ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN
2019 International Nuclear Atlantic Conference - INAC 2019
Santos, SP, Brazil, October 21-25, 2019

Agência Brasileira do ISBN
ISBN 978-85-99141-08-3

DEVELOPMENT OF AN ACRYLIC EMULSION PAINT WITH AQUEOUS CELLULOSIC DISPERSIONS BY ELECTRON BEAM IN CONCEPT OF LCA AND CIRCULAR

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ABSTRACT

Decorative paint, whether a polyvinyl or acrylic emulsion, is one of the most widely used coating forms in the world. According to the Brazilian Association of Coatings Manufacturers (ABRAFATI) [1], decorative paints accounted for 82.7% of the volume of all paints produced in Brazil (2018). In 2016, this segment had revenues of US $2,352 million and produced 1,548 billion liters in 2018. This shows the relevance of the sector, besides the Brazilian market being one of the five largest in the world. The aim of this project was to propose the application of the concepts of Life Cycle Assessment (LCA) and Circular Economy in a premium acrylic emulsion architectural paint and to improve the properties of this paint by the addition of aqueous dispersion of cellulose waste processed by electrons. The methodology used was a case study, which consisted of the preparation of dispersion of industrial cellulose waste in demineralized water at concentrations of 5% to 10%, processed with electron beam in absorbed doses of 5 kGy to 50 kGy. Key achievements include minimizing environmental impacts and identifying opportunities to improve environmental performance throughout the product life cycle. Another result was to identify a new application of nuclear technology in the industrial area, especially involving the real estate paints area. In addition, maintaining and improving the properties of premium acrylic emulsion, such as appearance, specific mass, coating power, color, solids content, pH, biodegradability, and the possibility of cost savings, were excellent results that met the product specifications Abrafati Quality Program [1]. It is concluded that the research represents an innovative business opportunity by joining the cellulose paint and tissue segments in a sustainable way (economically, socially and environmentally), reusing the dispersed cellulose waste in electron beam-treated aqueous solution and improving the properties paint within the technical process cycle as it recommends circular economy through the application of regenerative and restorative process principles.

Keywords: acrylic paint, electron beam, sustainability, cellulosic waste, circular economy, Life Cycle Assessment (LCA).

1.INTRODUCTION

The present study had as object the paint formed by acrylic emulsion. It is relevant because the segment accounted for 82.7% of the volume of all paints produced in Brazil in 2018 (equivalent to 1.280 billion liters of paint) and, in 2016, had a net revenue of US $2,352 million. The sector's growth between 2017 and 2018 was 0.85% in the volume of paint produced. In addition, the Brazilian paint market is one of the five largest in the world. The purpose of this research was the application of the concepts of Life Cycle Assessment (LCA) and Circular Economy in a premium acrylic emulsion architectural paint and to improve the properties of this paint by adding aqueous dispersion of cellulose waste processed by electron beam (EB). Among the main reasons that contributed to this work are: the survey of environmental impacts through the use of LCA - Life Cycle Assessment (LCA); the application of the technical cycle concept defended by the circular economy philosophy as a sustainable contribution form; use of cellulose paper waste in the recycling process, as raw material in the paint industry, avoiding the extraction of extra natural resources (cellulose, minerals, among others); treatability of aqueous electron beam cellulose dispersion for breaking lignin; the possibility of developing a new paint with recycled materials, within the quality standards of QSP - Sectoral Quality Program of the paint segment and, finally, improving the biodegradability and cost reduction of the final product, and making the painting more sustainable according to standard functional standards. As research instruments were used technical articles, theses, dissertations, technical standards, research in specialized websites and the use of results developed in this research through laboratory tests in Senai and Ipen.

