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Multilayer System of Thermosetting Polymers and Specific Confining, Application to the Walls of the Hospital unit

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Abstract

The nature of materials structuring our health institutions promote the development of germs. The sustainability of nosocomial infections remains significant (12% and 15%). One of the major factors being the portland cement which is brittle and porous. As part of a national plan to fight nosocomial infections, led by the University Hospital of Blida, we opted for a composite coating, application by multilayer model, composed of epoxy-polyester resin as a binder and calcium carbonate as mineral fillers. The application of composite materials reinforce the wall coating of hospital units and eliminates the hospital infectious areas. The resistance to impact, chemicals, raising temperature and to a biologically active environment, gives satisfactory results.

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1. Introduction

Nosocomial infections are acquired in hospitals (OMS, 2005; INRS, 2007), Multiresistant bacteria are constituted in microbial clusters (biofilm). They find a favorable environment in the porous structure of coatings, primarily in the portland cement (Fukuzaki S et al., 1996; Liu Q et al 2000). As a result of the adhesion between microorganisms (bacteria, fungi, unicellular algae or protozoans) in exo-polysaccharide envelopes, biofilms remain a significant source of microbial contamination (Absolom D et al., 1987; Oliviera D et al., 1992). The hospital infectious areas that are triggered by the morphology of the coating in portland cement is an important link in the sustainability of hospital infections [Haras D., 2005; Bertron A et al., 2005; Bouzid M et al., 2013]. Due to the manufacturing process of portland cement (Table 1), the material is chemically sensitive (Grube H and Rechenberg W., 1989; Ghosh S N, 1983). Even if the macroscopic structure of the cement paste is uniform, the chemical composition, the crystal structure and the configuration of the solid phases are varied in the same inner paste (Zivica V, 2006; Neville A M, 2000; Berger R L and McGRegor J D, 1972). They are very sensitive to the

Table 1: *Composition of porthland cement*

80 %	20 %					
Ca CO_3	SiO_2	Al_2O_3	FeO_3	MgO	Na_2O	K_2O

Table 2: *Variety of co-polymer solvents polyester resin*

Styrene	The most widely used, light point 310° C
Methyl methacrylate	Improves transparency and resistance to aging
Diallyl phthalate	Low volatility, good thermal resistance for immersion and pultrusion
vinyl toluene	Removal of shrinking
chlorostyrene	Fire resistance
Triallyl cyanurate	High fire resistance (240° C)

Table 3: *Gel coat proprieties*

Reference	Application Instructions	Viscosity poises	Thixotropic index	Density
Euro gel GCTC 512	spraying	120 - 170	≥ 4	1,25

Table 4: *Results of bending test*

Parameters / Test piece	width b (mm)	height b (mm)	arrow Y (mm)	Force F (N)	E_f (N/mm^2)
Test piece 1	8,78	24,26	1,40	282	5,00*10^6
Test piece 2	8,82	24,37	1,36	308	5,64*10^6
Test piece 3	8,17	23,31	1,57	333	5,17*10^6
Test piece 4	8,92	23,31	1,40	304	5,17*10^6
Test piece 5	7,80	24,64	1,36	316	5,85*10^6
Average	**8,498**	**23,978**	**1,418**	**308,6**	**5,36*10^6**

Table 5: *The average of microbiological analysis of the wall (>1,6) of the blood transfusion center, Separation* Laboratory

Wall > 1,6 m					
Germs / Samples	yeasts (CFU/cm^2)	Molds (CFU/cm^2)	Mesophilic aerobic flora (CFU/cm^2)	Total coliform (NPP)	Faecal coliform (NPP)
Sample I	1,70.10^3	1,18.10^3	1,81.10^4	Absence	Absence
Sample II	3,33.10^4	1,83.10^3	2,64 .10^4	Absence	Absence
Sample III	2,65.10^4	2,12.10^3	5,90. 10^4	Absence	Absence
Average	1,56.10^4	1,71.10^3	3,45.10^4	Absence	Absence

Table 6: *The average of microbiological analysis of the wall (<1,6) of the blood transfusion center, Serology Laboratory*

Wall < 1,6 m					
Germs / Samples	Yeasts (CFU/cm^2)	Moisissures (CFU/cm^2)	Mesophilic aerobic flora (CFU/cm^2)	Total coliform (NPP)	Faecal coliform (NPP)
Sample I	1,66.10^2	1,66. 10	1,59. 10^3	Absence	Absence
Sample II	3,65. 10^2	5,41. 10^2	2,13.10^3	Absence	Absence
Sample III	4,91.10^3	8,33. 10^2	1,44. 10^3	Absence	Absence
Average	1,81. 10^3	4,63. 10^2	1,7.10^3	Absence	Absence

conditions of hydration and storage (temperature, humidity, pH) (George C M et al., 1997; - Bertron A et al., 2005; Revertag E., et al., 1992).

