Article

Development and Statistical Modeling of Dirt Resistive Latex Façade Paint

Sheraz Ahmed Qureshi [1*], Amir Shafeeq [1*], Aamir Ijaz [2] and Muhammad Moeen Butt [3]

[1] Institute of Chemical Engineering & Technology, University of the Punjab, Lahore 54590, Pakistan
[2] Muhammad Nawaz Sharif University Of Engineering & Technology, Multan 66000, Pakistan; ijazaamir@yahoo.com
[3] Department of Quantitative Methods, University of Management & Technology, Lahore 54770, Pakistan; muhammad.moeen@umt.edu.pk

[*] Correspondence: sheraz7_2000@yahoo.com, amirengr@gmail.com

Abstract: A highly dirt resistant paint for building facades without chemicals harmful to nature and environment, is developed which resolves the unattractive disfigurement of building walls caused by dirt. The experimentation is scientifically and statistically planned with the aid of computer programming. It consists of a sequence of phases which include the selection of appropriate raw materials, adopting of Basic Language computer programming to generate a target population of paint formulations. The average PVC percentage is computed using theory and found to be 54.98% for the target population of 543143 paint formulations hence verifies the literature results. Experimentation and statistical analysis are performed to compare the classical conventional agitator with latest lab equipment like Nano mill and it is concluded that Nano mill performs better on the average than conventional agitator in preparation of paint formulations. Hence the sample of paint formulations is prepared on Nano mill and tested in laboratory using advanced available technology for the analysis and comparison of paint properties to determine the best paint formulation. The results are analyzed using Analysis Of Variance Technique (ANOVA) and it is concluded that the paint formulation named "O3" has the highest dirt resistance on the average. The final selected formula O3 is compared with three other competitor paints in market under natural environment for a period of almost one year. A regression model is also constructed to study the effect of environmental factors like time, temperature and humidity on dirt resistance of paints. It is found that O3 formulation is the best environment friendly which performs equally well with one competitor paint and has higher dirt resistance than two other competitor paint formulations containing harmful chemicals. The regression model of dirt resistance on variables including time, temperature and humidity shows that these factors are significantly affecting the dirt resistance of a given paint at 5% level of significance. 95.34% variation in the dirt resistance of a given paint is due to and explained by the given factors. The regression model is useful to predict the average dirt resistance of a given paint with a certain level of confidence. The project exemplifies the work of an applied research from conceptualization to successful commercialization for the paint industry.

Keywords: agitator; dirt; humidity; nano mill; temperature; time

---

1. Introduction

Paint is a liquid which spreads over a substrate in the form of thin layer and transform it into a solid adherent film [1]. Paint is comprised of many constituents including solvent, pigment, filler, additives and binder. An important issue in today's paint industry is to develop paint with dirt resistant property. Dirt resistance finds its application important in high rise buildings where maintenance is not an easy task. The life of paint could be increased by improving dirt resistance property [2]. Dirt is responsible for the growth of algae on the surfaces [3]. Dirt present on the façade painted surfaces promotes microorganisms growth by providing them nutrients. Dirt on façade paint proves is helpful for fungal growth [4]. Air borne yeast, fungi and algae spores find nutrients in the dirt adhering to façade paint. Spores multiply and form unsighted colonies [5]. An

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 8 January 2019 doi:10.20944/preprints201901.0076.v1

estimated loss of about one million dollar per year has been recorded caused by deterioration of façade paint surfaces due to colonies [6].

Environmental pollutants have negative impact on human health and may cause different diseases like cancer, neurons disorders, immune system malfunctioning, hormonal disorders, etc [7]. There are severe threats to human life due to environmental pollution and weather changes [8]. Environmental stresses are increasing with industrial development because of air pollution. It is very essential to control pollution sources for healthy and clean world [9].

It has been observed that waxy material present on the leaves help them to resist penetration of dirt. If surface of the paint film could be made similar to the surface of leaves then the chances of penetration of dirt particles would be less. Paints having the self-cleaning mechanism could keep the paint clean and dry. Fig. 1 shows that the frictional force and interaction between water droplet and surface of paint film could be reduced by the flow of water droplet over the dirt particles thus leaving a clean surface [10]. The deposition of dirt on latex façade paint film also causes color change of the paint film [11]. Dirt deposited on the surface of the paint is also a source of food for oligotrophic fungi over the surface of the paint [12-18].