2. CONTEXTUALIZATION

Based on previous research on the subject, no cases of development of premium type acrylic emulsion based paint coud be found and no other type of paint, even based on organic solvents and on that, were added with aqueous dispersion of cellulose waste at concentrations of 0.1%, 0.2%, 0.3%, 0.4%, 1%, 2.5%, 5%, 7.5% and 10%, and subsequently submitted to ionizing radiation treatment by EB at doses of 5 kGy to 50 kGy, so that the physical and chemical properties could be improved, according to the Sectoral Quality Program [1]. However, it should be mentioned that there are isolated records of some innovative applications of the use of cellulose, paint, polymeric materials such as: Ionizing radiation in packaging polymer [2,3]; Influence of ionizing radiation on PVA paint [4,5]. Effect of radiation control on polymers [6~~5~~]; Studies of the influence of ionizing radiation [7-9] on cellulose materials [10-12] among others, but none of these studies addressed directly and with the same objectives proposed for this search and Application study of disposable diaper cellulose wastes for the manufacture of squares and polymeric automotive componentes [13,14].
It is noteworthy that these wastes can be reabsorbed in the industrial environment itself, as recommended by the solid waste standard [15] and the National Solid Waste Policy [16] and the Brazilian National Environmental Policy [17], the LCA [19] and Circular Economy, within the technical cycle in search of a better industrial ecology, in the construction of environmental sustainability. The fact is that these global movements today propose to analyze the life cycle of products, from the birth of the product until its final disposal, as recommended by the LCA (Life Cycle Assessment and the Brazilian LCA standards [19-21].
According to the Circular Economy [22], there are two types of cycle: the biological, which represents the transformation of organic waste into biocompounds or energy, such as food, and the technical cycle, which is much more complex, which seeks reuse of waste by the industry. Through the technical cycle of Circular Economy, it is expected that the industry itself will find technical solutions so that the waste generated can be reinserted and absorbed in the production cycle itself. All of these movements based on these philosophies aim at global sustainability, seeking to ensure that natural resources can be preserved for future generations, and in order to do so, it proposes and encourages process residues to be reused and recycled through of the development of new technologies that enable reuse. These actions are positive and necessary to avoid waste being sent to industrial landfills, sanitary and even, in the worst case, to some kind of improper disposal of solid waste, such as the so-called “dumps”.

3. METODOLOGY

In the sampling plan, it is shown in Table 1, project was divided into phases. The study in question presented only the 2 initial phases already carried out, which were based on the

national standards [15,23] ~~9~~],[~~20~~] and the Brazilian waste policy[16] ~~10~~] Phase 1 completed to answer the question, can a water-based premium acrylic emulsion based paint with an ionizing radiation treated aqueous cellulose dispersion be added and meet Abrafati PSQ standards?
In this phase, the addition of the aqueous cellulose dispersion were 5% and 10% by mass and treated with electron beam (EB) radiation with absorbed doses of 5 kGy and 50 kGy, and added to the paints in a ratio of 10% by volume to meet the technical requirements of the product QSP - Abrafati Quality Sector Plan. Since the results of **Phase 1** were promising, in Phase 2 we sought to refine the research by testing the behavior of paint with lower concentrations of cellulose waste (0.1%, 0.2%, 0.3% and 0.4%) treated with the radiation technology at the same doses as **Phase 1**, i.e. 5 kGy and 50 kGy and added to the paint at the same concentration of 10% by volume as cellulose dispersion.

Table 1: Sampling Plan

Paint Sample Identification	**Sample Description**
Phase 1	
Control sample	**Premium acrylic emulsion based paint in white, without addition of cellulosic residue and without radiation treatment**
FCN 5%RC – 5 kGy	10% dispersion with 5% Cellulosic Waste treated with 5 kGy
FCN 5%RC – 50 kGy	10% dispersion with 5% Cellulosic Waste treated with 50 kGy
FCN 10%RC – 5 kGy	10% dispersion with 10% Cellulosic Waste treated with 5 kGy
FCN 10%RC – 50 kGy	10% dispersion with 10% Cellulosic Waste treated with 50 kGy
Phase 2	
Control sample	**Premium acrylic emulsion based paint in white, without addition of cellulosic residue and without radiation treatment**
FCN 0.1%RC – 5 kGy	10% dispersion with 0.1% Cellulosic Waste treated with 5 kGy
FCN 0.1%RC – 50 kGy	10% dispersion with 0.1% Cellulosic Waste treated with 50 kGy
FCN 0.2%RC – 5 kGy	10% dispersion with 0.2% Cellulosic Waste treated with 5 kGy
FCN 0.2%RC – 50 kGy	10% dispersion with 0.2% Cellulosic Waste treated with 50 kGy
FCN 0.3%RC – 5 kGy	10% dispersion with 0.3% Cellulosic Waste treated with 5 kGy
FCN 0.3%RC – 50 kGy	10% dispersion with 0.3% Cellulosic Waste treated with 50 kGy
FCN 0.4%RC – 5 kGy	10% dispersion with 0.4% Cellulosic Waste treated with 5 kGy
FCN 0.4%RC – 50 kGy	10% dispersion with 0.4% Cellulosic Waste treated with 50 kGy

4. ANALYTICAL RESOURCES

The physicochemical tests to determine the control parameters are being carried out: in the paint lab accredited by INMETRO[1] of Mario Amato Senai School, at Senai College of Environmental Technology; the characterization and practical application tests have been done in the Laboratory of the Technology Center of Radiation, at IPEN.

