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Production of Household Paint using Clay Materials

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Abstract

The use of clay materials for the production of emulsion paints was investigated. Two types of clay: White tinged with Purple and Smooth clay (WSP) and Grey Brown and Coarse clay (GBC), were used for the production of Emulsion Clay Paints (ECP). Conventional Chemical pigmented Paint (CP) was also produced as a control. Atomic Absorption Spectroscopy, (AAS) was used to determine the chemical composition of the clay and the concentration of heavy metals on the paints produced. Total organic content (TOC) and quality control tests were also carried out on the paints. The results of the analysis on the two clay types showed that they contained (45.26 and 47.370) % of silicon oxide and (38.26 and 35.72) % of aluminum oxide respectively. ECP has TOC values of (0.34-0.52) % while CP has TOC value of (0.29-0.31). The cost per litre of CP was (₦262.17) while that of ECP was (₦111.64), which is about 50% lesser.

1. Introduction

Paint is a term used to describe a number of substances that consist of a pigment suspended in a liquid or paste called vehicle such as oil or water. Paint provides an economic protection, preservation, decoration, aesthetic and adds functionality to structures [1]. Paint's composition largely determines its characteristics, usage and classification. By suitable variation of the type of proportion of the various constituents, paint can be made dry, glossy or flat as desired. Other properties such as permeability to water could be varied accordingly [2].

Production of household paints produces volatile organic compounds (VOCs) when conventional chemical synthetic pigments, solvent, resin and additives are used. Hence, care must be taken to avoid health hazards poised on both the producers and consumers at the point of application. Thus, there is need to consider the use of clay to serve as the pigment and extender content of the paint. There is a close relationship in the characteristics of clay (kaolin clay), and extender pigment (calcium carbonate) used in the production of synthetic pigmented paint [3].

Clay paints do not pollute the environment unlike the household conventional chemical paints, but regulate humidity, control condensation and are anti-static because they do not contain any plastics and attract little or no dust. Clay paints, as oppose to the normal synthetic paints only contains naturally occurring and renewable solvent, binders and fillers. Clay has natural smell and is quite good in producing paint for asthma patients and people with respiratory problem. Clay paints are non-toxic and VOCs free [4].

The study is aimed at producing household paint free of Volatile Organic Compounds (VOCs) by using, clay materials which are non-toxic.

2. Materials and Method

2.1 Materials

The materials used in the production of natural clay paint and conventional chemical paint are:

a) **Kaolin clay:** Two samples (A and B) were used. Sample A, which is white tinged with purple and smooth clay (WSP) was obtained from Ikorodu area of Lagos State while Sample B, which is grey brown and coarse clay (GBC) was collected from the Termite Hill, Yaba College of Technology, Yaba, Lagos State.
b) **Edible Starch:** Edible starch was purchased from local market at Ebute-Metta, Oyingbo Market, Lagos.
c) **Natural Pigment:** It was purchased from local vendor at the Ebute-Metta, Oyingbo market, in Lagos State. It was used majorly for production of natural clay paint.
d) **Natrosol:** Natrosol was purchased from chemical vendor at Ojota area of Lagos State. It was used in preparation of both natural and conventional chemical paints.
e) **Water:** The water used was de-ionized water; it was the main diluents of the paint. It was purchased from water vendor.
f) **Texanol:** Texanol was purchased from chemical vendor at Ojota area of Lagos State. It was used in preparation of both natural clay and conventional chemical paints.
g) **Ammonia:** Ammonia was purchased from chemical vendor at Ojota area of Lagos State. It was used in preparation of both natural clay and chemical conventional paints.
h) **Acrylic Binder:** Acrylic binder was purchased from chemical vendor at Ojota area of Lagos State.
i) **Calgon:** Calgon was purchased from chemical vendor at Ojota area of Lagos State. It was majorly used in the production of chemical conventional paint.

j) **Defoamer:** Defoamer was obtained from chemical vendor at Ojota area of Lagos State. It wass used in the production of chemical conventional paints.

k) **Calcium carbonate:** Calcium carbonate was purchased from chemical vendor at Ojota area of Lagos State. It was used in production of chemical conventional paint.

l) **Acticide:** Acticide was obtained from chemical vendor at Ojota area of Lagos State.