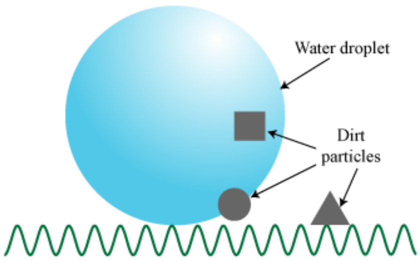

Figure 1: Self-cleaning effect on the surface of a leaf

The glass transition temperature (Tg) of the binder and pigment volume concentration (PVC) play a vital role in improving dirt resistance in the paint film. It has been observed that the dirt resistance is significant for paints that are formulated using polymers with higher TG [19]. If TG of acrylics is same then styrene-acrylic based latex paints offers more dirt resistance compared to acrylic based latex paints [20]. Dirt resistance also increases in the case of cross-linked binders [21].

Another effect of dirt over the surface of latex façade paint film is decrease in reflection coefficient, the solar heat reflectance and the temperature reduction performance in case of cool white coatings. It has also been observed that Zinc oxide (ZnO) nanoparticles are found efficient in the prevention of dirt accumulation over the surface of the paint [22].

It is internationally agreed that nanotechnology is a big revolution in production. Nanomaterials at present are being used in as electronics and cosmetics. Many other sectors for example polymeric composite materials are carrying out a lot of scientific and technological works and there are also plans for the wide range of projects being the nanomaterials in use [23]. It has caught tremendous attention and interest for the promotion of nanostructured coatings. All this is because of the unique properties that are at hand, offering possibilities of multifunctionality, reduction of thickness and great spectrum of applications relating technology [24,25].

With the passage of time, the atmospheric phenomena including humidity and temperature are major sources of dirt on façade paints. Multiple Linear Regression Modeling is an appropriate technique to study the impact of two or more than two independent variables on dependent variable [26]. In the present work, time (number of days), humidity and temperature have been taken as independent variables. The impact of these independent variables has been studied on dirt collection index (Dc) taken as dependent variable. Dc indicates the tendency of a surface to resist the accumulation of dirt. Dc reveals average dirt resistance.

The present study comprises of developing a new paint that could offer dirt resistance. In this work, different raw materials related to dirt resistance are suggested including an advanced process of paint manufacturing. Dirt resistive paint developed along with its Statistical Modeling. The present study focuses on developing an environment friendly paint which may have least negative impact on human health due to dirt resistance.

doi:10.20944/preprints201901.0076.v1

2. Application of visual basic programming for generating target population of paints theoretically

In this section the procedure adopted for generating the population paint formulae and selection of random sample is discussed. The program of paint formulations in visual basic (VB) is based on the following steps. The ranges of raw materials as per literature are generated with an interval of 0.001% by starting from minimum to maximum. This leads to 20001 values of water, 21001 values of Magnesium Silicate, 5001 values of Zinc Oxide, 10001 values of Anatase and Rutile Titanium dioxide, 2201values of dispersant, 401 values of 2-amino-2-methyl-1- propanol, 10001values of Styrene Acrylic, 19001 values of Polysiloxane emulsion, 901values of Hydrophobically modified Alkali Swellable Emulsion, 3001 values of Propylene glycol, 501 values of Mineral hydrocarbons and silicone-based surfactant. The tables of these ranges consist of over 700 pages stored in EXCEL sheet of which some are shown in Table given below.

On the basis of these ranges countably infinite number of paint formulae are generated by VB programming. However, the target population is taken from them by following the procedure discussed below.

These ranges are divided into three equal groups i.e. the lowest percentage range group, the middle range group and the uppermost range group. These groups are named as group 1, 2 and 3 respectively as shown in Table below.

One value from each group is selected randomly so that there are three different rows and twelve different columns corresponding to the twelve raw materials as shown in Table 1 In order to make one paint formulation one percentage value is selected randomly for each of the raw materials from each of the three groups. In this way the population count consisting of total possible number of formulae generated by VB programming 3^12 = 5,31,441 as shown in Table 2. As there are 531441 formulations generated encompassing more than 20000 sheets/pages on excel programming, therefore twenty paint formulae is shown in Table 2 for understanding the concept.