4.1. Research Methodological Steps: a) Separation of cellulose waste and quarting; b) Determination of possible microbiological contamination - microbiological test; c) Determination of moisture content; d) Drying of samples; e) Quantification of samples according to the Cellulose Waste Sampling Plan for the preparation of aqueous cellulose dispersion; f) Preparation of cellulose waste size dispersion in demineralized water by means

[1] **INMETRO** - National Institute of Metrology, Quality and Technology - It is a federal agency, linked to the Special Secretariat of Productivity, Employment and Competitiveness, Ministry of Economy /Brazilian government. Inmetro is responsible for managing the Conformity Assessment Programs within the Brazilian Conformity Assessment System.

of a high-power blender; g) Treatment of cellulose dispersion by electron beam, with absorbed doses of 5 kGy and 50 kGy; h) Preparation of the paint samples according to the Work Plan, adding them to 10% of the volume dispersion treated with radiation technology; (i) Quality testing to verify compliance with PSQ requirements; j) Analysis and discussion of the results obtained and introduction of improvement from the analysis; k) Application of the additive paint on tile to determine the performance of natural weathering; l) Analysis of results and introduction of continuous improvement; m) Patent application filed with the National Institute of Industrial Property (NIIP) and publications in indexed journals and Publication in scientific journal and participation in international and national congresses to disseminate the technologies developed.

4.2. Parameters to be met by Abrafati's PSQ (Sector Quality Program).

According to the SQP, survey paint samples should meet the following Brazilian standards to comply with the quality standards of premium class acrylic emulsion paint, as presented in Table 2.

Table 2: Main paint tests to be performed according to Abrafati's SQP

Item	TEST / STANDARD	METHODOLOGY
1	Determination of Abrasion resistance, without abrasive paste [24]	NBR 15078:2004
2	Determination of the Covering power of dry paint [25]	NBR 14942:2002
3	Determination of wet paint Coverability [26]	NBR 14943:2013
4	Color Determination [27]	NBR 15077:2004
5	UV Resistance [28]	NBR 15380:2015
6	Weathering resistance through Xenontest [29,30]	ASTM D2565: 2016 e ASTM G155:2013
7	Determination of Specific Mass [29]	NBR 5829:2014

4.3. Preparation of the cellulose dispersion in Phase 1 – it was performed at Ipen Radiation Technology Center Laboratory, as shown in Figures 1a and b. Dispersion was facilitated during preparation by shearing (reducing the size) of cellulose waste, by using scissors. The cutting process was manual after the cellulosic residues were dispersed in demineralized water, through the use of a low power mix to facilitate the dispersion and size reduction of the wet wipes cellulose fibers, as shown in Figure 1c.


(a)

(b)

(c)

Figure 1: Preparation of Cellulose Waste Samples.

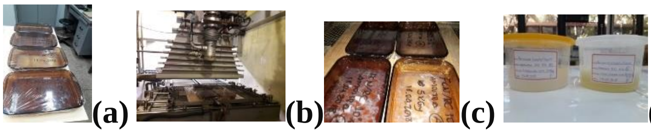
4.4. Preparation of cellulose dispersion in Phase 2 - accomplished at Ipen - Radiation Technology Center Laboratory. First, the samples of cellulose waste were separated and quantified on a Fortlab electronic scale, with a maximum capacity of 2 kg and an accuracy of 0.01 g, as shown in Figures 2a, and 2b, respectively, and subsequently sheared in a high-grade blender. Marchesoni brand power, with 25,000 rpm propeller rotation, maximum capacity of

2 L, to facilitate shearing of cellulose fibers and improve dispersion for 5 minutes, was used. See Figure 2c.

(a) (b) (c)

Figure 2: New equipment used to disperse in Phase 2.

4.5. Treatment of aqueous cellulose dispersion with irradiation technology: aqueous cellulose dispersion samples prepared in demineralized water from **Phase 1** at 5% and 10% by mass and from **Phase 2,** at 0.1%, 0.2%, 0.3% and 0.4% by mass were submitted to electron beam irradiation with absorbed doses of 5 kGy and 50 kGy, as shown in Figure 3 (a, b, c, d).



(a) (b) (c) (d)

Figures 3: Treatment of cellulosic dispersions by radiation technology in Phase 1.

4.6. Paint preparation - performed at Ipen - CETER Laboratory

4.6.1. Preparation of Phase 1 paint: for this phase, five paint samples were prepared, which were identified as: control sample (no residue addition and no electron beam irradiation) and samples with 10% by volume of dispersion (FCN 5% RC 5kGy); (FCN 5% RC 50kGy); (FCN 10% RC 5kGy); FCN 10% RC 50kGy).

4.6.2. Preparation of Phase 2 paint: Nine paint samples were prepared: control sample (no residue addition and no electron beam irradiation) and 10% by volume of samples dispersions at the following concentrations and radiation absorbed doses: (FCN 0.1% RC 5kGy); (FCN 0.1% RC 50kGy); (FCN 0.2,% RC 5kGy); (FCN 0.2% RC 50kGy); (FCN 0.3% RC 5kGy); (FCN 0.3% RC 50kGy) and (FCN 0.4% RC 5kGy); (FCN 0.4% RC 50kGy).

