925 SILVER AND 18K GOLD ELECTROPLATED JEWELRY: A COMPARATIVE ANALYSIS OF ENVIRONMENTAL IMPACTS

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ABSTRACT

Decisions about materials and production processes are very important to designers, manufacturers and users, due to not only product aesthetics or durability but also to environmental impact, which is a new requirement that begins to have more influence on purchasing decisions. To satisfy environmentally conscious consumers it is necessary for designers and companies to consider and disclose information regarding choice of materials and processes. Companies need to rethink how this information reaches consumers and also the way in which consumers have access to data about the impact of their purchasing decisions. This paper presents a comparison between pieces of jewelry: two identical models of scapulars, one in silver and the other in brass plated with 18k gold – identifying the production processes that differentiate them and presenting the specific impacts that the choice of materials can entail. It considers the main stages of production and maintenance requirements of the products throughout their lifetime, based on informational and photographic surveys applied in a company that manufactures the scapulars. Based on the analysis of each production process, a qualitative point-by-point comparison was performed, including price, environmental impact in production, environmental impact on maintenance and disposal, possible return of the material to the production cycle and cost-benefit. The results allow the discussion of environmental and health issues, as well as certain consumer behaviors, providing an in-depth comparison about similar products.

KEYWORDS: *Jewelry, sustainable product development, consumption*

I. INTRODUCTION

Whether made with bones, stones and other rudimentary materials in prehistory, or with gems and metals in ancient Egypt, jewelry has been present throughout human history. Humans considered their ornaments as important symbols of social status and through them it is possible to know the political, economic, social, symbolical and religious aspects of civilizations [1]. Throughout history, materials have limited the designs in jewelry. For example, the stone, bronze and iron ages received their name according to the technical skills and the material used at the time [2]. The contemporary age is not defined by one material, but by a huge variety of materials in fast and continuous evolution, many of them obtained by non-renewable sources, such as metals. Even with the introduction of new materials in the twentieth century, metallic materials have prominence in the field of jewelry. Even the definition of jewelry has always been linked to the materials used. Traditionally, jewelry is a personal ornament made of noble materials, usually metals and gems [3]. The relation between material and jewelry has always been present, when we recognize the association of the object with its symbolism of economic value [4]. The evolution of technological processes, such as electroplating, allowed the development of jewelry that uses non-noble metals with a cover layer of noble material, usually silver or gold. The result is an increase in the mix of products developed by the jewelry industry, with the insertion of electroplated jewelry and even costume jewelry, representing 10% of the world's total exports in the segment [5].

Currently the most used metals are gold, silver and brass. In the Brazilian jewelry industry, gold jewels cover 44% of the variety of products offered [6]. This index is followed by silver with 36%, costume jewelry (pieces composed of zinc alloys, tin alloys, zamaq, which can use plastic components, beads and other materials of low value in its composition) with 32%. Lastly, electroplated jewelry with 27%, and pieces composed mainly of zinc alloys, tin alloys and even zamaq, which have not yet undergone the electroplating process, with 21%. The metallic alloy called brass is largely used in these three last types of jewelry.

The use of these metals is very common and there is a traditional knowledge related to its symbolic value, which makes many consumers analyze only the value of the finished product when they buy it. However, with the increasing number of environmentally conscious consumers, buying a product may generate questions beyond cost-benefit. For example, what kind of environmental damage has the development of the product created? What level of toxicity does the product cause in its production, throughout use and in its disposal? A specific group of people may make these questions, but designers and entrepreneurs of the jewelry business must anticipate them. Understanding these questions is important for the informed use of raw materials that generally require large energy costs for their extraction, which results in significant environmental consequences.

In fact, many researchers works to optimize and reduce the impacts in the steps of the jewelry production. As example of analysis to decreasing raw materials, energy and waste disposal cost for each sector of the company [7]. Researching for improvement in management process an production control by tools from the Lean Thinking philosophy and manufacturing-execution-system software [8]. Analysis to define significant sources of environmental impact throughout a large jewelry manufacturing value chain, understanding the consequences of using material from different sources [9]. However, this research analyze the whole cycle of a jewel production, from the extraction of the raw materials until the final discard, makes it possible to identify and evaluate the impacts of the product, allowing a discussion on the consequences not only regarding environmental aspects, but also social and economic aspects.

With this premise, the present article describes a comparative study between two scapulars produced by the same company. They are identical models, but made with different materials, within a price range in which the products are categorized as similar. The first is made of silver and the second is gold-plated. A gold scapular would cost approximately twenty times higher than the products analyzed, so it was not similar in the eyes of the consumer. We choose to analyze scapulars because of their symbolic value and for being a traditional piece used by different publics. The comparative analysis is a search to understand the system in a macro analysis of both inputs and outputs throughout the productive process. Most products have a cradle-to-grave flow, it means, the extraction of the raw material to the final disposal occur in a linear process. Obviously, this flow has returns in internal cycles such as reuse, recycling, but the final destination is always residue and will hardly feed a new system without loss. For the intrinsic value of the raw material, there are initiatives that encourage the return of gold products of which users wish to dispose. However, this occurs with jewelry that contains a high percentage of noble metal, which is not the case in electroplated pieces, where small-scale metal separation is not feasible. Thus, we considered here the linear flow of extraction, production, consumption and disposal.