Table 1. Raw Material Value Selection

RO WATER	Talcum	Zinc-O	Anatase	Rutile	Dispersant	AMP	Binder	Wacker	Hase thick	Propylene	Anti foam
16.05	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.25
23.17	16.64	7.47	22.8	7.86	2	0.6	25.4	11.9	0.69	4.85	0.39
27.16	23.96	9.35	25.38	8.68	2.98	0.79	29.9	19.82	0.844	6	0.556

Table 2. Population Count

RO WATER	Talcum	Zinc-O	Anatase	Rutile	Dispersant	AMP	Binder	Wacker	Hase thick	Propylene	Anti foam	Total
16.05	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.25	**85.85**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.39	**85.99**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.556	**86.156**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	4.85	0.25	**86.88**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	4.85	0.39	**87.02**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	4.85	0.556	**87.186**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	6	0.25	**88.03**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	6	0.39	**88.17**
16.05	10	5	20	7	0.84	0.52	20	2	0.37	6	0.556	**88.336**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	3.82	0.25	**86.17**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	3.82	0.39	**86.31**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	3.82	0.556	**86.476**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	4.85	0.25	**87.2**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	4.85	0.39	**87.34**

16.05	10	5	20	7	0.84	0.52	20	2	0.69	4.85	0.556	**87.506**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	6	0.25	**88.35**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	6	0.39	**88.49**
16.05	10	5	20	7	0.84	0.52	20	2	0.69	6	0.556	**88.656**
16.05	10	5	20	7	0.84	0.52	20	2	0.844	3.82	0.25	**86.324**

Since the total of all formulae do not sum upto 100 independently. Adjustments are done as per following formula in every raw material to get total of 100 in each formula as shown in Table 3.

= (value of a raw material) x 100 / (total sum of a particular formula)

Table 3. Total sum 100 of population count

RO WATER	Talcum	Zinc-O	Anatase	Rutile	Dispersant	AMP	Binder	Wacker	Hase thick	Propylene	Anti foam	Total	PVC %
18.695	11.648	5.824	23.296	8.154	0.978	0.606	23.296	2.330	0.431	4.450	0.291	100.000	53.376
18.665	11.629	5.815	23.259	8.140	0.977	0.605	23.259	2.326	0.430	4.442	0.454	100.000	53.376
18.629	11.607	5.803	23.214	8.125	0.975	0.604	23.214	2.321	0.429	4.434	0.645	100.000	53.376
18.474	11.510	5.755	23.020	8.057	0.967	0.599	23.020	2.302	0.426	5.582	0.288	100.000	53.376
18.444	11.492	5.746	22.983	8.044	0.965	0.598	22.983	2.298	0.425	5.573	0.448	100.000	53.376
18.409	11.470	5.735	22.939	8.029	0.963	0.596	22.939	2.294	0.424	5.563	0.638	100.000	53.376
18.232	11.360	5.680	22.720	7.952	0.954	0.591	22.720	2.272	0.420	6.816	0.284	100.000	53.376
18.203	11.342	5.671	22.683	7.939	0.953	0.590	22.683	2.268	0.420	6.805	0.442	100.000	53.376
18.169	11.320	5.660	22.641	7.924	0.951	0.589	22.641	2.264	0.419	6.792	0.629	100.000	53.376
18.626	11.605	5.802	23.210	8.123	0.975	0.603	23.210	2.321	0.801	4.433	0.290	100.000	53.376
18.596	11.586	5.793	23.172	8.110	0.973	0.602	23.172	2.317	0.799	4.426	0.452	100.000	53.376
18.560	11.564	5.782	23.128	8.095	0.971	0.601	23.128	2.313	0.798	4.417	0.643	100.000	53.376
18.406	11.468	5.734	22.936	8.028	0.963	0.596	22.936	2.294	0.791	5.562	0.287	100.000	53.376
18.376	11.450	5.725	22.899	8.015	0.962	0.595	22.899	2.290	0.790	5.553	0.447	100.000	53.376
18.342	11.428	5.714	22.856	7.999	0.960	0.594	22.856	2.286	0.789	5.542	0.635	100.000	53.376
18.166	11.319	5.659	22.637	7.923	0.951	0.589	22.637	2.264	0.781	6.791	0.283	100.000	53.376
18.138	11.301	5.650	22.601	7.910	0.949	0.588	22.601	2.260	0.780	6.780	0.441	100.000	53.376
18.104	11.280	5.640	22.559	7.896	0.947	0.587	22.559	2.256	0.778	6.768	0.627	100.000	53.376
18.593	11.584	5.792	23.169	8.109	0.973	0.602	23.169	2.317	0.978	4.425	0.290	100.000	53.376