4.7. Moisture test - Test performed to determine the moisture content presented by the samples received from the partner company, manufacturer of wet wipes. After testing the moisture content, it was found that the result presented by the samples was close to **70.41%.** A Mettler Toledo electronic analytical balance was used, with a maximum capacity of 500 g and an accuracy of 0.01 g plus a greenhouse manufactured by Fanem, with a maximum temperature of 300 ºC;

4.8. Microbiological test - The microbiological characterization of organic material (cellulosic residues) was determined to avoid possible contamination of additive paint with cellulosic wipes [30,31].

4.9. Moisture Covering Power Test [26] – Test performed as determined by Abrafati's PSQ. This standard states that premium acrylic emulsion type paint should have a wet covering power ≥ 90%.

4.10.Specific Mass Determination Test [29] - The purpose of this test is to confirm that the raw materials have been added as specified. Based on this principle, it was verified if the additions of the aqueous cellulose dispersion, treated with radiation technology, had shown Control sample with some interference in the test results.

4.11.Dry Covering Power Test [25] This is a test to determine the ability of a paint to completely hide, opacify (cover) a surface on which it has been deposited. Any paint should have full coverage with as few coats as possible or as small/thin deposited dry film thickness as possible [1].

4.12.Yield Determination Test [25] This is a test performed to determine the amount of paint needed to cover a given area by means of a polymeric paint coating, taking into account the covering capacity and the defined thickness. According to what the standard specifies, the result should be expressed in m^2/packaging / finished [1].
4.13.Determination of the paints Abrasive Resistance Test [24] – This test measures the degree of resistance a paint has when it is washed and, therefore, under abrasion friction.
4.14.Paint appearance determination test –This test was performed only in **Phase1** - sample control and samples: FCN 5% RC 5kGy; FCN 5% RC 50kGy; FCN 10% RC 5kGy and FCN 10% RC 50kGy. The objective was to verify the paint behavior when applied to a particular substrate.
4.15.Color Determination and Color Difference Test [24] –This test measures color determination and color difference based on the CIELab[2] equation. The result of this test is expressed in number of cycles [1,32].
4.16.Natural Weathering Resistance –The purpose of this test is to verify the real behavior of the paint against natural weathering, which involves subjecting the paint to sun, rain, wind, heat, cold, among other climatic conditions, which a building may be subjected to in everyday life. The test consisted of using, as a substrate, a new ceramic tile. The preparation process was carried out by using two sandpapes, one with # 100 grain size and, then, with # 120 (Figure 6,). In the sequence, the tiles were wiped with a cloth to remove the dust generated in the sanding process (Figure 7). The tiles were painted by applying two coats of the control sample and the additive paint samples. After touch and total drying in the laboratory, the specimens were placed on the roof of the RTC - Radiation Technology Center, on August 1, 2019. The test will be carried out for six months, with monthly observation to follow and detect the paint performance.

			
New tile	**Sandpaper # 100; 120**	**Sanded Tiles**	**Painted and identified tiles**

Figure 6: Process for preparing masonry tiles (sanding with # 100 and # 120 sandpaper, dusting) for painting with cellulosic dispersion additive acrylic emulsion paint treated with radiation technology.

			
	Control sample, 0.1% RC 5kGy and 0.1% RC 50 kGy	**Control sample, 0.2% RC 5kGy and 0.2%RC 50 kGy**	**Control sample, 0.3% RC 5kGy and 0.3%RC 50 kGy**

[2]**Color system based on CIELab equation -** according to pseudo-Euclidean space, the coordinates are called L *, a *, b *. These coordinates mean: L * - represents the luminosity (light / dark); a * - represents the opposite colors red / green; b * - represents the opposite colors - yellow / blue; DE - color difference; DL - Brightness difference; DC - purity difference and DH - shade difference [30]

			
Control sample	**Control sample, 0.4% RC 5kGy and 0.4%RC 50 kGy**	**Control sample, 5% RC 5kGy and 5%RC 50 kGy**	**Control sample, 10% RC 5kGy and 10%RC 50 kGy**

Figure 7: Samples of tiles painted with acrylic emulsion paints and additives with 10% by volume cellulosic dispersion, in various mass concentrations (0.1%, 0.2%, 0.3%, 0.4%, 5% and 10%) treated with radiation technology (5 kGy and 50kGy), exposed to natural weathering.

5. RESULTS, ANALYSIS AND DISCUSSIONS

The results of the microbiological analysis are presented in Table 3. For the tests, two samples, called sample 1 and sample 2, were studied.