II. RESEARCH STRATEGY

The initial exploratory study was a bibliographic survey of the characteristics of the main metals used in the two products analyzed. This review is reported in Section 3 of this research. The main extraction data were analyzed, such as world reserves, annual production utilization and recycling rates, reflecting on how much impact these activities have in resource consumption. The informed use of metals is extremely necessary, since the level of environmental impact generated by extraction activities is

extremely high. The main problems caused by mining can be put into five groups: water pollution, air pollution, noise pollution, land subsidence, coal fires and radioactive waste [10].
The list of harmful effects originating from mining on air, water and soil has been well documented for a long time, including: sewage drainage, silting, acid drainage and heavy metals in streams; acid gases or contaminated with lead and other harmful gases or unpleasant odors in the air; explosion and rock dismantling; dust clouds from the trucks, mining front and reject in hydrographic basins; landslide of mining fronts; and perhaps the most depressing of all, the decadence of mining cities. [11].
Section 4 presents the numerical data relating reserves and world production and a discussion about the environmental problems of the mining activity. Afterwards, a survey of the information available in the commercial environment on the study objects was carried out. The analysis follows with a morphological study of the scapulars, identifying their main formal characteristics, described in Section 5. This substantiated the survey that was carried out in a company that manufactures the two types of product. In this part of the study, we documented in detail how the products are manufactured, with photographic and informational surveys. This production analysis identified the main differences between the productive processes of the two scapulars, highlighted the electroplating process, indices of sale and maintenance, described in item 6.
A comparative analysis was carried out, based on the sources of information, considering the following criteria: (i) price, (ii) allergenic index, (iii) production impact, (iv) maintenance and discard possibilities, (v) return of the material to the productive cycle, (vi) cost benefit. The results were put in a table to summarize the comparison between the two products with the items studied, highlighting their main differences.

III. MATERIALS OF THE PRODUCT IN ANALYSIS

The materials that compound the scapulars are 925 silver and gold-electroplated brass. Both these materials are highly widespread in the jewelry industry and used in large-scale production projects.

Silver

Is a white noble metal represented chemically by the initials Ag, from the Latin *argentum*. It is very ductile and malleable, making it possible to obtain 0.3 mm thick plates, with a melting point of 960°C. It can be used for very different products, such as cutlery, coins, dentistry, and jewelry, among others. When pure, it is called 1000 silver. In jewelry, it is frequently used in alloys with 7.5% copper and 92.5% silver, and it is called 925 silver. This alloy have a large scale of use once improve mechanical properties increasing resistance and toughness despite become more susceptible to oxidation [12].
World reserves of silver are estimated at 570,000 tons, with annual world production of 27,000 tons [13]. Thus, maintaining world reserves and current production rates, roughly 21 years of extraction can be predicted.

Brass

It is a yellow (pale) metal alloy, generally composed of more than 50% copper (Cu) and 5% to 45% zinc (Zn). This variation depends to the desired application, small amounts of aluminum, tin, lead and arsenic can be added in order to potentiate desired characteristics. Brass is malleable, easily shaped into plates, high ductile and is good conductor of heat and electric current. The melting point varies according to the proportion of the metals that form it; however, it is generally relatively low, ranging from 900°C to 940°C, and so it can be easily melted in small, specialized furnaces. The use of proportion 70% cooper and 30% zinc are common for brass alloy in jewelry industry, identified in 4 samples from São Paulo companies and 11 samples from Guaporé companies [14].
Copper has world reserves of 720,000 tons and annual world production of 19,400 tons. Zinc has world reserves of 220,000 tons and annual world production of 11,900 tones [13]. According to these data, while copper extraction is estimated in 37 years, zinc extraction is even shorter, with an expectation of 18 years.

Gold

Gold is a yellow noble metal represented chemically by the initials Au, from the Latin *aurum*. Ductile and malleable, the melting point of this metal is 1070°C. Pure gold, denominated gold 1000 or 24k (carats), is too soft for jewelry production, been necessary to use it in alloy with another's metals to increase the toughness, resistance and elasticity [12]. Therefore, 750 or 18k gold is more widely used;

this alloy has 75% pure gold and 25% other metals, usually 12.5% silver and 12.5% copper. It is resistant to oxygen, water, bases, and most acids, and this is why it is a very valuable metal for jewelry. The world's gold reserves are estimated at 57,000 tons while the world's annual production is at 3,100 tons [13]. In a simple estimate, the availability of gold extraction is about 18 years.

