International Journal of Sciences

Research Article Volume 3 - May 2014 (5)

# Formulation and Characterization of Waterborne Paints from the Blends of Natural Rubber (NR) Latex and Polyvinyl acetate (PVAc) Emulsion

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**Abstract**: Natural rubber (NR) latex and polyvinyl acetate (PVAc) emulsion were blended into various compositions as follows: NR/PVAc (0/100; 25/75; 40/60; 50/50; 60/40; 75/25; 100/0). The resulting blends were used as binders in the formulation of waterborne paints which were then characterized for some physical properties such as total solids contents (TSCs), pH, viscosity, opacity, antifungal index, and water-repellency. From the results, the formulation based on binder composition, 25/75 (NR/PVAc) tends to demonstrate unique property profile that is favourable for waterborne paints. The resulting paint is suitable for both interior and exterior wall protection. The presence of natural rubber in the binder composition improves the water resistance and fluidity of the paint while PVAc simultaneously imparts the films' strength.

**Keywords***:* Polyvinyl acetate; Natural rubber; Latex; Waterborne; binders; blends

## INTRODUCTION

Waterborne paints are currently preferred to their solvent based counterparts because of stringent regulations by Environmental Protection Agencies (EPAs) to either eradicate or reduce to barest minimum, volatile organic compounds (VOCs) pollution-related problems. The latter are due to preparations and applications of solvent based systems. The use of waterborne coatings has made it possible to control pollution, to reduce risks of fire, and to improve aspects of occupational health and safety (Tambe *et al*., 2008; McGinnis, 1996; Kojima and Watanable, 1993). Solvent based systems are not encouraged, not only because they are major cause of environmental degradation but due to the fact that the petroleum which is the main raw material source is finite, i.e. non-renewable. The need to replace solvent based systems with waterborne systems has, therefore, become imperative. Consequently, much attention is now being directed to polymer latexes or emulsions, as an ideal response to the legislation against solvent-based systems, especially in the manufacture of surface coatings and paints.

Nigeria is endowed with wide plantation of largely unexplored natural rubber (NR) trees which are a good source of latex. Potentially, NR latex is a promising raw material for development of waterborne paints which can, therefore, be exploited to replace acrylics currently being imported for manufacture of waterborne paints. However, NR alone is easily susceptible to heat and light effects. In order to improve its resistance to these effects, this research is based on blends of NR with polyvinyl acetate (PVAc) emulsion for the formulation of the waterborne paints.

## 1. MATERIALS AND METHODS

**Materials:** The various materials used and their respective characteristics are shown in Table 1.

**Preparation of blends**: NR latex and PVAc emulsion were mixed in presence of a suitable stabilizer to obtain various blend compositions (NR/PVAc: 0/100; 25/75; 40/60; 75/25; 100/0, respectively) on dry weight basis.

**Paint preparation process**: The paint components (Table 1) were dispersed homogeneously in water inside a plastic bowl which had been previously charged with the required additives. The dispersion was aided by means of the Mechanical stirrer (Model: Heidolph RZ 2101 electronic mechanical stirrer).

**Preparation of buffered formalin**: The formaldehyde was converted to buffered formalin using the procedure described by Swanson (2011) and used as biocide (anti-fouling agent).

**Analyses of the produced emulsion paints**:
Total solids contents (TSCs) were determined in line with ISO (2008), while pH was determined using laboratory pre-standardized pH meter.

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Opacity was evaluated indirectly using UV-Visible Spectrophotometer (CAMSPEC M106) by measurement of transmitted light (%T) through very dilute dispersion of the emulsion paint samples at 430nm.
Viscosity was carried out by use of Brookfield Viscometer DV-I Prime at 30ºC (ambient temperature), at 30 RPM with Spindle No.2 in a 500ml LabScience (England) glass beaker.

Anti-fungal and anti-bacteria screening were done using the modified Kirby and Bauer method (1966), also known as disk-diffusion technique.

Drying: Set-to-touch drying method (ASTM 1973) was used to measure the drying rate of cast films of the paint samples.

Washability: Washability of cast dry films from substrates was carried out by soaking dry cast films of the paint samples while still on the substrate in water for a fixed period of time, after which they were then examined visually.