Table 3 :Microbiological test results [32,33]

Sample	Date of Analysis	Bacteria		Fungi	
		UFC/100 cm^{3} (*)	**Results**	UFC/100 cm^{3}(*)	**Results**
1	08.03.2019	0 (zero)	conform	0 (zero)	conform
2	08.03.2019	0 (zero)	conform	0 (zero)	conform

(*) UFC - COLONY FORMING UNIT

MICROBIOLOGICAL TEST - According to the results obtained, it is observed that the samples are compliant and free of contamination by any type of microorganism, what is a good indicator for the research to be continued, since the paint is not in danger to be contaminated. The methodologies used to determine the possible presence of microorganisms [32,33] in cellulosic residue samples were: Swab of surface colors and yeast[3] and Swab of total surface count of **microorganisms[4].**

Test results of Moisture Covering Power Test for phases 1 and 2 are shown in Table 4.

[3]**Swab surface colors and yeasts [32] -** POPMB - UNI174, AOACO Official Method 997.002 - POPMB - UNI184. ISO 21527-1:2008 Microbiology of food and animal feeding stuffs – Horizontal method for the enumeration of yeasts and mouds – Parte 1 Colony count technique in productys with waters activity greater than 0,95;

[4]Microorganism Total Count Surface Swab [33] - POPMB - UNI057, AOACO 2000. Official Method 990.12 – POPMB - UNI178. ISO 4833:2003 - Microbiology of food and animal feedingstuffs – Horizontal method for the enumeration microorganism – Colony count technique at 30ºC.

Table 4: **Wet Covering Power** [26]

Samples analyzed	**CP01**	**CP02**	**CP03**	**Results**	**Specification (%)**
Sample control	95.69	95.43	96.24	**95.79**	≥ 90
FCN 5%RC 5kGy	94.20	94.41	88.93	**92.51**	≥ 90
FCN 5%RC 50kGy	95.65	94.04	90.76	**93.48**	≥ 90
FCN 10%RC 5kGy	93.88	91.23	94.79	**93.30**	≥ 90
FCN 10%RC 50kGy	93.25	96.06	95.35	**94.55**	≥ 90
Amostra controle	95.88	96.48	96.73	**96.36**	≥ 90
FCN 0.1%RC – 5 kGy	96.51	96.17	97.24	**96.64**	≥ 90
FCN 0.1%RC – 50 kGy	96.44	96.03	96.07	**96.18**	≥ 90
FCN 0.2%RC – 5 kGy	96.14	96.15	97.44	**96.58**	≥ 90
FCN 0.2%RC – 50 kGy	95.55	96.76	96.66	**96.32**	≥ 90
FCN 0.3%RC – 5 kGy	95.58	96.73	96.50	**96.60**	≥ 90
FCN 0.3%RC – 50 kGy	95.84	95.87	95.80	**95.84**	≥ 90
FCN 0.4%RC – 5 kGy(*)					Not analyzed
FCN 0.4%RC – 50 kGy	94.74	94.86	95.84	**95.15**	≥ 90

CP - sample - Each sample was tested in triplicate**.**
(*) The FCN 0.4% RC - 5kGy (*) sample presented a transfer problem and was disregarded for analysis

WET COVERING ASSAY - According to the results presented in Table 4, it was observed that all samples were **COMPLIANT WITHIN SPECIFICATIONS,** wet covering power ≥ 90%. It should be noted that the average results of all **Phase 1** samples were 93.55% and **Phase 2**, 96.19%, indicating that the research path is correct and promising.
Following, there are some photos of the wet cover power test, shown in Figure 4. Analyzing the photos, it is possible to notice that there is, practically, no difference between the control sample (without additive of the treated cellulosic dispersion) and the samples of additive paints.

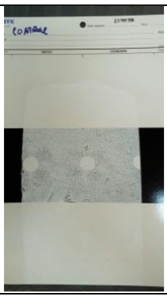
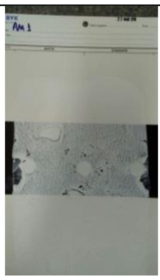
Control	**FC5%RC 5kGy**	**FC5%RC 50kGy**	**FC10%RC 5kGy**	**FC10%RC50kGy**
				

Figure 4: Results of wet covering power tests [26].