IV. EXTRACTION AND IMPACTS DATA

The extraction data of the four widely used metals are in Table 1, with the size of world reserves, world production, use and recycling rates; the last two are regarding the United States. This informational survey belongs to the 2017 annual report developed by the U.S. Geological Survey based on the data collected over the year 2016, and it allows an understanding about production indices and world reserves. We can see how high the annual demand for these metals is, in varied sectors of the economy, among them the production of jewelry, mainly in the demand for both gold and silver metals. This factor underscores the importance of the informed use of these non-renewable raw materials. Although gold has an expressive recycling index, this does not happen with the other metals, as observed in Table 1. This point reinforces the need to rethink the consumption of these metals, turning to applications that have a higher recycling rate.

Table 1: Reserves and world production, use and recycling in the USA, of the four metals widely used in jewelry. Adapted.

Metal	World Reserves	World Production	Use in the United States	Recycling in the United States
Gold	55.000 ton.	2.860 ton.	41% jewelry 35% electrical and electronic 18% coins 4% odontology 2% others	200 ton. Exceeded the reported consumption in 165 ton.
Silver	530.000 ton.	26.100 ton.	42% electrical and electronic 35% coins and medals 13% photography 7% jewelry 3% others	1.400 ton. About 20% of consumption.
Cooper	700.000.000 ton.	18.000.000 ton.	43% building 19% electrical and electronic 19% transport equipment 12% general products 7% industrial equipment	180.000 ton. Of old scrap, approximately 10% of consumption and 640,000 tons. of new scrap.
Zinc	230.000.000 ton.	13.300.000 ton.	80% galvanizing 6% brass and bronze 5% zinc alloys 9% others	95.000 ton. About 52% of the year production.

The impacts resulting from the extraction are present in several spheres, which makes it hard to measure the negative effects generated by the activity. The rupture of the Fundão dam, in Mariana - Minas Gerais, Brazil, is an example of what the lack of care for mining waste can entail. The incident launched about 62 million cubic meters of tailings into the local watershed [15]. This resulted in impacts to flora, fauna, water supply quality, and there were socio-environmental repercussions to communities that depend on local activities. Another example is the activity of gold mining, which, usually occurs by manual or industrial mining [16]. Manual mining is based on the use of mercury, an extremely toxic metal with cumulative effects, and the part that does not form an amalgam to capture the gold particles is lost in the environment. The same occurs later with the amalgamated portion during the process of burning this alloy to purify the gold. This process occurs in both legal and informal mining, despite in legal mining are a series of standards that must be done, measurements and compensation of environmental impacts. At least 90% of the mining in the Amazon is informal and illegal; the illegal, in addition to not complying with part of the regulations, carries out activities in prohibited areas [17]. About 3 thousand tons of mercury used over the last 20 years are contaminating the waters and sediments in the Amazonian rivers [18]. The results in the riverside populations are an index of 1.4 mg/kg of mercury per individual, when the maximum allowed by the World Health Organization is 0.5

mg/kg. This index contributes to the abnormal development of children, near 1.5 mg/kg of which have presented sub-clinical. The formal sector use predominant sodium cyanide (NaCN) for gold exploitation. For each ton of ore, 250 grams of cyanide are used for the dissolution of gold, as well as other necessary substances such as caustic soda and hydrochloric acid [16]. This process involves a series of complex chemical reactions and requires strict control, because cyanide does not act in a chronic cumulative process in the tissues of the organism, it can kill quicker if not handled with technical rigor. The main environments affected by the contaminants are water bodies, which are already threatened by the infiltration of fossil fuels, sewage, pesticides, fertilizers and other chemical compounds, and now face cyanide as a new risk factor in expansion. This study does not consider energy consumption and water consumption indices for the processing of the material, among other factors that the exploitation entails. However, with this specific analysis about the exploration of gold, we can see how shocking this practice is, even if looking at only one sphere of action, in this case, residues.

V. PRODUCT ANALYSIS

The research analyzed two scapulars made by the same company, of the same model, but made with different materials; they can be seen in in Figure 1. The analysis of morphological aspects of the products identified the characteristics of the samples, shown in Table 2.

Figure 1: Left side, 18k gold electroplated scapular; right side, 925 silver scapular.

Despite the similarity of the scapulars, the production processes have variations that result in different impacts to the system. These small variations in a large-scale industrial scenario convert into relevant factors for the environment, the economy and the consumer.

Table 2: Commercial information about the scapulars, acquired in 2014.

Scapular	Silver 925	18k Gold Electroplated
Price	R$ 61,83	R$ 40,48
Weight	4.7 g	4.2 g
Thickness	3 mm	3 mm
Medals	10 x 12.8 mm	10 x 12.8 mm

VI. PRODUCTION CYCLE OF THE SCAPULARS

The history of jewelry has its origins in the process of craftsmanship. From the ornaments made with bones and stones in prehistory, to goldsmith professionals, manual skills have always been fundamental in making the pieces. The artisanal characteristic is still used mostly in the development of exclusive jewelry [19], a high-value market niche developed by renowned brands and their high jewelry lines, like Boucheron, Cartier and Van Cleef & Arpels.