The volume porosity of the cement matrix can be higher than 10%, which gives the material a permeability to gas, to volatile solvents,airborne microorganisms and dust

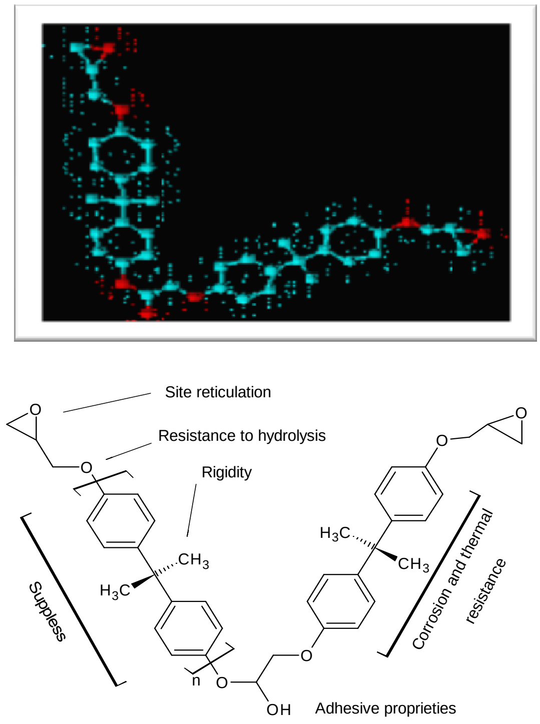
(Feldman R F and Cheng-Y H H., 1985).

The voids in the solid matrix of the cement present an active hydric state [Shi-Ping J and Grandet J., 1989]. The state of the system thermodynamically favors the "alkali-aggregate reactions (George C M et al., 1997).Studies show that the alkali - silica give birth to composites that propagate in capillaries and micro cracks. The swelling of these gels favors breakings (Ghosh S N., 1983). In addition, the atmospheric carbon dioxide in the capillaries favors the formation of $CaCO_3$ which weakens the cohesion of the solid phase of the cement (Bertron A et al., 2005). Thus, hydrolysis governs the pore water loaded with minerals and metal oxide. The dissolution and the microbial fermentation accentuate the phenomenon (Hearn N and Young F., 1999). The morphology induced by complex events, physic-chemical and biological of the cement paste appears, on its own, unable to meet the most stringent hygiene requirements of a hospital unit (Bouzid M et al., 2013). The sampling and microbiological analysis on wall surfaces of hospital units, medical analysis laboratory and the operating room have highlighted multi-resistant and resident pathogens (Bouzid M et al., 2013).Understanding of modes of existence in biofilms, emphasizes the coexistence between bacterial communities with the diffusion of endurance plasmids, adaptation to extreme conditions and nutrition. All these observations plead the urgency for an alternative in terms of additional coating.

As part of a plan to fight against nosocomial infections led by the University Hospital, we opted for a coating by composite materials "system of epoxy resin - polyester mineral fillers" in accordance with multilayer composite method described by (Hamelin P., 2002; Hachemane B et al., 2013).

Figure 1*: Hospital blood transfusion center of Blida worktop, Serology Laboratory beforework*