The determined specific mass results for the control samples and **Phase 1** and **Phase 2** are available in Table 5. The tests were performed by the Inmetro-accredited Senai Mario Amato School Paint Laboratory, in compliance with the standard - Determination of specific mass [31]

Table 5: Determination of Specific Mass [31]

Samples analyzed	Determination of specific mass (g/cm^3)		
	CP01	Results	Specification
Sample control	1.39	**1.39**	1.20 a 1.50
FCN 5%RC - 5kGy	1.36	**1.36**	1.20 a 1.50
FCN 5%RC - 50kGy	1.35	**1.35**	1.20 a 1.50
FCN 10%RC - 5kGy	1.34	**1.34**	1.20 a 1.50
FCN 10%RC - 50kGy	1.36	**1.36**	1.20 a 1.50
FCN 0.1%RC – 5 kGy	1.40	**1.40**	1.20 a 1.50
FCN 0.1%RC – 50 kGy	1.39	**1.39**	1.20 a 1.50
FCN 0.2%RC – 5 kGy	1.40	**1.40**	1.20 a 1.50
FCN 0.2%RC – 50 kGy	1.39	**1.39**	1.20 a 1.50
FCN 0.3%RC – 5 kGy	1.38	**1.38**	1.20 a 1.50
FCN 0.3%RC – 50 kGy	1.37	**1.37**	1.20 a 1.50
FCN 0.4%RC – 5 kGy(*)			Not analyzed
FCN 0.4%RC – 50 kGy	1.35	**1.35**	1.20 a 1.50

CP - sample - Each sample was tested in triplicate.(*) FCN 0.4% RC - 5kGy (*) sample presented a transfer problem and it was disregarded for analysis.

Specific Mass Assay - According to the results presented in Table 5, it was observed that all samples were **COMPLYING WITH THE SPECIFICATIONS.** This is a specific mass value in the range of 1.20 g/cm^3 at 1.50 g/cm^3, as specified by the standard - Determination of specific mass [31]. It indicates that the presented addition of the treated aqueous cellulosic dispersion does not interfere with the specific acrylic emulsion mass test.

The assay **Dry Covering Power Test** results are in Table 6.

Table 6: Determination of Hiding Power [25]

Samples	CP01 (m^2/L)	CP02 (m^2/L)	CP03 (m^2/L)	Results (m^2/L)	Specification (m^2/L)
Control	**8.48**	**9.05**	**9.17**	**8.90**	≥ 6
FCN 0.1%RC – 5 kGy	**8.21**	**8.33**	**8.07**	**8.20**	≥ 6
FCN 0.1%RC – 50 kGy	**6.96**	**6.72**	**6.80**	**6.83**	≥ 6
FCN 0.2%RC – 5 kGy	**6.92**	**6.77**	**6.76**	**6.82**	≥ 6
FCN 0.2%RC – 50 kGy	**6.72**	**6.71**	**6.78**	**6.77**	≥ 6
FCN 0.3%RC – 5 kGy	**9.06**	**9.26**	**8.91**	**9.08**	≥ 6
FCN 0.3%RC – 50 kGy	**7.87**	**7.66**	**7.48**	**7.67**	≥ 6
FCN 0.4%RC – 5 kGy(*)	**-**	**-**	**-**	**-**	Not analyzed
FCN 0.4%RC – 50 kGy	**7.04**	**7.15**	**7.34**	**7.18**	≥ 6

CP - sample - Each sample was tested in triplicate.
(*) The FCN 0.4% RC - 5kGy (*) sample presented a transfer problem and it was disregarded for the analysis.

Dry Covering Power Test - According to the results presented in Table 5, it was observed that all samples were **ACCORDING TO AND IN THE SPECIFICATIONS,** this dry coverage value presented higher specified value ≥ 6 m^2/L than that specified in the **Determination of dry covering** power [25]. It was shown that the addition of the treated aqueous cellulosic dispersion does not interfere in the dry coverage test. What demonstrates that the research led to the expected results.

This **Yield Determination Test** assay was performed and the results are in Table 7.

Table 7: **Determination Yield of a paint (m^2/packing) [25]**

Samples	CP01	CP02	CP03	Results	Specification
Control	**178.60**	**184.48**	**182.48**	**181.85**	≥ 110
FCN 0.1%RC – 5 kGy	**175.37**	**182.48**	**181.95**	**179.93**	≥ 110
FCN 0.1%RC – 50 kGy	**109.21**	**108.55**	**107.38**	**108.38**	≥ 110
FCN 0.2%RC – 5 kGy	**110.19**	**109.38**	**109.09**	**109.55**	≥ 110
FCN 0.2%RC – 50 kGy	**111.25**	**112.30**	**111.25**	**111.60**	≥ 110
FCN 0.3%RC – 5 kGy	**159.03**	**160.78**	**154.29**	**158.03**	≥ 110
FCN 0.3%RC – 50 kGy	**157.67**	**164.62**	**157.47**	**159.92**	≥ 110
FCN 0.4%RC – 5 kGy(*)					Not analyzed
FCN 0.4%RC – 50 kGy	**156.67**	**158.41**	**163.43**	**157.54**	≥ 110

CP - sample - Each sample was tested in triplicate.
(*) The FCN 0.4% RC - 5kGy (*) sample presented a transfer problem and was disregarded for analysis.