Industrial branch of jewelry produced in large scale developed in such a way that it does not depend so much on the technical skills of a goldsmith, by dividing knowledge into processes developed more and more by machines. The development of new production instruments is a constant need in the search for maximization of production and minimization of time spent for production [20]. The machines made large-scale production possible, the transition from artisanal and hand-made to factories. Despite the levels of mechanization vary greatly among companies and that some sectors work with more artisanal and hand-made than with machine production.

The company that manufactures the scapulars is a small to medium sized company, with approximately 50 employees. It has been in the market for 40 years and is located in the city of Guaporé, Rio Grande do Sul, Brazil. The level of mechanization is very expressive, supplying more than five thousand items to the national and international markets.

During the visit to the company, an informational and photographic survey on the production of the study objects was carried out, thus structuring the production chain, shown in Figure 2.

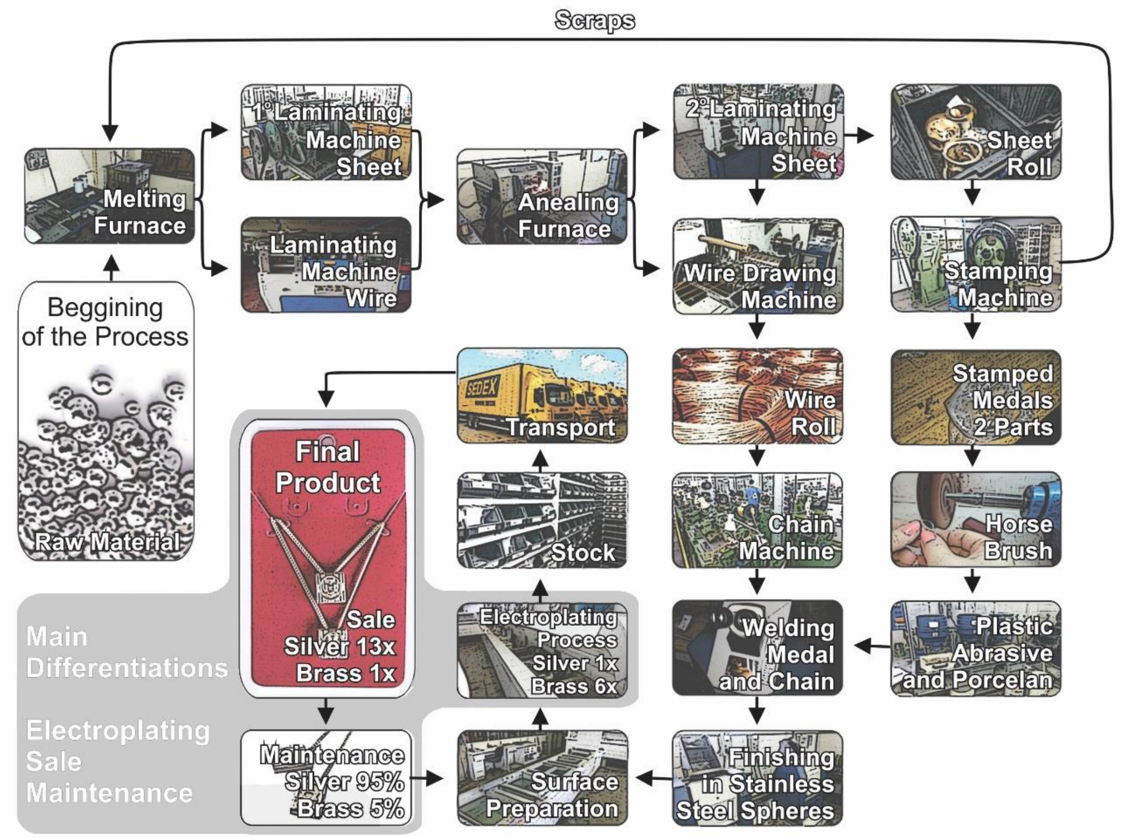

Figure 2: Production chain of the scapulars.

The process begins with the melting of the raw material, transformed from solid metal to liquid trough high temperatures, which depends to the metal alloy used. Part of the metal is poured into molds forming rectangular billets, while another part is poured into molds that form cylindrical billets.

The rectangular metal billets are laminated successively, and the metal is forced to pass through cylinders positioned more closely each time. With the decrease in thickness of the metal there is an increase in length and width. The laminations are intercalated with metal annealing processes in the furnace and fast cooling in water. The annealing process recovers the crystalline structure of the metal, preventing them from rupturing due to plastic deformations, increases ductility but decreases mechanical resistance [21]. It is common the use of two laminating machines, the first for the thicker billets and the second for the final lamination processes, producing the 0.3-mm-thick laminated rolls. After the laminating process, the metal rolls go to the stamping machines, stamping front and back of the medals by hydraulic presses according to the tempered steel die of the scapulars, Figure 3.