Considering these 531441 paint formulations as a population, the PVC% and Mean PVC% value is computed by the formulae given below:

The PVC of a system is defined as the volume percentage of solid particles in the system after film formation:

$$PVC = \frac{V_p + V_f}{V_p + V_f + V_b} \times 100\%$$

Where

Vp : total volume of all pigments in the system.
Vf : total volume of all fillers in the system.
Vb : volume of the non-volatile part of the binders in the system.

 doi:10.20944/preprints201901.0076.v1

The average PVC % for the population is computed as 54.98%. In order to determine the best processing mill, three Paint samples are randomly selected and prepared 5 times on each of the two available machines, Conventional agitator mill and Nano mill respectively. Paints are applied on panel cards to test gloss and particle size. The results are analyzed using SPSS 22 and are given in Table 4 & 5.

Table 4. Bootstrap for Independent Samples Test

	Mean Difference	Bootstrap[a]			
		Std. Error	p-value	95% Confidence Interval	
				Lower	Upper
Gloss	-23.39600	1.63048	.000	-26.54	-20.16

Unless otherwise noted, bootstrap results are based on 10000 bootstrap samples

Table 5. Bootstrap for Independent Samples Test

	Mean Difference	Bootstrap[a]				
		Bias	Std. Error	p-value	95% Confidence Interval	
					Lower	Upper
Particle_size	-23.39600	-.12323	1.65060	.001	-26.68330	-20.10687

Unless otherwise noted, bootstrap results are based on 10000 bootstrap samples

Based on 10000 bootstrap samples, p-value is less than 0.05, hence it is concluded that an average Gloss of paint is higher for Nano mill than that of Conventional Agitator mill at 5% level of significance. We are 95% confident that the mean Gloss for Nano is higher by at least 20.16 and at most 26.54 than the mean Gloss for Conventional Agitator mill. Based on 10000 bootstrap samples, p-value is less than 0.05, hence we conclude that the average particle size of paint is smaller for Nano mill than that of Conventional Agitator mill at 5% level of significance. We are 95% confident that the minimum particle size resulted from Nano mill exceeds by 20.11 from Conventional Agitator mill and the maximum particle size resulted from Nano mill exceeds by 26.68 from Conventional Agitator mill.

Keeping in view the cost, time and resources available, a sample of 70 paint formulations are selected randomly from the given population of 531441. These paints are prepared in nano mill to compare the population mean Dc values among paint formulae population. In order to compare the difference among 70 paint formulations with respect to average dirt collective index values (Dc values), one-way Analysis Of Variance (ANOVA) technique is used as shown below:

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Formula	69	5193	75.260	11.00	0.000
Error	630	4310	6.842		
Total	699	9503			

Since p-value is less than 0.05, therefore it is concluded that there is significant difference among population of paints with respect to mean Dc values at 5% level of significance and hypothesis of equal Dc value means is rejected. In other words, the sample evidence supports the fact there is difference between at least two paint formulations in the population of paint formulae with respect to average dirt collective index values. Tukey Test is used for evaluation of significant differences among means and significant estimated Mean Dc value difference as well as Confidence interval for Significant Mean Dc value difference among paint formulae population are also calculated. It is concluded that Paint formulae No 50 (newly developed paint) mean Dc value is significantly the highest among all paint formulae. It has an estimated mean Dc-value of 95.07. We are 95% confident that the highest mean Dc-value for the population of paint formulae lies in the interval (94.096, 97.345).

3. Preparation of sample of newly developed paint

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 8 January 2019 doi:10.20944/preprints201901.0076.v1

The preparation of newly developed paint formula number 50 which performed best among all paints is described below.