Determination of a paint yeld test. According to the results presented in Table 7, it was observed that, practically, the vast majority of the samples presented were within the specifications, that is, a presented yield value higher than the specified value, which is ≥ 110 m^2/ package, as specified in the standard [25] - Determination of dry covering power. The addition of treated aqueous cellulosic dispersion indication does not interfere with the dry coverage test, showing that the research is within what it was planned. It is, also, worth mentioning that only two samples from **Phase 2** - FCN 0.1% RC - 50 kGy and FCN 0.2% RC - 5 kGy presented results bordering the lowest specification limit and need to be re-analyzed so that these results may be confirmed or not. It is, also, interesting to note that, as the concentration of cellulosic waste increased, there was, also, an increase in the paint yield. In general, all other samples presented an average result higher than the specified average, ranging from 111.25 to 182.48m^2/package. These obtained values were inform that the increase of the yield, as a function of the cellulosic residues concentration differences, varied from 1.14% to 68.89%, in relation to the specification, when taking the results of each sample related to the specification. On average, it was observed that the results of the samples reached a value 39.12% above the specification (removing samples that did not meet the patterns).

The results of **Abrasive Resistance Test** should be expressed in number of cycles [1], as seen in Table 8.

Table 8: **Determination of Paint Abrasive Resistance (cycles) [24]**

Samples	CP01	CP02	CP03	Results	Specification
Control	> 400	> 400	> 400	> 400	>100
FCN 0.1%RC – 5 kGy	> 400	> 400	> 400	> 400	>100
FCN 0.1%RC – 50 kGy	> 400	> 400	> 400	> 400	>100
FCN 0.2%RC – 5 kGy	> 400	> 400	> 400	> 400	>100

FCN 0.2%RC – 50 kGy	> 400	> 400	> 400	> 400	>100
FCN 0.3%RC – 5 kGy	> 400	> 400	> 400	> 400	>100
FCN 0.3%RC – 50 kGy	> 400	> 400	> 400	> 400	>100
FCN 0.4%RC – 5 kGy(*)	> 400	> 400	> 400	> 400	>100
FCN 0.4%RC – 50 kGy	> 400	> 400	> 400	> 400	>100

CP - sample - Each sample was tested in triplicate.
(*) FCN 0.4% RC - 5kGy (*) sample presented a transfer problem and it was disregarded for analysis.

Determination of Abrasive Resistance of Paints Test. According to the results presented in Table 8, it was observed that all samples were **COMPLIANT WITHIN SPECIFICATIONS**. This is a displayed abrasive value greater than the specified value is **> 100 cycles,** as specified in [35] - Determination of paint abrasive resistance. The addition of the treated aqueous cellulosic dispersion does not interfere with the dry coverage test. It is also worth mentioning that the results presented exceeded the specification by 400%. This fact shows that the research findings are within the planned parameters.
The results of **Paint appearance determination test** are in Figure 5.

Control	FC5%RC 5kGy	FC5%RC 50kGy	FC10%RC 5kGy	FC10%RC50kGy

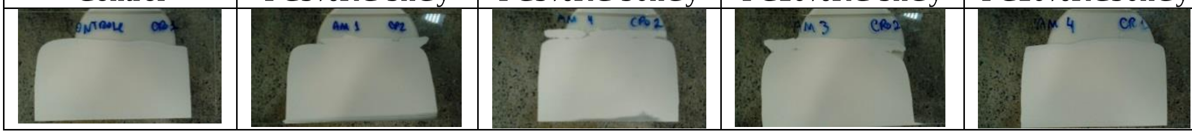


Figure 5: Results of the paint appearance test. Nascimento (2019)

Test of Paint Appearance Determination - This was a very important visual test to test continuity, so it was performed as early as **Phase 1**. According to the results shown in Figure 6, it was observed that all samples considered as **COMPLIANCE WITHIN SPECIFICATIONS**, namely: no lumps, dirt or any other material were found to impair the performance of the paint applied to the paint sample plates, prepared with the addition of 5% dispersion, and 10% treated with radiation technology, both at doses of 5 kGy and 10 kGy: the paints added in the ratio of 10% by volume. Therefore, it can be observed that the samples presented, practically, the same result and performance of the control sample. This fact indicates that the presence of the addition of the treated aqueous cellulose dispersion does not interfere with the dry coverage test. This result shows that the research is within the planned target.
The results of **Color Determination and Color Difference Test** are presented in Table 9.

