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# Comparative Analysis of Local Raw Materials for the Production of a Non Toxic and Erasable Water Base writing Ink for White Board Marker Refill.

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**ABSTRACT**

*This research is aimed at carrying out comparative analysis of local raw materials for the production of a non-toxic and erasable water base writing ink for white board maker refill. Different formulations were adopted in this research for the produced inks with physical properties such as pH, viscosity and drying time similar to those of an imported ink. The viscosities of the formulated inks in mPa.s were 9.8, 10.3, 9.1, 8.2, 6.0 and 5.4 for sample A, B, C, D, E and F respectively with sample D being the moderate viscous ink. Also, the G.C.M.S test carried out showed that the formulated inks were non-toxic because of the low concentrations of chromium, Manganese and Strontium Oxides; and were slightly erasable as a result of low concentration of Titanium Oxide. This can be improved by incorporating materials containing Titanium.*

**Keywords:** *Ink, erasable, viscosity, refill, whiteboard, toxic,raw materials, marker, water-base.*

## INTRODUCTION

Ink can be defined as a liquid or paste that contains pigment or dyes used for writing, printing or drawing (*Barrow, 1982*). All inks contain two basic components: a pigment or dye called colorant and a vehicle which is refer to as the solvent in which the colorants are dispersed easily. Other substances known as additives are sometimes added to the ink to impact special properties. These components can either be organic or inorganic and sometimes both can be use; their composition also varies according to the purpose the ink will serve (*Mark, 1974*). The production and use of ink can be trace back to Egyptians and Chinese writings around 1100B.C. These inks were combination of carbonaceous materials such as lamp black or soot and a vegetable oil. In the late 1800s, Binney and Smith through their company created a line of carbon black pigments (*Smith, 1992*) that were used by Goodrich Company to color its white auto tyres black. Initially, ink was fashion from different colored juices and plant and animal extracts. Today, synthetic materials are used in addition to these natural substances. The major difference between pigment-based ink and dye-based ink is in the solubility and color intensity of the colorants. Dyes generally produce ink with much stronger color than pigments and are soluble in the liquid phase making the ink to soak into an impervious writing surface and less efficient. While on the other hand, pigments being insoluble produce inks that are more color-fast than dyes and are expensive *(Helmut, 2011*).Colorants also known as pigments are particulate insoluble powder which come in different colors. Pigments are the chief component of ink responsible for ink color and opacity. Pigments are of either organic or inorganic origin; a combination of various pigments may be used to provide the vast range of color.Dyes are also used as colorant in ink; they are soluble and give high color intensity as unlike pigments. It is these colorants that are bonded unto the surface the ink is applied.

Pigments are chosen for their color appearance but also for various properties they possess for resistance to ultra-violet rays, heat, solvent, water etc. Carbon black is the most widely used pigment for making ink; chrome yellow is another pigment used but has lost favor because it contains lead which is poisonous to humans and environment.Some properties of ink are as follows: pH, viscosity, specific gravity, refractive index, erasability, drying time.pH is the measure of acidity or alkalinity of the ink ( Sharon, 2004) This is determined by the nature of the solvents and other additives contained in the ink. If these substances are acidic the pH of the ink tends to be low. The lower the pH, the more acidic the ink and the higher the pH, the more alkaline the ink is. It is generally acceptable for the pH of an ink to be within the optimum pH range i.e. 6.5-7.5.

### Viscosity

This is the measure of flow of ink. The more viscos the ink is, the less it will flow and vice-versa. The viscosity of an ink is contributed by the size of the pigment, mass of the pigment, volume of the solvent, type of resin used and other additives in the ink composition. The viscosity of ink varies from 5-10 mPa.s depending on the ink compositions.

### Refractive Index

This property show how the ink affect light passed through it. The lower the refractive index, the more light can be reflected i.e. less opaque and the higher the refractive index, the less light is reflected (more opaque). The pigment used contributes to the opacity of the ink.

### Erasability

This is the ability of the ink to be erased easily on the surface of the ink. When the amount of liquid compound is too small, the resultant ink is not readily erasable whereas when the liquid compounds is too large, the resultant ink writes bad and stains the writing surface. The resin used also provides the writing with a good adhesion to a writing surface.