Schema 1*: Epichlorohydrin ether of bisphenol*



Schema 2*: Reaction between an epoxide and an amine function*

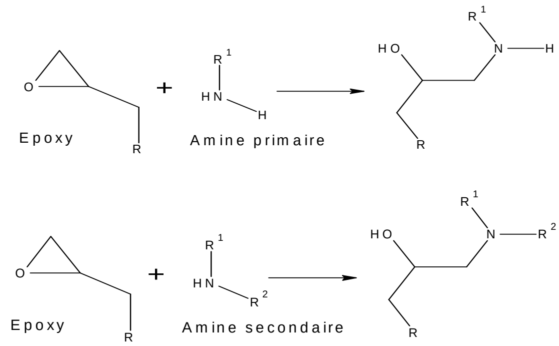


Figure 2*: Circular blender*

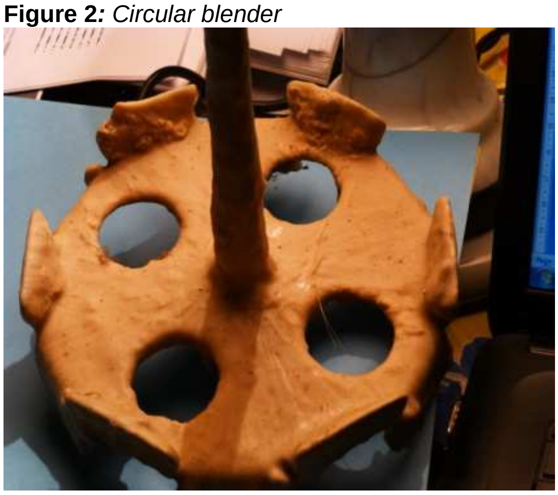


Figure 3: *Cross-section image to control intake air in the materials: Polyester resin - $CaCO_3$ powder*

Figure 4: *Blood Transfusion Centre, Serology Laboratory, coating of Portland cement*