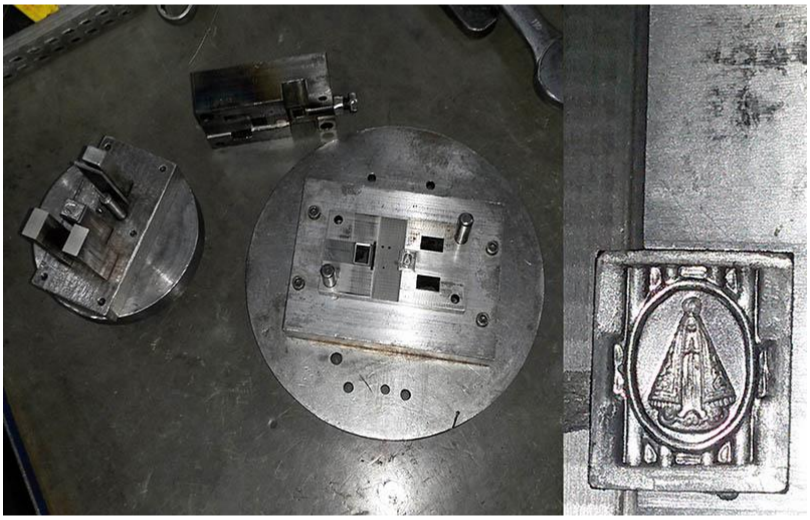

Figure 3: Tempered steel die of one scapulars side.

The pieces that have already been stamped go to the first finishing process, which is manual, with horsehair brush. The next finishing step is automatic, using rotary tumblers, shown in Figure 4. The pieces remain for 40 minutes in a tumble with plastic abrasives based on oxide, silicate and carbonate chemically assembled by urea-based resin. This case used the abrasives of green color, whose granulometry is of 400 grains per square centimeter.

Figure 4: Second stage of finishing with plastic abrasives based on oxide, silicate and carbonate in rotary tumbles.

The second stage of automated finishing uses porcelain abrasives, commonly formulated with quartz, aluminum oxide, alumina or calcined. The pieces are placed inside vats for approximately 1 hour, and the process occurs by vibration. After the finishing process, the pieces are put in dryers at 60°C for 20 minutes.

The cylindrical metal billets go to laminating machine wire, intercalating the process of annealing in the oven. Once the billets have a reduced diameter they are adapted in the wire drawing machine, it use several spinnerets to make possible to reduce the diameter of the thread to very small measures such as 0.26 mm. These spinnerets are steel molds with gradually decreasing circular apertures through which the metal is forced to pass, Figure 5. At the end of the process, machines transform the wire into chains, sectioning, forming and closing every link one by one.

Figure 5: Wire drawing machine, with five spinnerets adapted in the machine.

With the two semi-finished half-medals and the chain, the next step is to assemble the scapulars. The chain is putted inside the body of the half-medal and the two halves are welded together. The assembled scapulars go to the final finishing process, which occurs by the vibration of the pieces in tubs with stainless steel balls with virtually zero abrasiveness, giving the final brightness to the pieces. The following process is the surface preparation of the pieces for electroplating. This step is the same for silver and brass pieces, and consists in submerging the pieces into four consecutive tanks in the following order:

1st: exposure to a sodium hydroxide-based degreaser;
2nd: first wash in water;
3rd: exposure to sulfuric acid 5%, which removes the oxides from the piece;
4th: second wash in water, to remove contaminants from the previous operations;

The washing waters should be reused to minimize the demand of water from springs and reduce the quantity of effluent discharged in sewers or rivers [22]. After being prepared, the pieces go through the electroplating process. The silver 925 only goes through one process, whereas the brass has six different processes, further explained in topic 7.1.

After the pieces are finished, the scapulars are stored and sent to stores and sales stations according to requests. A sale survey was carried out at the physical store of the company that manufactures the scapulars. It found that thirteen 925 silver scapulars were sold for every 18k gold-electroplated scapular. The percentage of scapulars returned to the factory consists in 95% of 925 silver and 5% of 18k gold-electroplated.

Understanding the main points about the productive process evidences the points where there are more differences. Considering the process from the input of raw material to the post-sale, the electroplating process of the pieces, the sales index and the maintenance index were the items that presented more variation, guiding the analysis reported in this article.

VII. Analysis of the Electroplating Process, Sales Index and Maintenance Index

The processes described in this section may vary at some specific points depending on the methods used by each company, considering that these variations would not entail significant impacts. Although this is the description of the process used by the company that develops the scapulars in question, it is relevant to present it as a characterization to compare the two types of products.

Electroplating Process

The electroplating process is a finishing method that consist in the immersion of the jewel in an electrolytic solution with the desired metal. [12], Figure 6. The objective of electroplating is to protect against corrosion, improve the appearance of objects, increase durability, and improve surface properties such as strength and thickness [23].

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Figure 6: Recipients used in the electroplating process; detail of the parts manually handled in a rotary reel.