### Drying Time

Drying time is the time taken for ink to dry on the surface. Drying time is related to the viscosity of the ink. The higher the viscosity, the slower it dries and the lower the viscosity, the faster it dries *(Paul Fisher 1983)*.

## METHODOLOGY

### Experimental Procedure

A gum Arabic solution was prepared by dissolving 28.36g of gum Arabic granules in 100.00$cm^3$ portion of the gum Arabic solution from a varnish.30.00 g of carbon soot was dispersed into the prepared varnished and stirred thoroughly and 10.00 $cm^3$ of distilled water was added. 10.00 g of colour and 6.00g of polyvinyl acetate were also added and stirred. The ink mixture was filtered using filter paper to obtain a clear ink. 5.00 $cm^3$ of antecede was added into the ink as preservative and the product is stored for the following physical and chemical test: PH, viscosity erasability, drying time, toxicity and gas chromatography mass spectroscopy (GCMS) of the ink produced were carried out. The procedure was repeated using lamp black and dye as the pigment by varying the volume of ethanol and mass of pigment respectively while the composition of other components used were kept constant.

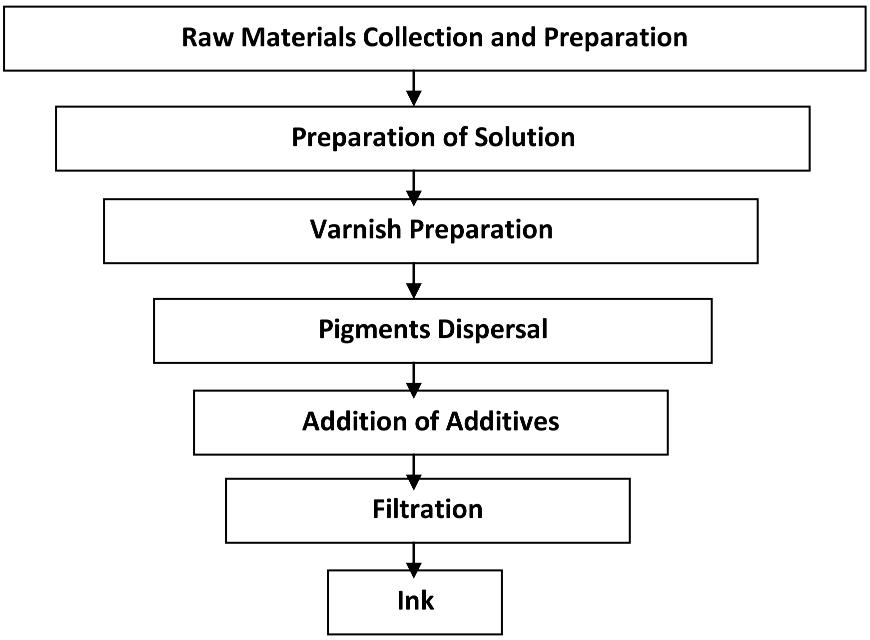


**Figure1.** *Block diagram for Ink Manufacturing Process*

**Table1.** *Formulations of ink produce from soot of Sodom apple*

| Sample | Component | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pigment(G) | Distilled Water(Ml) | Polyvinyl Acetate(G) | Colour (G) | Anticides (Ml) | Gum Arabic Solution(Ml) | Ethanol (Ml) |
| A | 30.00 | 10.00 | 6.00 | 10.00 | 5.00 | 20.00 | 20.00 |
| B | 30.00 | 10.00 | 6.00 | 10.00 | 5.00 | 20.00 | 30.00 |

**Table2.** *Formulations of ink produce from lamp black*

| Sample | Component | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pigment(G) | Distilled Water(Ml) | Polyvinyl Acetate(G) | Colour (G) | Anticides (Ml) | Gum Arabic Solution(Ml) | Ethanol (Ml) |
| C | 30.00 | 10.00 | 6.00 | 10.00 | 5.00 | 20.00 | 50.00 |
| D | 30.00 | 10.00 | 6.00 | 10.00 | 5.00 | 20.00 | 40.00 |

**Table 3.** *Formulations of ink produce using dye*

| Sample | Component | | | | | | |
|---|---|---|---|---|---|---|---|
| | Distilled Water(Ml) | Ethanol (Ml) | Polyvinyl Acetate(G) | Anticides (Ml) | Colour (G) | Gum Arabic Soluton(Ml) | Pigment (G) |
| E | 10.00 | 20.00 | 6.00 | 5.00 | 10.00 | 20.00 | 30.00 |
| F | 10.00 | 20.00 | 6.00 | 5.00 | 10.00 | 20.00 | 20.00 |

## Quality Test

After production of the ink, the drying time, pH, viscosity, erasability, refractive index and toxicity of the inks produced as well as that of an imported ink were tested so as follows:

## Drying Time Determination

At room temperature ($28^0$C) the ink was used to write on a whiteboard and the approximate time it took to dry up was measured and recorded.