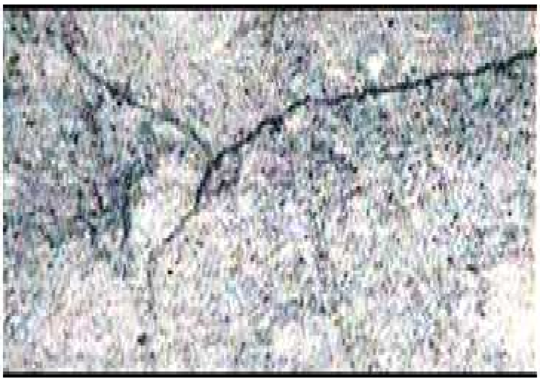


Figure 5: *Wave propagation (amount of motion) / increase in wall fringes*

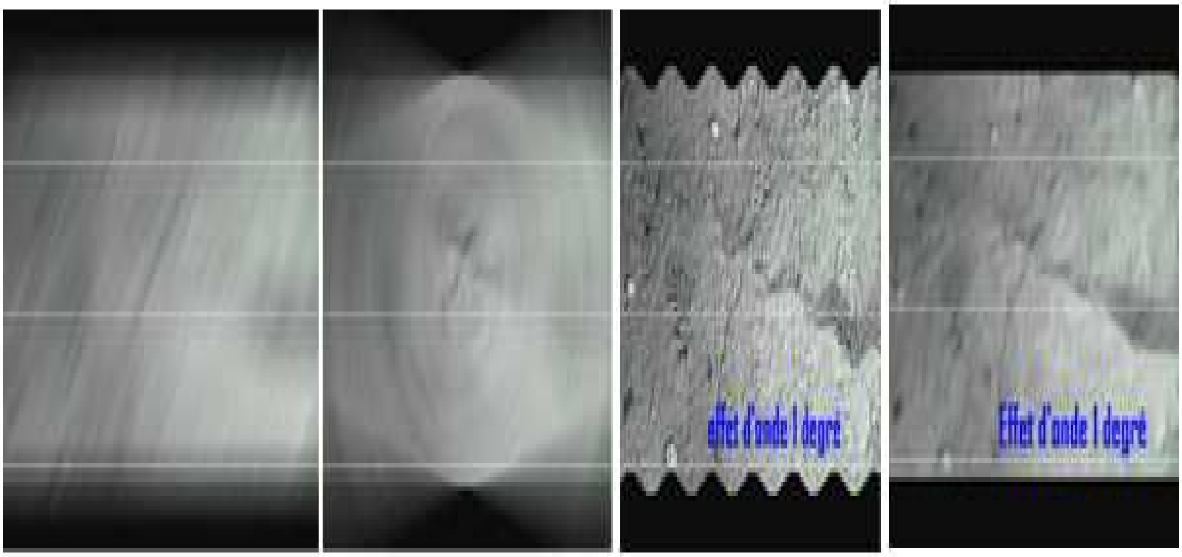


Figure 6: *Wall after impregnation in epoxy resin.*

Figure7: *Gelification*

Figure 8: *Polymerization (hardening)*

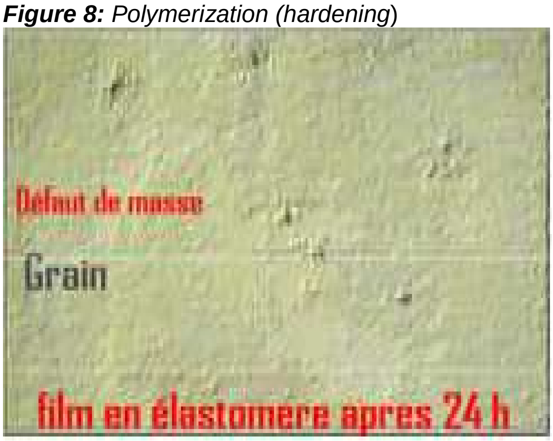


Figure 9: *Simulation test, photograph of composite materials on the wall*

Figure 10: *Temperature influence: behavior of the composite material.*

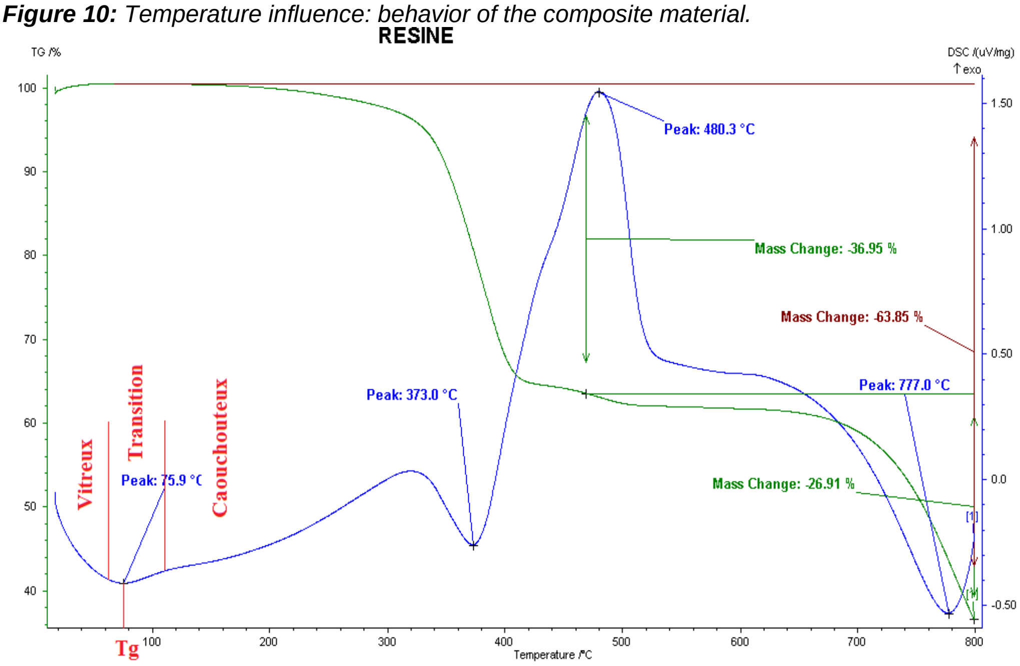


Figure 11: *Bending behavior of the tile*.

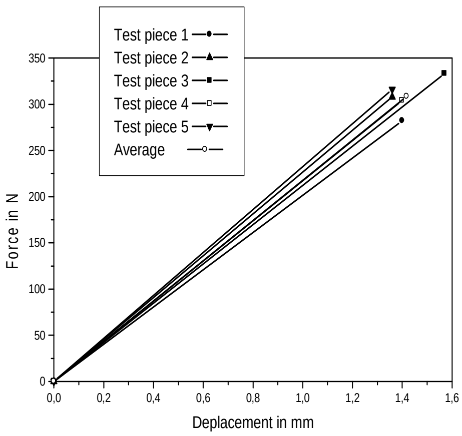


Figure 12: *Wall after impregnation in polyester resin.*

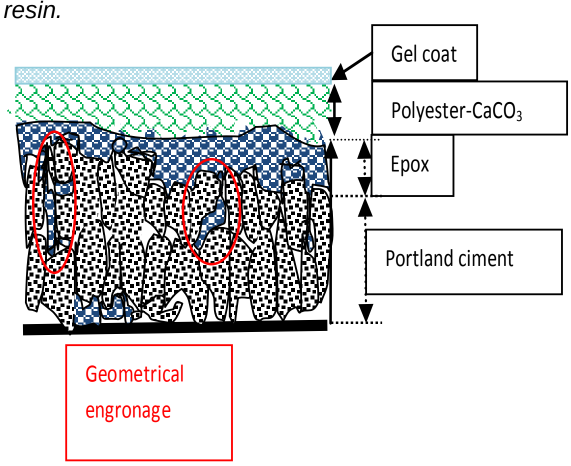


Figure 13*: Wall after impregnation in gel coat resin*

Figure 14*: Identification of yeasts, molds and mesophilic aerobic flora in the wall (> 1,6 m) of the blood transfusion center , Separation laboratory*

