et al., 2012). Molar extinction coefficient of water colours under investigation is indicative of the amount of colour that would be fixed on the substrate when used in the classrooms., however the values obtained seem to be lower when compared with other known dyes whivh are used for dyeing fabrics, this probably due to the fact that water colours are not required to be fixed permanently to the substrate and when used on the substrate, it is required to be easily wiped off easily without staining the substrate in most cases.

V. IMPLICATION FOR PRIMARY EDUCATION

The water colours studied here are those commonly used in our pre primary and primary schools, the implication of this in education is that since this categories of pupils are in their early developmental levels, a stage at which they are bound to their physical environment and most of their activities involve trial and error, constant practice becomes the order of day. Also pupils are not required to produce a more permanent and long term works, therefore water colours are perfectly suited to this stage of development as the dye in this colours are not that substantive.

Furthermore, to avoid pupils painting their bodies and school uniforms with a more substantive dyes water colours becomes a close call. Pupils are also fascinated by the bright colours of the dyes in water colours as it arrest and sustain their attention. Equally, for rough work, class display, decoration, instructional materials, painting and so on water colours have become sight to behold in early schooling.

CONCLUSION

The UV-Vis spectroscopy of twelve (12) commonly available water colours in use in primary schools were examined, the result showed that the λmax tend to shift to longer wavelength which according to literature is associated with increase in conjugation. Absorption peak wavelength tend to shift towards the long wavelength regionwith increase in conjugation in the molecular structure of dye molecule. The experiment results also showed that the molar extinctioion coefficient of the colours range between 3.5 x 103 to 2.9 x 104 with water colours (WC) 12 having the highest value. The value obtained although within the acceptable level (≥ 1 × 104) is low. This is indicative of the reason for water colours being used in primary education where substantivity of the colours are not required due to a number of reasons. However the molar extinction value of WC 2 and 3 could be increased to meet up with the acceptable value if need be. Also the UV-Vis spectroscopy of the WC studied did not reveal the chemical structure of the dyes, there is the need to carry out IR and GCMS or NMR spectroscopy of the colours in order to determine their chemical structure.

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