The silver scapular electroplating process consists of the rapid deposition of a thin layer of pure silver. This serves to homogenize the color, especially in possible welding points, to emphasize the brightness and the white coloration of the pure silver, besides delaying its oxidation. While for the gold-electroplated scapular there are, commonly, six electroplating procedures, described below:

1st: a layer of alkaline copper, with a cyanide copper base, prepares the piece, protecting it to receive the next acidic layer;
2nd: acid copper, with a copper sulfate and sulfuric acid base, levels the piece, filling the pores and enhancing brightness;
3rd: nickel, with a sulfate and nickel chloride and boric acid base, isolates the copper and provides strength, leveling and gloss;
4th: pre-gold layer, a 24k gold layer prepares the piece to receive the thickest layer;
5th: plating with a thicker layer of 18k gold;
6th: color, final layer with a 22k gold and potassium cyanide base, to make the color uniform.

The fact of adding more manufacturing processes by itself represents a greater environmental impact due to the greater consumption of natural resources, such as water, energy and/or materials. Electroplating is highly impacting, acting in seven fronts: (i) water consumption and effluent generation; (ii) atmospheric emissions; (iii) generation of solid waste; (iv) energy consumption; (v) generation of soluble metal salts [24]. Figure 7 exemplifies the entries and exits throughout the gold electroplating process. The stage responsible for the greatest generation of liquid effluents is the electrolytic metallic coating, which, addition to the washing steps, requires sporadic discharges of the used contents [23].
The use of these metals can be considered regarding the safety and health of consumers in daily use, especially factors related to allergic reactions. The layer used to electroplate the piece in 925 silver presents a very low degree of allergic reactions, since it is composed of pure silver. Silver intoxication, known as argyria, is uncommon and occurs when there is chronic exposure by injection, inhalation or ingestion [25].
Intoxication by merely using pieces made of copper is rare, like silver. The most common cases occur due to inhalation of particles for those who work with the metal or intoxication by contaminated water. Copper is an essential element for living organisms and the daily requirement for people is 2 to 3 mg [23]. However, high concentrations can damage the kidneys and even death [25]. Also, high

concentrations due to industrial residues are harmful to aquatic organisms, and can cause liver problems in people [27].

Nickel, which is the third layer of the gold electroplated piece, is highly allergenic. Many cases of dermatitis are associated with nickel present in metal alloys [28]. A research found that 16.2% of patients presented allergic reactions, more commonly in children and teenagers. The most common sources of exposure identified are belt buckles, metal buttons on clothing, glass frames and accessories, especially earrings. Nickel lesions cause skin bubbles or dryness, scaling and thickening. Continuous contact may develop into more frequent and complicated outbreaks called cross-reactions. With time they form open wounds that burn and are susceptible to infections and other complications.

Finally, it is important to note that pure gold is non-irritating and non-toxic. There are even studies on the application of gold nanostructures to decontaminate sewage and wastewater from organic contaminants [29].

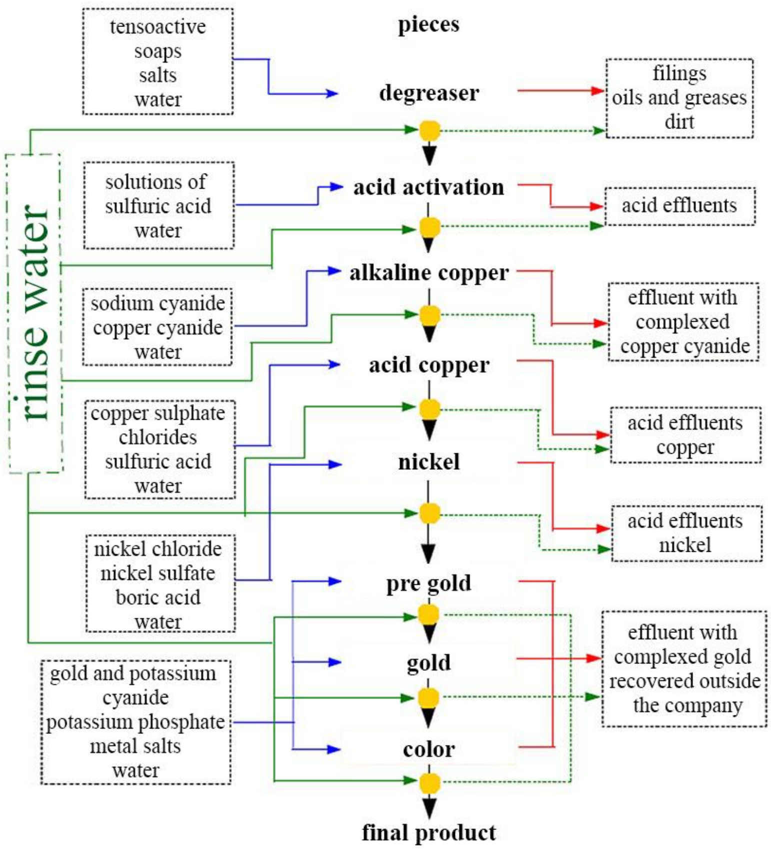

Figure 7: Inputs and outputs of the 18k gold surface preparation and electroplating process. Adapted [24].