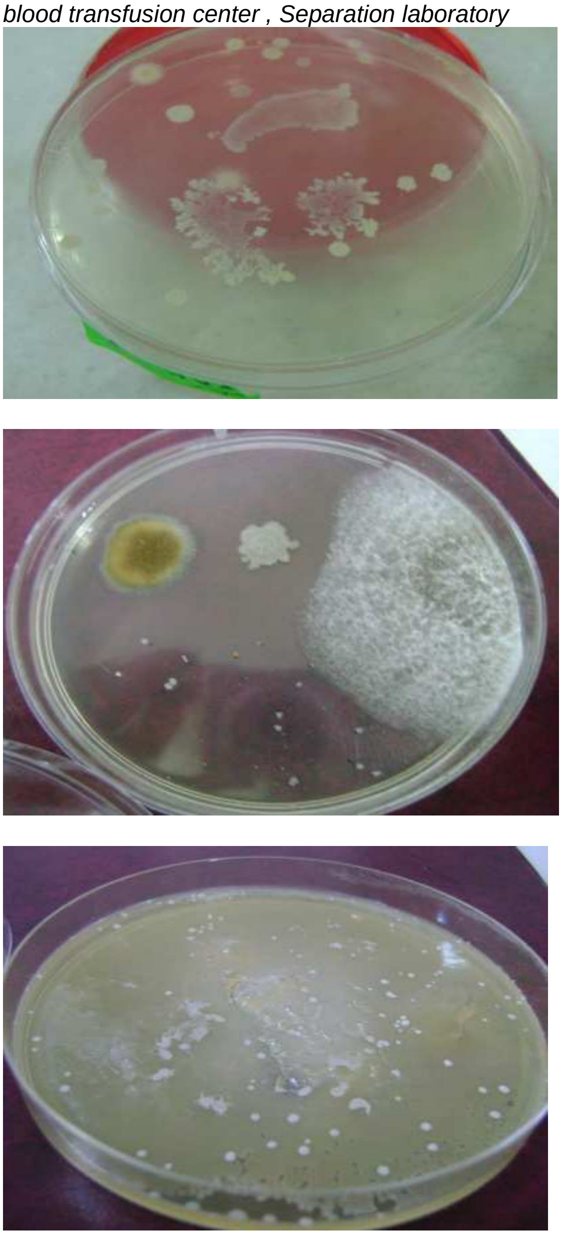
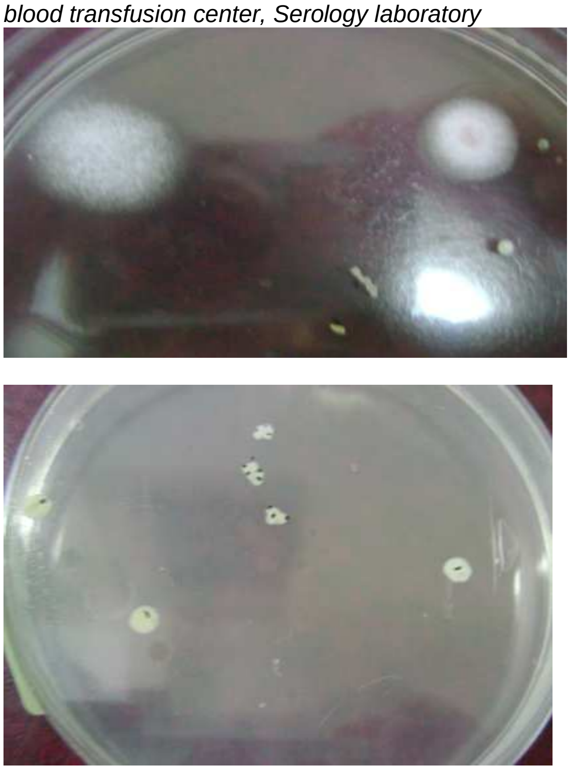


Figure 15*: Identification of yeasts, molds and mesophilic aerobic flora in the wall (<1,6 m) of the blood transfusion center, Serology laboratory*



We fancied strengthening the portland cement coating in four steps:

First step: Remediation of the cement surface: Treatment of the surface to be coated, in order to eliminate the layer of a very low consistency, in the a first place, but also to obtain a surface of a desired roughness and open the surface porosity [Toutanji H and Ortiz G., 2001] by compressed air under pressure followed by a thrust aspiration. This step helps to unclog pores, cracks, grain and capillary.