2.2 Procedure for Preparing Clay Pastes

The clay sample was oven dried at 120^{o} C for 30 minutes after which the samples were milled to obtain fine grain size using 65 micron sieve. 250g of clay samples A and B were measured out in three separate batches and kept in three different containers. A mixture of pigments blue and yellow was mixed in ratio 7:3 and added to the first batch of clay samples powder to form a paste in the ratio 1:1 and stirred for four minutes until consistency was achieved with a stainless steel pallet knife. A mixture of pigments blue and white was mixed in ratio 7:3 and added to the second batch of the clay sample powder to form a paste in the ratio 1:1 and stirred for four minutes with a stainless steel pallet knife until consistency was achieved. Pigment white was added to the third batch of the clay sample powder to form a paste in the ratio 1:1 and stirred for four minutes with a stainless steel pallet knife until consistency was achieved. 1.2 g of ammonia was added to the mixture and stirred for preservation.

2.3 Procedure for Preparing Clay Paints

15.5g of starch was mixed with 15.5g of de- ionized water and stirred till consistency was achieved. 33.58g of boiled de - ionized water was added continuously until a translucent semi-liquid was achieved and the mixture was stirred to consistency and allowed to cool down. 19.69g of green clay paste was added and stirred to consistency. 22.5g of acrylic binder was added and stirred to consistency. 0.9g of coalescing agent (texanol) was added and stirred to consistency. 0.15g of preservation (ammonia) was added and stirred to consistency. 1.85g of dissolved thickener (natrosol) in water in the ratio 1: 4 was added and stirred to consistency. The mixture was finally mixed using a roto miller. The procedure for producing green paint was repeated using blue clay paste and white clay paste.

2.4 Procedure for Preparing Conventional Chemical Paint

16.25 g of dispersant (calgon) was added to 430 g of water and stirred until consistency was achieved. 5 g of defoamer was added to reduce foaming and stirred until consistency was achieved. 5 g of inorganic pigments (titanium dioxide) was added to the mixture and stirred until consistency was achieved. 5 g of mixture of pigments blue and yellow was mixed in ratio 7:3 and added to the inorganic pigment in ratio 1:1 and stirred until consistency was achieved. 50 g of calcium carbonate (the extender) was added to the mixture and stirred until consistency was achieved. 5 g acticide was added to the mixture and stirred. 5 g of the thickener (natrosol) in water, in ratio 1:4 was added and stirred. 2.5 g of texanol was added and stirred. 3.75 g of ammonia was added and stirred. 25 g of binder (acrylic) was added to the mixture and stirred. The mixture was finally mired (milled) using roto miller for one hour. 5 g of mixture of pigment blue, green and white were added in turns to inorganic pigment in ratio l:l and stirred until consistency was achieved.

The notations for all the paints produced are stated below:

BWSP -	Blue Emulsion Natural Clay Paint produced with WSP
GWSP -	Green Emulsion Natural Clay Paint produced with WSP
WWSP -	White Emulsion Natural Clay Paint produced with WSP
BGBC -	Blue Emulsion Natural Clay Paint produced with GBC
GGBC -	Green Emulsion Natural Clay Paint produced with GBC)
WGBC -	White Emulsion Natural Clay Paint p roduced with GBC)
BCP -	Blue Conventional Chemical Paint
GCP -	Green Conventional Chemical Paint
WCP -	White Conventional Chemical Paint

2.5 Laboratory Tests

Atomic Absorption Spectroscopy, (AAS) was used to determine the chemical composition of the clay which are: titanium dioxide, calcium oxide, magnesium oxide, potassium oxide and sodium oxide. The concentration of heavy metals (chromium, cobalt, copper, iron and zinc) in the paints produced was determined using AAS. Total organic content (TOC) and quality control tests were also carried out on the paints. The following quality control tests were carried out on the paint samples at the quality control laboratory of Carl-Plus (CAPL) Ikeja, Lagos State and chemistry laboratory of the University of Lagos, Akoka, Lagos: Finesse Test, Viscosity Test, opacity Test, pH Value Test, Drying Time Test, Specific Gravity (SG) Test, Coarse Particle (CP) Test. All tests conducted were in accordance with NIS 278: 1990 [5].

3. Results and Discussion

3.1 Chemical Composition of Clay

Table 1 showed the elemental chemical constitutes of the clay samples. It could be observed from the Table that sample A contains lower percentage of silicon (45.26%) as compared to sample B which contains (47.36%). Both clay samples contain less than 65% silicon as recommended by World Health Organisation (WHO) (2005) [6]. Paint with more than 65% silicon can result in fibrosis, silicosis and lung cancer as reported by WHO. The result further showed that samples A and B contained silicon oxide (45.26 and 47.36) % and aluminium oxide (38.32 and 35.72), an indication that both clay samples contained kaolinite which forms the basis for the type of clay to be used for production of clay paint.