## Determination of Viscosity

A volume of water was allowed to flow freely from a flow cup and the time was noted. Equal volume of the ink was also allowed to flow freely and the time noted. This relationship was used to determine the viscosity of the ink:

$$\frac{\text{Time of flow of water } (t)}{\text{Time of flow of ink } (t)} = \frac{\text{Viscosity of water } (\mu)}{\text{Viscosity of ink } (\mu)}$$ (McCabe et al, 1986)

## Eras-Ability

The ink samples were used to write on a white board at room temperature (25̊C) and allowed for 5 minutes to dry then erased to determine the eras-ability, if it was easily erased or not.

## Determination of the $P^H$

The pH values of the various samples of ink produced were determined using a digital hand-held pH meter and the reading for each sample was noted and recorded.

## Result And Discussion

**Table4.** *Table showing the physiochemical properties of an imported ink and the produced*

| Property | Imported Ink | Locally Produced Ink Samples | | | | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F |
| Ph | 7.5 | 6.4 | 6.2 | 7.6 | 7.3 | 5.9 | 6.0 |
| Viscosity (Mpa.S) | 10.0 | 10.2 | 9.8 | 9.1 | 8.2 | 6.0 | 5.4 |
| Erasability | Readily | Readily | Fairly | Fairly | Readily | Slightly | Slightly |
| Drying Time (S) | 13 | 24 | 13 | 13 | 12 | 12 | 11 |
| Refractive Index | 1.469 | 1.426 | 1.438 | 1.464 | 1.448 | 1.478 | 1.472 |
| Toxicity | Slightly Toxic | Non Toxic | Non Toxic | Non Toxic | Non Toxic | Non Toxic | Non Toxic |

**Table5.** *GCMS analysis for the Ink samples*

| Oxide / Element Present | Concentration (Wt. %) | | | |
|---|---|---|---|---|
| | Imported Ink | Sample A | Sample C | Sample E |
| $Na_2o$ | 0.000 | 0.000 | 0.192 | 0.000 |
| Mgo | 0.102 | 0.059 | 0.000 | 0.000 |
| $Al_2o_3$ | 3.394 | 1.698 | 2.083 | 1.576 |
| $Sio_2$ | 40.463 | 52.926 | 49.385 | 43.953 |
| $P_2o_5$ | 3.857 | 17.101 | 19.768 | 26.566 |
| $So_3$ | 16.517 | 5.506 | 7.235 | 4.137 |
| Cl | 10.675 | 2.895 | 4.905 | 2.282 |
| $K_2o$ | 0.242 | 10.724 | 15.188 | 1.572 |
| Cao | 0.000 | 8.763 | 0.965 | 19.111 |
| $Tio_2$ | 23.437 | 0.021 | 0.040 | 0.090 |
| $Cr_2o_3$ | 0.792 | 0.011 | 0.012 | 0.016 |
| $Mn_2o_3$ | 0.399 | 0.033 | 0.012 | 0.073 |
| $Fe_2o_3$ | 0.054 | 0.166 | 0.069 | 0.514 |
| Zno | 0.000 | 0.063 | 0.146 | 0.070 |
| Sro | 0.067 | 0.034 | 0.000 | 0.049 |

## Discussion of Results

Different formulations for the formulations of the various samples of ink produced were presented in Tables 1, 2 and 3.