Second step: Injection of the epoxy resin diluted by spraying under pressure. This step allows the filling of pores, cracks and capillary. It happens in two stages:

- First slow spraying with very diluted solutions (high penetration, delayed reticulation).

- Second spray after 24 hours, less diluted, shortened exposure time (filling of fringes, capillaries and cracks).

Formulation of the pre-polymer is the diglycidyl ether of bisphenol resulting from the condensation of epichlorohydrin and bisphenol in an alkaline medium. This product represents a good compromise between several desirable properties (Schema 1).

The choice is based on the assessment of the viscosity of the reactive mixture, its lifetime, the responsiveness of the system during the implementation, the behavior of epoxy resins in alkaline medium (Vaysburd A M., 2001). This was confirmed in the case of representative water of the pore water of the concrete (pH ~ 13.5) (Wu L et al., 2004). The two main classes of organic compounds that can open the oxirane ring are the amine products and the anhydrides of diacids which respectively give rise to polycondensation reactions and chain polymerization.

Aliphatic polyamines (R - NH2) hardening in 24 hours at ambient temperature, with a duration of use of 1/2 hour to 1 hour. - Polyamino amides (R - CO - NR ') with this type of hardener the duration of use is longer and gives more flexibility to the finished product.

Third step: Application of composite materials “polyester resin- calcium carbonate. Application of composite materials “polyester resin- calcium carbonate
Formulation: the mortar is prepared by mixing equal weight of pre-accelerated polyester resin and the powder of calcium carbonate under vigorous mechanical stirring. The homogenization is obtained by a circular wheel with inverted teeth and a diameter of D = 160 mm, rotation speed Ω = 550 rev / min, 15 minutes on average per batch of paste 10 Kg (Figure N °2). The grain of $CaCO_3$ has a diameter of 1.0 micrometer (Fig N °3).
Hardener: polyester resin catalyzed plus calcium carbonate finely prepared in a 50/50 ratio.
.
Fourth step: Application of gel coat finish by the method of spraying:
Gel time / min / mass 200 g / 20° C / 1 % Hardener

***2.1**. Materials and Methods in the Analysis of Microbiological Pollution in the Hospital*

We conducted an analysis of the internal environment of the hospital (air, wall, floor and bench), we used the technique of swabbing, an indirect method of sampling surface. This easy technique can be used for large areas, non-absorbent, irregular or with corners (Squinazi F and Festy B., 1985). The project of European Standards CEN/TC 243 will standardize the swabbing (European standards CEN/TC 243., 1994). After the dry swabbing with cotton swabs, the sample is incubated in different growth mediums according to the nature of the organism to search (Lebreton-Doussaud V et al., 1998).

***2.1.1** Ambient Air*
The technique used for the determination of airborne bio-contamination is to lay open Petri dishes in different places with the growth medium according to the category of the germ to determine. The particles suspended in the air are generated by sedimentation on the surface of the growth medium. After an exposure to the air of 15 to 20 min, the Petri dishes are incubated at 30° C for 3 days (Lebreton-Doussaud V et al., 1998).

***2.1.2**. Wall, Floor and Bench*
Coliform: culture medium: Brilliant green lactose bile broth. Incubation at 37° C for 48 h. Confirmatory test: culture medium: Bromocresol purple lactose broth + peptone water for indole. Incubation at 44° C for 24 h [Lebreton-Doussaud V et al., 1998].

Staphylococcus aureus: culture medium: Giolliti Cantoni broth. Incubation at 37° C for 48 h. Isolation on selective solid medium: culture medium: Chapman agar. Incubation at 37 °C for 24 h (Lebreton-Doussaud V et al., 1998).

Total mesophilic flora: culture medium: Plate Count Agar. Incubation at 30° C for 72 h (Lebreton-Doussaud V et al., 1998).