Nano mill slurry was prepared using 27.16 gm of water (TDS 0.01, hardness 4) in nano mill. 0.84 gm of dispersant (Dispex A-40, A solution of an ammonium salt of an acrylic polymer in water, BASF) and 0.6 gm of AMP-95 (2-Amino-2-Methyl-1-Propanol Solution, Angus Germany) were also added in the mixer of nano mill under constant agitation of 700 rpm. 10 gm of magnesium silicate 65 microns, 5 gm of zinc Oxide, 20 gm of anatase titanium dioxide and 7 gm of rutile titanium dioxide were added successively in the mixer of nano mill. The revolutions per minute (rpm) of the mixer were increased to 1000 rpm. The slurry was transferred through the nano mill chamber with the help of pneumatic pump whose pressure was regulated between 0.2 to 0.4 MPa. Rpm of nano mill was set at 2500. Nano mill output flow rate was adjusted at 2 gm/s. Fineness of dispersion of prepared mill base slurry was determined using Hegman-Type Gage [26] following the standard test ASTM-D 1210 and found to be 10 microns.

70.6 gm of nano mill slurry prepared above was taken in the agitated tank of conventional agitator. 20 gm of styrene acrylic copolymer emulsion was added in the tank under constant stirring at 1400 rpm. 6 gm of propylene glycol, 2 gm of Emulsion of a polysiloxane modified with functional silicone resin, 0.844 gm of Hydrophobically modified anionic thickener and 0.556 gm of mineral hydrocarbons defoamer were also added in the tank as shown in Table 6. All materials were blended at 1400 rpm for 10 minutes.

Table 6. Latex Paint Composition

Serial No.	Ingredients	Quantity
	Step-1---Nano mill Slurry	
1	Water	27.16
2	Dispersant	0.84
3	AMP-95	0.6
4	Magnesium silicate	10
5	Zinc oxide	5
6	Anatase titanium dioxide	20
7	Rutile titanium dioxide	7
	Step-2---Conventional Agitator	
8	Styrene acrylic	20
9	Propylene glycol	6
10	Emulsion of a polysiloxane modified with functional silicon resin	2
11	Hydrophobically modified anionic thickener	0.844
	Mineral hydrocarbons Defoamer	0.556
Total		100

4. Comparison of Newly developed paint with conventional paints under natural atmospheric conditions

Four slabs were painted with newly developed and conventional paints. The slabs were placed in an open area where they were exposed to sun light and environment was also humid. The slabs were placed in external conditions for about one and half year. Dc readings were taken after at least every 10 days interval along with temperature and humidity according to ASTM D-3719 (Standard Test Method for Quantifying Dirt Collection on Coated Exterior Panels). L, A, B values were noted by using spectrophotometer. L, A, B color space is a color-opponent space with dimensions L for lightness and A and B for the color- opponent dimensions. Color wheel indicating L, A, B values is shown in Fig 2.

 doi:10.20944/preprints201901.0076.v1

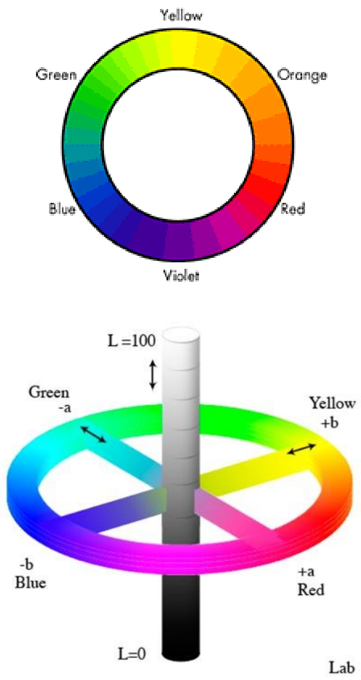

Figure 2: Color wheel indicating L, A, B values

5. Discussion and Results

The results obtained as per above conditions for four conventional paints are analyzed using SPSS 22 and Minitab-V-17 are discussed below. We assume the following notations for analysis purpose.

Y = Dirt Collection Index, Dc
X_1 = Number of days
X_2 = Temperature, ^{0}C
X_3 = Humidity, %
X_4 = 1, Newly developed paint
= 0, other paint
X_5 = 1, Conventional paint A, Brighto All Weather
= 0, other paint
X_6 = 1, Conventional paint B
= 0, other paint

In the model, Y is taken as dependent variable while X_1, X_2, X_3, X_4, X_5 and X_6 are assumed as independent variables.