3.2 Total Organic Content (TOC) of Paints

The results of TOC on the paints produced are presented in Table 2. It could be observed from the table that Natural Clay Paint Produced with White Tinged with Purple and Smooth Clay (WSP) has TOC of 0.34, 0.36 and 0.35 for blue green and white paints respectively. Similarly, Natural Clay Paint Produced with Grey Brown and Coarse Clay (GBC) has TOC of 0.50, 0.52 and 0.51 for blue green and white paints respectively. The Conventional Chemical paint has TOC of 0.3, 0.31 and 0.29 for blue, green and white paints respectively.

The close range in TOC values is an indication that kaolin clay can readily replace the chemical pigment in paints. Based on the TOC, WSP is a better type of clay for producing natural paints since the values obtained are closer to those of conventional paints.

Table 1: Chemical Composition of Clay Samples

S/N	PARAMETER	LEVEL DETECTED (%)	
		SAMPLE A (WSP)	SAMPLE B GBC
1	SiO_2	45.26	47.36
2	$A1_20_3$	38.32	35.72
3	Fe_2O_3	0.77	0.55
4	$Ti0_2$	0.04	0.74
5	CaO	0.05	0.2
6	MgO	0.05	0.25
7	K_20	0.13	0.81
8	Na_2O	0.58	0.07
9.	L.O.I	14.81	14.30

Table 2: Total Organic Content (TOC) of Emulsion Paints

S/N	DESCRIPTION	Total Organic Content (%)		
		Blue	Green	White
1.	Natural Clay Paint Produced with White Tinged with Purple and Smooth Clay	0.34	0.36	0.35
2.	Natural Clay Paint Produced with Grey Brown and Coarse Clay	0.50	0.52	0.51
3.	Conventional Chemical Paint	0.30	0.31	0.29

3.3 Concentration of Heavy Metals in the Paints Produced

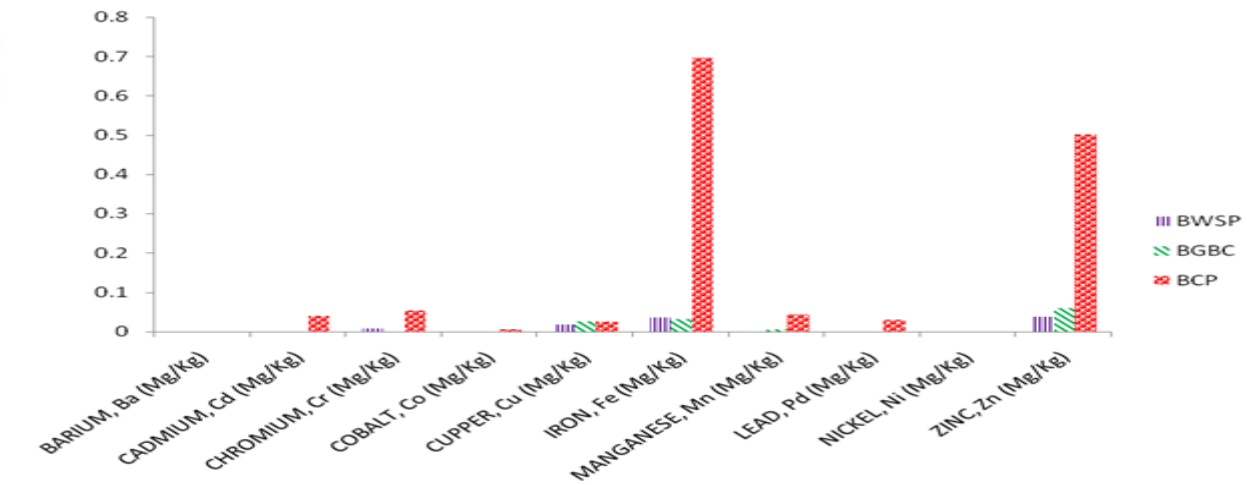
The concentration of heavy metals in the Blue, Green and White paints produced are presented in Figures 1 to 3 respectively. The heavy metals detected in all the paints are chromium, cobalt, copper, iron, manganese and zinc. Barium and Nickel were not detected at all in the paints produced. Cadmium, lead and titanium oxide were detected only in the conventional paints. The level of detection was limited to 0.001 mg/kg.