**Table 1**. Paint components, functions and grade

| Components | Functions | Manufacturer/Grade |
|---|---|---|
| Water | Dispersion medium | N/A |
| $TiO_2$ | White pigment | Industrial |
| $CaCO_3$ | Extender | Freedom Group, Benin city, Nigeria |
| Sodium Lauryl Sulphate | Wetting agent | Fissons Scientific, Loughborough, England |
| CarboxylMethyl Cellulose | Anti-settling agent | Kermel (Exchange capacity, 0.6mmol/g) |
| LV silicone oil | Anti-foaming agent | N/A |
| Formaldehyde | Biocide (anti-fungal agent) | BDH (37-41% w/v) |
| KOH | pH control | Sigma-Aldrich, Riedel-de-Haen, England |
| NR | Binder-1 | RRIN, Benin city |
| PVAc | Binder-2 | Solvochem Holland |

Key: N/A = Not available

## 2. RESULTS:

**Table 2**. Anti-bacterial characteristics of the emulsion paint samples

| Binder (NR) blend composition | Zones of inhibition/mm | | | | |
|---|---|---|---|---|---|
| | Bacillus subtilis | Staph. aureus | Streph. feacalis | Klebsilla pneumonea | Salmonella typhi |
| 0 | - | - | 05 | - | 09 |
| 25 | 04 | - | - | 09 | - |
| 40 | - | 11 | - | 07 | 05 |
| 50 | 09 | - | 11 | - | - |
| 60 | 03 | - | - | 05 | 09 |
| 75 | 21 | 13 | 11 | 05 | - |
| 100 | 18 | 09 | 09 | - | 07 |

Key: **-** (negative) means 'No activity' against the strains; values means 'Activity'

**Table 3**. Anti-fungal characteristics of the emulsion paint samples

| Binder (NR) blend composition | Zones of inhibition/mm | | | |
|---|---|---|---|---|
| | Aspergillus Niger | Aspergillus fumigatus | Aspergillus flavus | Penecillum spp. |
| 0 | 20 | 24 | 19 | 23 |
| 25 | 21 | 20 | 20 | 20 |
| 40 | 21 | 22 | 14 | 23 |
| 50 | 21 | 20 | 16 | 26 |
| 60 | 21 | 23 | 17 | 20 |
| 75 | 20 | 22 | 44 | 27 |
| 100 | 21 | 21 | 16 | 21 |