Table 4 showed that the pH value of the imported ink and sample A, B, C, D, E and F were 7.5, 6.4, 6.2, 7.6, 7.3, 5.9, and 6.0 respectively. The higher the pH value, the more the alkalinity and the lower the pH value the more the acidity. A neutral substance i.e. a substance that is neither acidic nor alkaline has a pH of 7.0 while the optimum pH range is 6.5 - 7.5. The pH of the ink is dependent on the acidic or alkaline nature and quantity of the components used in making the ink. If the raw materials used are alkaline and in high quantity, the resultant ink will have high pH i.e. alkaline; while if the raw materials are acidic, the ink formed will have low pH i.e. acidic. However, the pH can be controlled by adding pH modifier reagents and checking the pH ensuring it doesn't exceed the desired value. The pH values in table 4 indicate that the imported ink has a pH of 7.5 which is within the optimum pH range and none of the ink produced is neutral. It is also seen that sample C with a pH of 7.6 is the most alkaline ink produced even though not highly alkaline and very near to the optimum pH range; this is because it contain more of ethanol which is alkaline in nature than any other sample. Sample D has a pH of 7.3 which is within the optimum pH range. Sample E is the most acidic ink followed by sample F with pH of 5.9 and 6.0 respectively. This is because they contain less ethanol; sample E contains more pigment being acidic than sample F. sample A with a pH of 6.4 very close to the optimum pH range contains less quantity of gum Arabic solution than sample B with pH of 6.2 and also has an ethanol content of 30ml which is between samples C and D of 50ml and 40ml respectively. Samples A, C and D have acceptable pH values of 6.4, 7.6 and 7.3 respectively. the pH of sample D is 7.3 which is within the optimum pH range because it contains 40ml ethanol which is between the quantity of ethanol contained in samples A and C i.e. 30ml and 50ml respectively. This shows that the content or composition of ethanol and other alkaline raw materials used in making ink should not be low or high but moderate.

Similarly, the viscosities of the inks produced and the imported ink in mPa.s were also presented in Table 4 as follows: 10.0, 10.2, 9.8, 9.1, 8.2, 6.0 and 5.4 for the imported ink, sample B, F, E, A, D and C respectively. These viscosities of the different ink samples are as a result of the amount of pigment used, resin (gum Arabic) and the volume of liquid components such as the solvent (ethanol) and the diluent (water) used. An ink that has more pigment, more binder and less solvent will be more viscous while an ink that contains less pigment, less binder and more solvent will be less viscous. A more viscous ink will flow slowly while a less viscous ink will flow fast. Sample B is the most viscous ink produced because it contained more gum Arabic as binder than other samples having equal or lower pigment and solvent as shown in tables in section 3.3 of this report followed by sample F; while sample C is the least viscous ink sample. This is because it has more solvent than other samples with equal or lower pigment and gum Arabic followed by sample D; while sample E and A were samples produced having moderate viscosities as compared to the viscosity of the imported ink and other samples that were produced. These samples produced using local raw materials possess viscosities similar to those imported since the result showed their viscosities to be in the range 5-10 mPa.s.

Also, the drying time of the different samples produced were determined as follows: 13 secs, 12 secs, 24 secs,12 secs, 11secs and 13 secs for sample C, D, A, E, F and B respectively while the imported ink have a drying time of 13 secs. At room temperature, the drying time of an ink will be affected by the viscosity of the ink. The more viscous the ink is, the longer the time it takes to dry i.e. the higher it's drying time. Conversely, the lower the viscosity of the ink, the faster it dries i.e. lower drying time.

Furthermore, the refractive indices of the different samples analysed as depicted in Table 4 were 1.469, 1.426, 1.438, 1.464, 1.448, 1.478, and 1.472 for the imported sample, sample A, B, C, D, E and F respectively. These results indicate the concentration of the pigment in the ink and how light passed through the sample i.e. its opacity. High refractive index means low light can passed through the ink meaning it is more opaque because it contains high content or concentration of pigment while on the other hand, sample with low refractive index implies less opaque i.e. more light can pass through it because it has low quantity of pigment. Samples E and F have high refractive indices of 1.478 and 1.472 respectively i.e. more opaque because they are darker or have high colour intensity than other samples.

More so, the test on the erasability of the ink samples showed that samples A and D were readily erasable, samples B and C were fairly erasable while sample E and F were slightly erasable; thereby, staining the writing surface. This is because sample E and F have dye as the pigment in their compositions which is soluble in water while the other samples are pigment-based inks.