The results are given in following tables and expressions.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 8 January 2019 doi:10.20944/preprints201901.0076.v1

Table 7: Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	6	768.754	128.126	223.91	0
Day1s	1	253.486	253.486	442.99	0
Temp	1	13.068	13.068	22.84	0
Humid	1	0.832	0.832	1.45	0.23
PaintNew1	1	15.14	15.14	26.46	0
Brighto1	1	7.169	7.169	12.53	0.001
Other-1	1	9.149	9.149	15.99	0
Error	113	64.66	0.572		
Total	119	833.414			

Table 8. Model Summary

R-sq	R-sq (adj)
92.24%	91.83%

Table 9. Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	95.576	0.772	123.77	0.0000	
Day1s	-0.01846	0.000877	-21.05	0.0000	2.05
Temp	0.0613	0.0128	4.78	0.0000	2.36
Humid	0.00867	0.00719	1.21	0.23	1.37
PaintNew1-1	1.005	0.195	5.14	0.0000	1.5
Brighto1-1	0.691	0.195	3.54	0.001	1.5
Other-1-1	-0.781	0.195	-4	0.0000	1.5

Regression Equation for PaintNew-1 Paint-type

$$Y = 96.581 - 0.018463 X_1 + 0.0613 X_2 + 0.00867 X_3 \qquad (a)$$

Refer to Table 7, Table 8 & Table 9. it is concluded that for newly developed paint, the Regression model of Dc values on Humidity, Temperature and Time, is significant at 5% level of significance. The Dc of newly developed paint is 1.005 units more than that of other paints. An increase in One degree in temperature increases Dc of the paint by 0.0613. An increase in One unit in humidity level increases Dc of the paint by 0.00867, however this change is statistically insignificant. Regression Equation (a) of dirt resistance on newly developed paint with Temperature and Humidity as Control Variables are used to predict Average Dirt Resistance for given no of days, temperature and humidity level. Refer Table 5, 91.83% variation in Dc is explained by Temperature, Humidity and Number of days.

6. CONCLUSIONS

The research is conducted and planned to theoretically generate a population of paint formulations and population mean PVC % is determined as 54.98%. nano mill is found to be the best processing mill in preparation of paint. The comparison of paint formulae with respect to dirt resistance yields newly developed paint as the best paint. The newly developed paint when compared with conventional paint samples performed better on the average with respect to dirt resistance properties. A statistical model for newly developed paint is developed to study the average Dc value for any given level of temperature and humidity with certain time period. Comparison among paints revealed that average dirt resistance of newly developed paint is 1.005 Dc units more than conventional paints. While observing the impact of time period on dirt resistance from the fitted model we note that due to one day increase in the time period there is significant decrease of 0.01846 Dc units in the average dirt resistance. An increase in temperature by one degree the Average dirt resistance significantly increases by 0.0613 Dc units. An increase in humidity by one unit the Average dirt resistance insignificantly increases by 0.00867 Dc units. The developed statistical model for newly developed paint is also used to predict the average Dc value for any given level of temperature and humidity with certain time period.

Author Contributions: Conceptualization, S.A.Q.; Methodology, S.A.Q., A.S. & A.I.; Software, S.A.Q. and M.M.B.; Validation, S.A.Q. & M.M.B.; Formal Analysis, S.A.Q. and M.M.B.; Investigation, S.A.Q & M.M.B.; Resources, S.A.Q. & M.M.B.; Data Curation, S.A.Q. and M.M.B.; Writing-Original Draft Preparation, S.A.Q., A.S. & A.I.; Writing-Review & Editing, S.A.Q., A.S., A.I. and M.M.B.; Visualization, S.A.Q. and M.M.B.; Supervision, A.S., A.I. and M.M.B.; Project Administration, S.A.Q., A.S., A.I. and M.M.B.

Funding: This research received no external funding.