Figure 1 indicated that the concentration of chromium, cobalt, copper, iron, manganese and zinc for BWSP, BGBC and BCP are (0.007, 0.002, 0.018, 0.036, 0.002, 0.038); (0.003, 0.004, 0.026, 0.031, 0.006, 0.059) and (0.053, 0.005, 0.025, 0.696, 0.044, 0.502) respectively. It could be observed from the results that high concentration of iron (0.696) and zinc (0.502) were recorded for BCP which also have traces of cadmium (0.039), lead (0.03) and titanium dioxide (0.480).

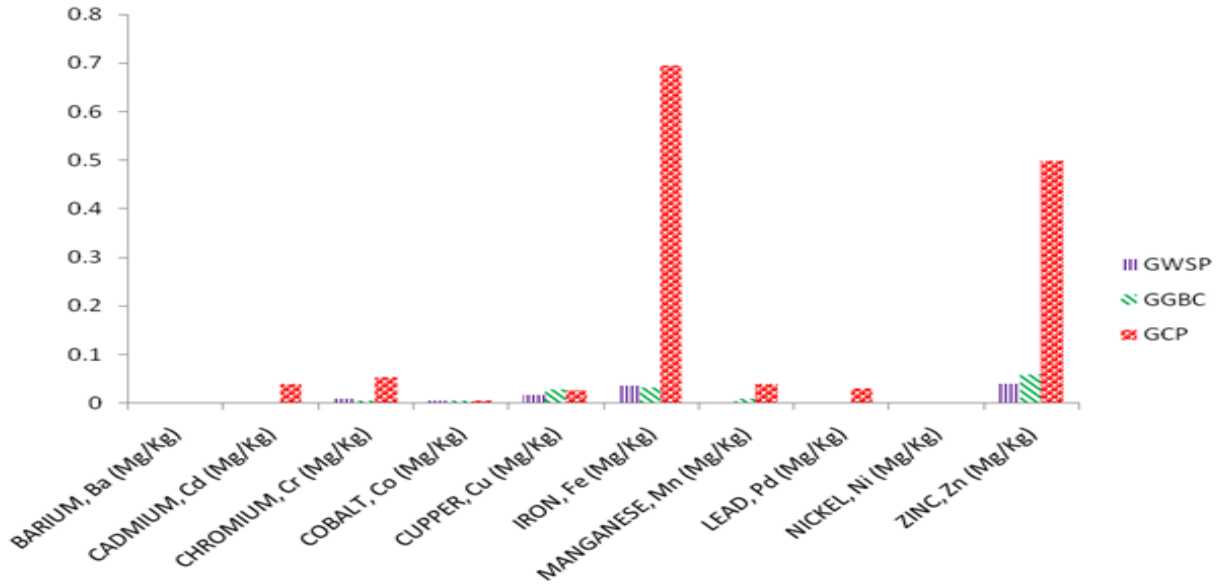
The concentration of chromium, cobalt, copper, iron, manganese and zinc for GWSP, GGBC and GCP as shown in Figure 2 are (0.008, 0.004, 0.016, 0.036, 0.002, 0.04); (0.005, 0.005, 0.028, 0.031, 0.008, 0.059) and (0.053, 0.005, 0.025, 0.694, 0.040, 0.50) respectively. High concentration of iron (0.694) and zinc (0.50) were also recorded for GCP with traces of cadmium (0.04), lead (0.03) and titanium dioxide (0.480).

As observed from Figure 3, the concentration of chromium, cobalt, copper, iron, manganese and zinc for WWSP, WGBC and WCP are (0.006, 0.003, 0.017, 0.036, 0.001, 0.039); (0.004, 0.004, 0.027, 0.031, 0.007, 0.059) and (0.053, 0.005, 0.024, 0.695, 0.043, 0.501) respectively. It was also noticed from the results that high concentration of iron (0.695) and zinc (0.501) were recorded for WCP with traces of cadmium (0.039), lead (0.03) and titanium dioxide (0.490).