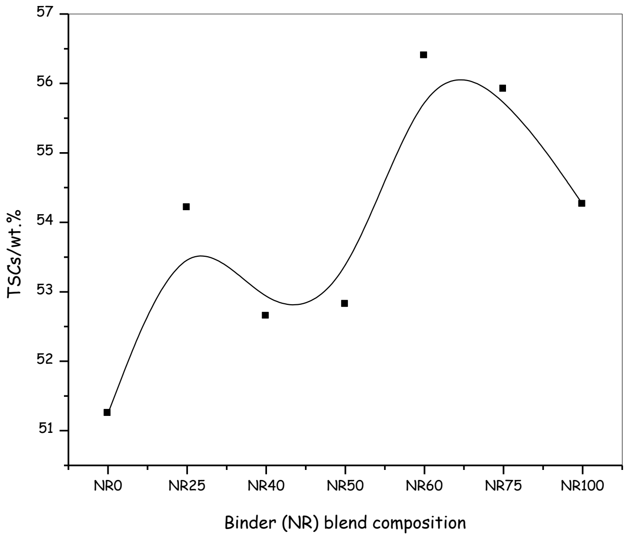


Fig.1. TSCs against paint's binder composition

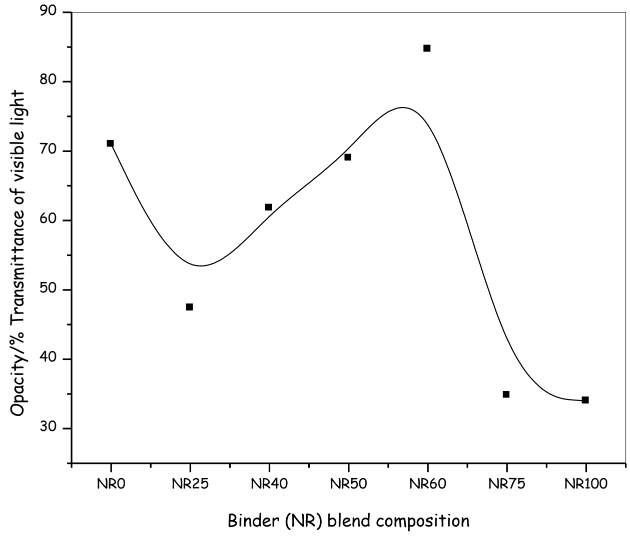


Fig.3. Opacity against paint's binder composition

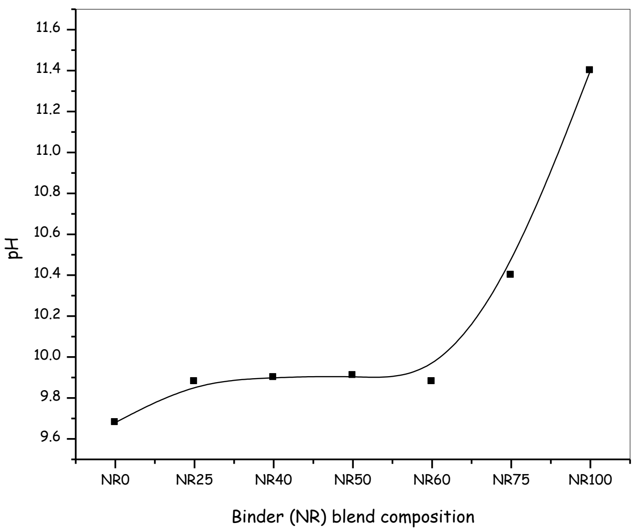


Fig.2. pH against paint's binder composition

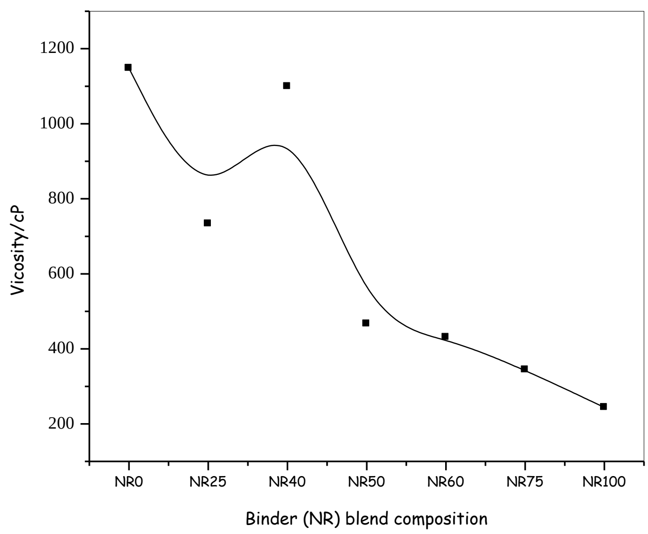


Fig.4. Viscosity against paint's binder composition

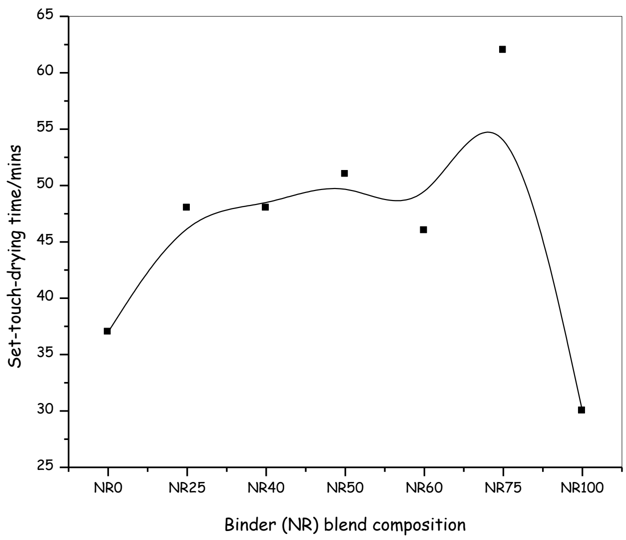


Fig.5. Set-to-touch drying time against paint's binder composition

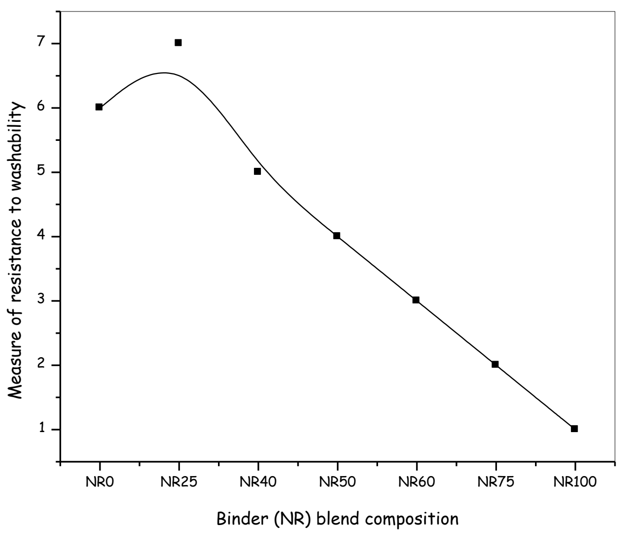


Fig.6. Dry films' resistance to washability against paint's binder composition
(**Key**: NR0 = 0wt. %NR; NR100 = 100wt. %NR; NR25-NR75 = blends)