Sale Indexes

Sales indices for scapulars vary 13 to 1, that is, for every thirteen 925 silver scapulars sold, one 18k gold plated was sold. The greater demand for the silver jewel can be explained in part by the origin of the material, a noble metal, but very accessible when compared to pieces made with 18k solid gold. Good oxidation resistance is another positive factor, although oxidation can happen, normally depending on the amount of uric acid that the user transpires, air pollution and contact with cosmetics. The low allergenic index favors the use of a silver model. Wearing electroplated products requires great care, since they have several layers of different materials, and the control in the use of harmful metals such as nickel and in some cases cadmium is difficult to establish. This latter metal is highly toxic for people [30].

Maintenance Indexes

Maintenance ratios are close to 95% in 925 silver to 5% in 18k gold plating. At first glance, it may be contradictory that a noble metal has a higher maintenance index than brass. However, if we consider that the sales indexes of the 925 silver scapulars is quite high compared to the 18k gold plated scapulars, it is natural that the number of 925 silver pieces returned for maintenance is also higher. Another factor is the material and emotional value users give to the 925 silver scapular, seen as a jewel in the traditional sense, unlike the electroplated pieces, that are seen more as costume jewelry. With the idea that jewels last years, for generations, the care we have with its maintenance is much greater than the one that we have with electroplated pieces, which have a more seasonal and ephemeral character. Thus, it is believed that the consumers really are interested in maintaining the silver scapulars and simply discard the electroplated scapulars.

VIII. Comparison Between Silver and Gold electroplated Scapulars

Table 3 was formulated from the analysis of the positives and negatives of each model, listing the main differences between them. This comparison enables a more simple analysis of these differences and provides to consumers a clear view of the advantages and disadvantages of each scapular. In Table 3, the indexes highlighted in green are those that stand out, that is, are advantageous compared to the opposite model.

Table 3: Comparison between scapulars.

Comparison Criteria	Silver Scapular	18k Gold Electroplated Scapular
Price	R$ 61,83	R$ 40,48
Allergenic Index	Free	Varying
Production impact	Lower	Higher
Maintenance/Disposal	Maintenance	Disposal
Return of material to the cycle	High	Low
Cost benefit	Best	Worst

Since there is a higher volume of sales per unit of silver scapulars, it can be said that consumers already tend to make the choice with less environmental impact due to the better quality of the finished product. This choice occurs in a scenario where the price difference holds both options within a close range of values, for which the customer is willing to pay. This is an important point when discussing the reduction of environmental impacts and product sustainability in a comprehensive way. The price to be paid should be within a range acceptable to the consumer or at least not much different for similar products. In this case, even when the information about the manufacturing process, the substances involved and the consumption of water and energy are not clearly reported, consumers prefer the alternative with a lower environmental impact due to the symbolic value and durability, which are highly valued in sustainable products. However, the result of this specific product does not reflect the behavior of the whole jewelry market. A niche called fashion jewelry is in expressive expansion. Market share is in steady and solid growth, with Brazil as a major consumer, encouraging these products. The high turnover of jewels and trends imposed by the fashion market reflect the accelerated way in which the launch of new collections in the Brazilian jewelry industry takes place. For the first time in the history of the jewelry field, fashion jewels exceed the sales of gold jewelry in a country, in this case, Brazil [31].

It is likely that the scapulars do not follow this pattern because they are timeless, classic and to some extent still largely acquired by older people. This public is used to objects made to last, and the fact of passing an object from father to son is present in their culture and valued. People who lived in a time when planned obsolescence would not even go near a field that used to be completely noble, that is, jewelry.

IX. Conclusions

The present study contributes to the understanding of factors that provide a comprehensive view about products which, although similar, present important differences. It explains in part the current consumption behavior. Through environmental factors, linked to human health, the study had the intention of highlighting information that should be taken to users in order to enable informed consumption. This vision goes beyond the cost factor of the product itself, aiding in the process of making consumers increasingly environmentally conscious.