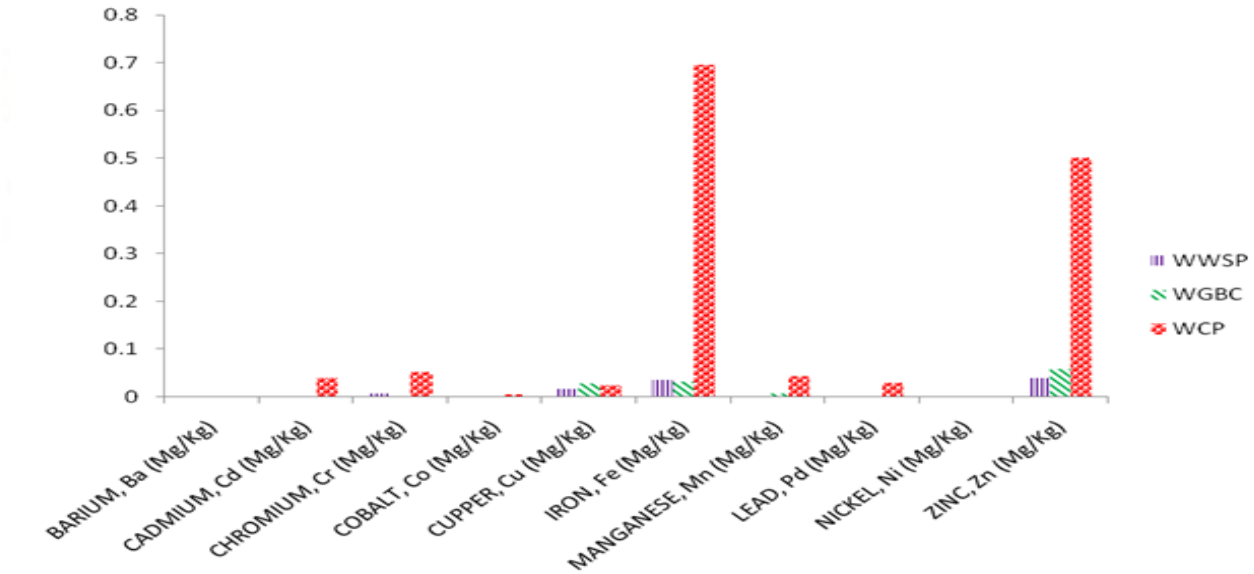
All the values detected are within the European Network of the Heads of Environment Protection Agencies (EPA Rule 4C: 2011) [7] of maximum value of 1.0 mg/kg. However, the results revealed that conventional chemical emulsion paints contained higher content of iron and zinc than clay paints irrespective of its colour. This is an indication that clay paints are safer to use than conventional chemical paints. Also, there were traces of cadmium, lead and titanium dioxide in all the conventional chemical paints. These elements, according to [6, 8] are principal causes of cancer to paint producers, painters and occupant alike.



Figures 1: Concentration of Heavy Metals in the Blue Paints



Figures 2: Concentration of Heavy Metals in the Green Paints



Figures 3: Concentration of Heavy Metals in the White Paints

3.4 Quality Control

The natural emulsion clay paints produced have a starchy smell. There is no piece of hard or solid particles in the paints produced normally referred to as "lumps". Also, there is no thin layer of membrane on the surface of the paint, normally referred to as "skin". No residue settles at the base of the container and no bubbles of air at the surface of the paint normally referred to as "foaming". The natural emulsion clay paint produced did not congeal, that is, it does not become thick and partly solid called "coagulation". The result conforms to NIS 273:1990 which stipulates that paint shall not have an offensive or irritating odour. The paint shall be free from lumps and skin. It shall not exhibit excessive setting. Caking, granulation, levering, colour separation and shall be easily stirred to smooth and homogeneous state.

The blue, green and white emulsion paints produced have viscosity values of (8.5, 8.4, 8.4), (7.7, 7.8, 7.7) and (7.5, 7.5, 7.0) poises for WPS, GBC and CP respectively, as shown in Table 3. All the paint samples satisfied the minimum requirement of 6.0 poises recommended by NIS 273:1990

The specific density of the paints produced ranges between 1.04 and 1.56 %. All the paints satisfied the NIS 273:1990 requirement of 2 % maximum. Similarly, all the paints produced met the surface dry and hard dry times of 20 and 120 minutes respectively as recommended by NIS 273:1990.

Table 4 showed that clay paints produced with WSP have pH value of (8.76, 8.74, 8.78) for blue, green and white emulsion natural clay paints respectively. Similarly, clay paints produced with GBC have pH values of (6.26, 6.28, 6.3) for blue, green and white clay paints respectively. The conventional chemical emulsion paints have pH value of (8.37, 8.38, 8.38) for blue, green and white paints respectively. Only WSP clay paints and conventional chemical paints conform to the NIS 273:1990 requirements of between 7.0 and 9.0. This further confirms that WPS is a better type of clay for paint production.