## 3. DISCUSSION:

Anti-bacteria assay (Table 2) indicates that all the paint samples, except the two that are based on NR0 and NR40, show resistance against Bacillus subtilis; only three samples, namely NR40, NR75 and NR100, are resistant against Staph aureus; while four-NR25, NR40, NR60, and NR75, show resistance against Klebsilla Pneumonea, and again four, namely samples of NR0, NR40, NR60 and NR100, show resistance to strains of Salmonella typhi. A more critical observation reveals that the frequencies of resistance to the tested strains of bacteria summarized out as follows: NR0-two, NR25-two, NR40-three, NR50-two, NR60-three, NR75-four, and NR100-four. From these results, those samples with higher content of NR tend to exhibit higher frequencies of resistance level. Resistance, therefore, in this situation may be due to pH condition of the sample; the more alkaline is the medium, the more the inhibition.

The results of anti-fungal analysis are shown in Table 3. All the samples are resistant to the standard strains of fungi tested. This is supported by the fact that no sign of fungi growth was observed in any of the samples over the almost two-year period of storage to date. The highest value of resistance (44mm) and next to this value (27mm) was recorded by paint sample of NR75 against Aspergillus flavus and Penecillum spp, respectively. This is followed by sample NR50 with 26mm level of resistance against Penecillum spp, then NR0 with 24mm against Aspergillus fumigates.

TSCs (Figure 1.) shows two non-equivalent maxima seen at NR25 (small) and NR75 (big), respectively. By and large, there is a tendency towards higher TSCs with NR content. This might be due to increasing oxidative polymerization because of higher NR latex content in competition against the effect of pseudoplasticity of NR. The pH analysis (Figure 2) shows that all the paint samples are alkaline. Alkaline condition is reported (Bentley and Turner, 1998) to act as stabilizing effect to emulsion based paints. Expectedly, the lowest pH is due to NR0 sample. This is attributed to the fact that the binder here is inherently acidic (pH~4-4.5), which has only been modified by the process of formulation. Sample based on NR100 is the highest in pH due to high ammonia concentration in this binder from source. The pH of the samples however begins to stabilize as from NR25 keeping a plateau until NR60, from where it now increases sharply to a peak at NR100.

The result of opacity test is shown in Figure 3. The measures of opacity of NR75 and NR100 represent the lowest obtained, followed by NR25. From this point, the value increases gradually until it attains peak against NR60. Because opacity is assessed indirectly in this case by %transmittance of visible light that passes through the sample's dispersion, higher value of this parameter means lower opacity. Thus, the most opaque is the one with least % transmittance value.

From the viscosity results (Figure 4), there is a general decrease in this parameter with increase in NR content, attributable to pseudoplasticity of NR particles. However, a viscosity 'deep' on one hand and a 'peak' are seen against NR25 and NR40, respectively. This is may be due to unusual change in pH at these points, which have correspondingly impacted on the viscosity. Results of Set-to-touch drying tests indicate that all the samples undergo drying within 1h period maximum, which represents a reasonable drying time for emulsion based paints. The shortest drying time recorded against NR100 is due to effect of ease of oxygen diffusion through the thin film layer of this sample, thus causing it to undergo fast oxidative polymerization ("curing"). The drying of NR0 is accomplished by evaporation of water, followed by coalescence of the emulsion particles; the blends, by combination of curing and evaporation of water cum coalescence, while NR100 is evaporation of water with curing only. Resistance to washability by the dry films decreases with increasing NR content. A sudden jump in this parameter is seen against NR25, emphasizing again the uniqueness of this formulation.

In conclusion, the characteristics of the samples show somewhat striking dependence on the binder (NR) blend composition. It is noteworthy to observe that the formulation based on NR25 consistently shows unique behaviours in the following parameters: TSCs, pH, opacity, viscosity and washability. This makes this formulation a point of interest and further investigation for formulation.

**ACKNOWLEDGEMENTS**
The authors hereby appreciate Engnr. Felix Ogundipe of Upper River Niger Development Authority, Regional Water Quality Laboratory, Minna and Mr. Bala Amedu of the Department of Chemistry, Federal University of Technology, Minna for their technical assistance. Mr. Gabriel Ibikunle assisted with the measurement of opacity.

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