Streptococci: culture medium: Roth broth. Incubation at 37° C for 48 h. confirmatory test: culture medium: Litsky broth. Incubation at 37° C for 24 h (Lebreton-Doussaud V et al., 1998).

Yeasts and molds: culture Medium: oxytetracycline glucose agar. Incubation of 20-25° C for 3 days (Lebreton-Doussaud V et al., 1998).

3. Results and discussion

***3.1**. Application: portland cement*
After the demolition of tiled splashbacks, the coating of portland cement ((NF 197-1) is applied (masonry work) - the time of rest observed (30 days)-. The traditional material used, portland cement, has physical characteristics unsuitable to the hospital milieu. The shrinking of 2 to 5 mm after one month of its application is observed; its overcautious aspect with a surfacing rich in ground faults (Figure 4) cause the formation of fringes, fragmentation and detachment of surface coating.

The shrinking induced by the evaporation of water is aggravated by the vibration of the walls after the slamming of doors, windows, earthquake, work ... (Figure N°5

3.2. *Application: epoxy resin*

The application of epoxy elastomer (diglycidyl ether of bisphenol with a density of 1144 kg/m^3 at 23 °C) vertically after the remediation of the walls (Figure N°6) shows a satisfactory filling of cracks. The Differential Scanning Calorimetry gives a glass transition temperature Tg at 57° C.

The idea of the mechanical adhesion pattern is that the liquid resin penetrates into the pores of the cement. Pores and asperities represent areas where the adhesive can be attached by simple geometric effects. The roughness is a favorable factor to a good adhesion since it allows to increase the contact area and the number of sites of action (Hachemane B et al., 2013).

3.3 *Application of mortar polyester*

Then we add 1% of the volume of the catalyst (organic peroxide) to initiate the polymerization. The application of reinforced composite polyester comforts and corrects the geometry of the wall (Fig N° 7-8).

The polyester mortar is characterized by a glass transition temperature (Tg) = 76° C. (Figure 10).

In this case, the Differential Scanning Calorimeter (DSC) showed only the decomposition of the resin. It is appropriate to clarify that there is no need to introduce decomposition model including mineral filler which is non combustible.

The composite material has mechanical properties which change according to the strain rate. However, for static strains at ambient temperature, the mechanical behavior of reticule resins can be modeled by an elastoplastic law (I) and (II). Figure 11 shows the result of the curve: stress / elongation found during a tensile test of five samples.

The five tested specimens show an elastic behavior, with an average breaking strength of approximately 300 N and a displacement of 1.5 mm corresponding to this load. These results confirm the hardness and brittleness of loaded polyester resins observed in the literature [Beyler C and Hirschler M., 1995; Budrugeac P and Segal E., 2005; Vyazovkin S., 2008]. The Young's modulus E of this material is determined by the following relationship:

$$E = \frac{F\,L^3}{48YI} \quad [\text{MPa}] \quad (I)$$

$$I = \frac{bh^3}{12} \quad (II)$$

E: Young's modulus (MPa); I: quadratic moment; B: width of the section (mm); h: thickness of the section (mm); L: distance between the supports (mm); Y: the spire of the specimen (mm).

3.5. *Polyester gel coat finish*

The gel coat finish is applied by spraying under high pressure. The sooth, homogenous layer assures an excellent protection against chemical products.

3.6. *Behavior in a biological environment*

3.6.1. *Microbiological analyzes of the wall of the blood separation laboratory of the transfusion center*

The samples that are more than 1.6 m from the ground, a part made in porous and brittle materials with paint finish, show a significant microbial load (Table 5 - Figure 14), the risk is even higher because this part is not disinfected. The part lower than 1.6 m from the ground with composite materials reveals also, a significant microbial load (Table 6 - Figure 15). On the part of non-porous composite materials, the decontamination as well as the disinfection is convenient. It gives zero microbial and viral load after disinfection. This result is in accordance with the literature (Koziarz J and Yamazaki H., 1998).

Conclusion

Standardized containment of a laboratory as sensitive as the blood transfusion center is required. Composite materials meet the highest hygiene requirements. The formulation provides a wide range of materials with different properties. Their behavior to fire, chemical and biological impact is satisfactory. Moreover, the continuous nature of the thermosetting material reinforced the portland cement coating, avoid chipping, cracking and breaking. The multilayer system Epoxy - polyester mineral filler provides homogeneous systems of materials with good adhesion to the portland cement. The preparation and application technique depends on the specifications of the laboratory.

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