Table 5 showed the results of coarse particle content in the paints produced. Paints produced with WSP, GBS and CP have coarse particle content of (0.06, 0.07, 0.05) %, (0.09, 0.08, 0.07) % and (0.06, 0.07, 0.05) % for blue, green and white paints respectively. These values met the requirement of Nigerian Industrial Standard (NIS 273:1990) of 1% maximum coarse particle content. It could also be observed that the coarse particle content of WSP paints are the same with those of CP paints.

Table 3: VISCOSITY

PAINT SAMPLES	VISCOSITY RATING (POISES)	NIS REQUIREMENT
BWSP	8.5	6
GWSP	8.4	6
WWSP	8.4	6
AVERAGE VISCOSITY	8.43	6
BGBC	7.7	6
GGBC	7.8	6
WGBC	7.7	6
AVERAGE VISCOSITY	7.73	6
BCP	7.5	6
GCP	7.5	6
WCP	7	6
AVERAGE VISCOSITY	7.33	6

Table 4: pH of Paints Produced

PAINT NOTATION	pH VALUE	NIS REQUIREMENT
BWSP	8.76	7.0-9.0
GWSP	8.74	7.0-9.0
WWSP	8.78	7.0-9.0
BGBC	6.26	7.0-9.0
GGBC	6.28	7.0-9.0
WGBC	6.3	7.0-9.0
BCP	8.37	7.0-9.0
GCP	8.38	7.0-9.0
WCP	8.37	7.0-9.0

Table 5: Coarse Particle Content in Paints

PAINT NOTATION	COARSE PARTICLE (%)	NIS REQUIREMENT (%)
BWSP	0.06	1
GWSP	0.07	1
WWSP	0.05	1
BGBC	0.09	1
GGBC	0.08	1
WGBC	0.07	1
BCP	0.06	1
GCP	0.07	1
WCP	0.05	1

3.5 Solid Content

Table 6 showed that clay paints produced with WSP have solid content values of (11.99%, 11.98%, 11.95%) for blue, green, and white paints respectively; while those produced with GBC contains solid content of (10.66%, 10.65, 10.64%). The solid content values in the blue, green and white conventional chemical paints are (30.55%, 30.47% and 30.51%) respectively. All the paint samples satisfied the NIS 273:1990 requirement of 45% maximum solid content. The World Health Organisation (2005) [6] postulated that the solid content of paints is a measure of the VOC it contained. Thus, clay paints whose values of solid content are about one third that of conventional paints have less VOC and are safer to use.

Table 6: Solid Content in Paints

Paint Notation	Solid Content (%)
BWSP	11.99
GWSP	11.98
WWSP	11.95
BGBC	10.66
GGBC	10.65
WGBC	10.64
BCP	30.55
GCP	30.47
WCP	30.51

3.6 Cost Analysis of Paint

The cost analyses for natural clay and conventional paints are indicated in Tables 7 and 8 respectively. The cost per litre of clay paint is

₦111.64k while that of conventional paint is ₦262.17. Thus, the cost per litre of emulsion clay paint is about 50 % that of the conventional chemical pigmented paint.

4.0 Conclusion

From the analysis of the results of various tests conducted, the following conclusions are drawn:

(i) Clay can serve as replacement for chemical pigment in paint production.
(ii) WSP is a better type of clay than GBC for producing natural paints.
(iii) Natural clay paints have less VOCs based on the types of solvents, used in its preparation.
(iv) Natural clay paints are cheaper than the conventional chemical paints.

Table 7: Cost per Litre of Clay Paint

MATERIALS	QUANTITY PER LITRE (g/1)	COST PER LITRE (=N=)
Edible Starch	15.5	20.83
De-Ionized Water	64.4	56.25
Clay Paste	19.69	13.20
Binder (Acrylic)	22.5	10.00
Ammonia	0.15	8.75
Texanol	0.9	0.16
Thickner (Natrosol)	1.85	2.45
Total	**124.99**	**111.64**

Table 8: Cost per Litre of Conventional Chemical Paint

MATERIALS	QUANTITY PER LITRE (g/1)	COST PER LITRE (=N=)
Calgon	16.25	20.00
De-Ionized Water	127.5	82.27
Defoamer	5	12.50
Titanium Dioxide	5	20.00
Acticide	5	0.33
Natrosol	5	50.00
Ammonia	3.75	33.75
Binder (Pva)	25	15.60
Texanol	2.5	0.23
Calcium Carbonate	50	17.50
Pigment	5	10.00
Total	**250**	**262.17**

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