In addition, the result of the GCMS test as given in table 5 shows that the inks produced from the different pigments contain titanium oxide ($TiO_2$), manganese (IV) oxide ($Mn_2O_3$), chromate oxide ($Cr_2O_3$)and strontium oxide (SrO) which are all oxides of heavy metals among others. The presence of these oxides contributes to the toxicity of the inks depending on their concentration. Inks with high concentrations of heavy metals or their oxides have high toxicity; and the lower the concentrations of heavy metals or their oxides in inks, the lower its toxicity. The concentrations of titanium oxide, $TiO_2$ were 23.437 wt.%, 0.021 wt.%, 0.040 wt.%, and 0.090 wt.% for the imported ink, sample A produced from soot of Sodom apple, sample C produced using lamp soot and sample E produced using dye respectively. The concentrations of manganese (IV) oxide, $Mn_2O_3$ in wt. % were as follows: 0.399, 0.033, 0.012 and 0.073 for sample of imported ink, sample A, sample C and sample E respectively and the concentrations of strontium oxide, SrO were 0.067 wt.%, 0.034 wt.%, 0.000 wt.% and 0.049 wt.% for the imported ink, sample A, sample C and sample E respectively while the concentrations of dichromate oxide, $Cr_2O_3$ in imported ink sample, sample A, sample C and sample E were 0.792 wt.%, 0.011 wt.%, 0.012 wt.% and 0.016 wt.% respectively. These results show that the concentrations of these heavy metals and their oxides are very much higher in the ink imported hence, more toxic than the inks produced using local raw materials. Similarly, the results as contained in table 4.2 also indicate that after the imported ink, the ink produced using dye is more toxic followed by the ink produced using lamp soot while the ink produced using Sodom apple (*Calotropis procera*)soot having the lowest concentrations of oxides of heavy metals , is least toxic. In general, it can be concluded that the inks produced using the different pigments sourced locally are not toxic since they all contained oxides of heavy metals in very low concentrations as compared to the imported ink.

## CONCLUSION

From the results obtained, it can be concluded that an erasable and a non-toxic ink can be produced from local raw materials such as lamp black, carbon soot of Sodom apple (Calotropis procera ) and indigo (dye) as pigment; gum Arabic as binder together with a polyester polyvinyl acetate as an emulsifier; alcohol such as ethanol as a solvent and water as the diluent with other additives such as color and anticide as preservative.The results also showed that inks produced from dye have high refractive indices followed by those produced from lamp black and Sodom apple soot in that order, pH of the ink also indicates that inks from dye, soot obtained from Sodom apple and lamp black decreases in that order.Generally, the property of ink produced from any local raw material is dependent on the characteristics and compositions of the various constituents of the ink. However, the formulations used can result to ink with desired properties.

## Recommendation

The following recommendations were made based on the course of the research work:

Standard and automated equipment should be made available to improve the quality of ink and to make the production process fast and easy.

Entrepreneurs should invest in ink manufacturing at a smaller scale with high profit potentials and hence provide more job opportunities.

## References

[1] Ainsworth, Mitchell C. (1904), "Inks and their composition and manufacture" C. Griffin &Company limited.

[2] Audin, Maurice (2001),'A History of Technology and Invention.' Parrie Oak Publishers Maryville Missouri

[3] Barrow, W.J.,(1982) "Black Writing Ink of the Colonial Period," The American Archivist 11, (1948), p. 291-307.

[4] Fisher, Paul (1983). Drying operations and principles. Chicago: Adventure Press Plc

[5] *Kipphan, Helmut(2011). Handbook of print media: technologies and production methods (illustrated ed.)springer pp.130-144*

[6] Larrie R. A. and Deardurff A.Erasable inkjet ink composition. Retrieved 6th

[7] December, 2013 fromhttp://www.google.com/patents/WO20121661484AI?cl=en

[8] Martin Cul,J R. (2006). Chemical composition of a fountain pen ink. Journal of Chemical Education.

[9] Mark E. (1974). History methods of making ink. Newyork City; Mcgraw Hill Publishers

[10] Sharon J Huntington, (2004), "Think ink!" Christian Science monitorhttp://www.csmonitor/2004/0921/p18s02-hfk.

[11] Smith, Joseph A. (1992), "The pen and ink book: Materials and techniques for today'sartists" https://www.amazon.com> pen-Ink-Boo

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