Acknowledgements: The support from Brighto Paints Private Limited Pakistan to conduct this research work is gratefully acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. W.M. Morgans. Outlines of paint technology, third ed. Griffin, London, **1990**.
2. V. Gerald. Improved Dirt Pickup Resistance Critical to Future Coating Innovation. PCI journal, **2007**.
3. Y. C. Wee. Airborne algae around Singapore, International biodeterioration Bulletin. 18, I-5, **1982**.
4. T. Murtoniemi, M.R. Hirvonen, A. Nevalainen, M. Suutari. The relation between growth of four microbes on six different plasterboards and biological activity of spores. Indoor Air 13 (1), 65-73, **2003**.
5. J. Bentley, Turner, Introduction to paint chemistry and principle of paint technology, 4th edition, **1997**.
6. H. Winters. Latex paints. In: Rose, A.H. (Ed.), Economic microbiology. Microbial Biodeterioration, Vol. 6. Academic Press, Oxford, UK, pp. 307e321, **1981**.
7. W. Sanchez, Egea. Health and environmental risks associated with emerging pollutants and novel green processes**,** Environmental Science and Pollution Research, Vol. 25(7), pp 6085–6086, **2018**. https://doi.org/10.1007/s11356-018-1372-0.
8. R. Eldon, Rene, Li Shu, N. L. Piet, Lens, V. Jega. Tools, techniques, and technologies for pollution prevention, control, and resource recovery, Environmental Science and Pollution Research, Vol. 25(6), pp 5047–5050, **2018**.
9. T. Nakano, Y. Shibata, M. Denison, R. Weber. ESPR special issue on Asian environmental chemistry, Environmental Science and Pollution Research, Vol. 25(3), pp 7099–7100, **2018**.
10. W. Barthlott, C. Neinhuis. Purity of the sacred lotus, or escape from contamination in biological surfaces, **1996**.
11. K. Kitsutaka. Formula for the discoloration of external building materials. Durability of Building Materials and Components, p. 707–14. **1993**.
12. C. Grant, C. A. Hunter, B. Flannigan, A. F. Bravery. The moisture requirements of moulds isolated from domestic dwellings. International Biodeterioration, 25, 259-84. **1989**.
13. I.M. Ezeonu, J.A. Noble, R.B. Simmons, D.L. Price, S.A. Crow, D.G. Ahearn. Effect of relative humidity on fungal colonization of fiberglass insulation. Applied and Environmental Microbiology, 60, 2149-2151, **1994**.

 doi:10.20944/preprints201901.0076.v1

14. H. Viitanen. Factors affecting the development of biodeterioration in wooden constructions. Materials and Structures, 27, 483-493, **1994**.

15. J.C.S. Chang, K.K. Foarde, D.W. Vanosdell. Growth evaluation of fungi (Penicillium and Aspergillus Spp.) on ceiling tiles. Atmospheric Environment, 29 (27), 2331-2337, **1995**.

16. J.C.S. Chang, K.K. Foarde, D.W. Vanosdell. Assessment of fungal (Penicillium chrysogenum) growth on three HVAC duct materials. Environment International, 22, 425-431, **1996**.

17. B. Flannigan, P.R. Morey. Control of moisture problems affecting biological indoor air quality. ISIAQ-guideline. Task Force I. International Society of indoor Air Quality and Climate, Ottawa, **1996**.

18. K.K. Foarde, D.W. VanOsdell, J.C.S, Chang. Evaluation of fungal growth on berglass duct materials for various moisture, soil, use, and temperature conditions. Indoor Air, 6, 83-92, **1996**.

19. A. Smith, O. J. Wagner. Coating Technology, 68, (862), 37-43, **1996**.

20. R. Baumstark. Surface Coating. Int. B, 87(5), 210, **2004**.
21. W.Zeno, J. Wicks, N. Frank, Jones, P. Pappas, A. Douglas, Wicks. Organic coatings: science and technology, 3rd Ed. **2007**.

22. P.Roach, N.J. Shirtcliffe, M. Newton. Progess in superhydrophobic surface development, pp. 224–240, **2008**.

23. F. Klaus, F. Stoyko, Z. Zhong. Polymer Composites from Nano to Macro-Scale, Springer, USA, **2005**.

24. V.S. Saji. The impact of nanotechnology on reducing corrosion cost, in: V.S. Saji, R. Cook (Eds.), Corrosion Protection and Control Using Nanomaterials, Woodhead Publishing Series in Metals and Surface Engineering, Elsevier, Philadelphia, pp. 3–15, http://dx.doi.org/10.1533/9780857095800.1.3. **2012**.

25. S.H.M. Abdel, Ion Tiginyanu. Nanocoatings and Ultra-Thin Films: Technologies and Applications, Woodhead Publishing Series in Metals and Surface Engineering, Elsevier, Cambrigde, **2011**.

26. B. Robert McKay. Technological Applications of Dispersions, p. 43 (citing ASTM D1210-79 (1988). Marcel Dekker, Inc, **1994**.