Table 9: **Color Determination and Color Difference [27]**

Samples		**CP01**	**CP02**	**CP03**	**Results**
Control	**L**	96.06	96.06	96.05	96.07
	c	2.01	2.01	2.04	2.02
	a	-0.65	-0.67	-0.67	-0.66
	b	1.92	1.89	1.87	1.89
FCN 0.1%RC – 5 kGy	**L**	96.04	96.04	96.02	96.04
	c	2.00	1.99	2.01	2.00
	a	-0.66	-0.66	-0.66	-0.66
	b	1.87	1.86	1.88	1.87
FCN 0.1%RC – 50 kGy	**L**	96.06	96.03	96.03	96.04

	c	2.01	2.07	2.06	2.05
	a	-0.67	-0.67	-0.68	-0.67
	b	1.87	1.86	1.87	1.87
FCN 0.2%RC – 5 kGy	**L**	96.06	96.06	96.07	96.05
	c	2.01	1.96	1.99	1.99
	a	-0.66	-0.67	-0.69	-0.67
	b	1.86	1.85	1.87	1.86
FCN 0.2%RC – 50 kGy	**L**	96.08	96.06	96.06	96.07
	c	2.01	1.98	2.00	2.00
	a	-0.66	-0.66	-0.68	-0.67
	b	1.89	1.86	1.85	1.87
FCN 0.3%RC – 5 kGy	**L**	94.95	95.98	96.01	95.65
	c	2.02	1.99	2.04	2.02
	a	-0.66	-0.66	-0.68	-0.67
	b	1.85	1.87	1.88	1.87
FCN 0.3%RC – 50 kGy	**L**	95.94	95.95	95.99	95.96
	c	2.01	1.98	2.03	2.01
	a	-0.67	-0.68	-0.68	-0.68
	b	1.85	1.83	1.86	1.85
FCN 0.4%RC – 5 kGy(*)		Not analyzed			
FCN 0.4%RC – 50 kGy	**L**	95.90	95.87	95.88	95.88
	c	2.04	2.03	2.02	2.03
	a	-0.68	-0.68	-0.67	-0.68
	b	1.92	1.89	1.89	1.90

Determination and Color Difference - As there was no standard for comparison, the control sample was used as the “comparative standard”. Based on this sample, it was noted that there was little variation in the determination and color difference from the white standard of the control sample. From this finding, it can be inferred that the samples of Premium acrylic emulsion paints, additives with aqueous cellulose dispersion, in the various concentrations treated with radiation technology and analyzed as doses of 5 kGy and 50 kGy, interfering very little in the color parameter and maintaining similar properties to the standard sample. According to the results presented in Table 8, it was observed that all the samples considered were in accordance with and within the specifications, samples presented practically the same results and performance of the control sample. This indicates that the presence of the addition of the treated aqueous cellulosic dispersion does not interfere with the color difference and in the determination test. The fact shows that the research is within what was planned.

Natural Weathering Assay. According to the partial results shown in Figure 7a, b, it was observed that all samples considered are behaving **AS COMPLIANCE WITHIN SPECIFICATIONS**, by resisting natural weathering. It may be partially inferred that the samples are presenting, practically, the same results and performance as the control sample. This indicates that the presence of the addition of the treated aqueous cellulose dispersion does not interfere with the color difference and the determination test. This outcome shows that the research is within what was planned to. However, it should be noted that the final results may only be evaluated after February 1, 2020.

6. TECHNICAL FEASIBILITY

The results obtained for the project so far indicate great possibility of technical, economic and environmental viability. From the technical point of view, the analyzes presented above confirm this viability considering the condition of addition of 10% by volume of the aqueous cellulose dispersion treated with radiation technology. This type of treatment presented a satisfactory result observed by meeting the specification of the analyzed product. It was noted that increasing doses contributed to the improvement of properties as may be noted in the property wet covering power.

7. CONCLUSION

Considering the initial results obtained, it can be observed that it is possible to incorporate the moist industrial waste of cellulose paper by means of EB treated aqueous dispersion in a premium acrylic emulsion architectural paint, applying the concepts of Cycle Assessment Life (LCA) and Circular Economy, with improvement of its properties. It is a technically viable and sustainable project, considering the economic, environmental and social aspects.
In future research, the results of the quality requirements defined by Abrafati's QSP will be evaluated in samples containing aqueous cellulose dispersion with 0.1% to 10% mass-treated waste by EB with absorbed doses between 5 kGy and 50 kGy, added between 5% to 10% by volume in premium acrylic emulsion paints, as well as Life Cycle Assessment (LCA) and Circular Economy aspects.

ACKNOWLEDGMENTS

Sincere thanks to all CETER staff and management located at IPEN-CNEN/SP, also to Senai Mario School Paint Laboratory, located in São Bernardo do Campo, as well as to Sherwin William for supplying the paint.

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