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REFERENCES

[1]. CORBETTA, G. Joalheria de Arte. Porto Alegre: Ed. AGE, 2007. 143 p.
[2]. ASHBY, M. Materials Selection in Mechanical Design. 5. Ed. Burlington: Ed. Butterworth Heinemann, 2016. 660 p.
[3]. GOLA, E. A Jóia: História e Design.2. Ed. São Paulo, Senac:2013.
[4]. FAGGIANI, K. O poder do Design: da ostentação à emoção. Brasília: Thesaurus, 2006.
[5]. IBGM. O Setor em Grandes Números: Situação Atual e Perspectivas do Mercado Interno e Externo. Disponível em: <http://novo.infojoia.com.br/uploads/arquivos/file/35f70-285-OSetoremGrandesNumeros2012_Completo.pdf>. Accesse: 03/09/2015.
[6]. IBGM/SEBRAE. Pesquisa da Indústria: Outubro 2013. <http://novo.infojoia.com.br/uploads/arquivos/file/8abde-IBGM-Pesquisa-ind--stria---2013cor.pdf>. Accessed: 03/09/2015.
[7]. GIANNETTI, B. F.; BONILLA, S. H.; SILVA, I. R.; ALMEIDA, C. M. V. B. Cleaner Production Practices in a Medium Size Gol-Plated Jewlery Company in Brazil: When Little Changes Make the Difference. Journal of Cleaner Production, 16, 1106-1117, 2008.
[8]. ROCHA, H. T.; FERREIRA, L. P.; SILVA. F. J. G.; Analysis and Improvement of Processe in the Jewelry Industry. Procedia Manufacturing, 17, 640-646, 2018.
[9]. THAMMARAKSA, C.; WATTANAWAN, A.; PRAPASPONGSA, T. Corporate Environmental Assessment of a Large Jewelry Company: From a Life Cycle Assessment to Green Industry. Journal of Cleaner Production, 164, 485-494, 2017.
[10]. BROOKS, David B. Conservation of minerals and of the enviroment. World Mineral Supplies – Assessment and Perspective. Amsterdam: Elsevier, 1976. P. 287-314.
[11]. SOUZA, P. Impacto Econômico da Questão Ambiental no Processo Decisório do Investimento em Mineração. 1999. 268 f. Tese (Doutorado em Geociências) – Universidade Estadual de Campinas, São Paulo, 1999.
[12]. SANTOS, R. Joias: fundamentos, processos e técnicas. 1. ed. Rio de Janeiro: Senac Nacional, 2013. 296 p.
[13]. USGS. Mineral Commodity Summaries. Disponível em: http://minerals.usgs.gov/minerals/pubs/commodity/ Accessed:03/01/2018
[14]. MANFRON, M.; GOBBI, D.L.G.; MISTURA, C. M. ISRAEL, C. L. Análise Química de Ligas Metálicas Utilizadas em Joias e Bijuterias na Região de Passo Fundo. In: 56o Congresso Brasileiro de Química, 2016, Belém.
[15]. BRITO, C. Da Lama ao Caos, do Caos à Lama. https://zerohora.atavist.com/mariana Accessed: 02/02/2016.
[16]. CAHETÉ, F. A Extração do Ouro na Amazônia e Implicações para o Meio Ambiente. Novos Cadernos NAEA. v. 1, n. 2, 1998.
[17]. WANDERLEY, L. Geografia do Ouro na Amazônia Brasileira: uma Análise a Partir da Porção Meridional. 2015. 302 f. Tese (Doutorado em Geografia) – Universidade Federal do Rio de Janeiro, São Paulo, 2015.
[18]. BARBOSA, A.; SOUZA, J. Contaminação por Mercúrio e o Caso da Amazônia Química Nova na Escola. no. 12, p. 3-7, 2000.
[19]. GUILGEN, C. A.; FERRO, S. G. Design de Joias: Cerâmica Avançada e a Prototipagem Rápida na Joalheria. Revista E-Tech: Tecnologias para Competitividade Industrial. Especial Design, p. 141-156, 2015.
[20]. SOUZA, O. M.; GOMES, R. W. F.; PEREIRA MELO, J. J. Da Manufatura à Maquinaria Moderna: A Subsunção Real do Trabalho ao Capital. Revista Labor, v. 7; p. 65-78, 2012
[21]. BRESCIANI, F. E.; SILVA, I. B.; BATALHA, G. F.; BUTTON, S. T. Conformação Plástica dos Metais. 1. Ed. Dig. São Paulo: EPUSP, 2011. 254 p.
[22]. VALENZUELA, J. Tratamento de Efluentes em Indústrias Galvanotécnicas. 2 Ed São Paulo: Páginas e Letras, 2008. 126 p.
[23]. OLIVEIRA, MARIA J. N. (1990) Nota Técnica sobre Tecnologia de Controle - Galvanoplastias. Companhia de Tecnologia de Saneamento Ambiental – CETESB, São Paulo.

[24]. SANTOS, M. Bijuterias. São Paulo: Ed. CETESB, 2005. 54 p.
[25]. SUE, YUH-M.; LEE, YU-Y.; WANG MING-C.; LIN, TZU-K.; SUNG, JUNNE-M.; HUANG, JENG-J. Generalized Argyria in Two Chronic Hemodialysis Patients. American Journal of Kidney Diseases, v. 37, n. 5, p. 1048-1051, 2001.
[26]. LINDER, MC. Copper and genomic stability in mammals. Mutat Res. 475, p. 141-152, 2001.
[27]. LEMES, M. J. de I. Avaliação de Metais e Elementos-Traço em Águas e Sedimentos das Bacias Hidrográficas dos Rios Mogiguaçu e Pardo, São Paulo. 2001. Dissertação (Mestrado em Ciências em Tecnologia Nuclear) – INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES –Autarquia associada à Universidade de São Paulo, São Paulo, 2001.
[28]. DA-COL, J.; BUENO, M.; MELQUIADES, F. Nondestructive Determination of Allergenic and Toxic Elements in Jewelry: a Comparison of Benchtop and Portable Energy Dispersive X-Ray Fluorescence Spectrometers. J. Braz. Chem. Soc., v. 25, n. 5, p. 853-860, 2014.
[29]. DICYT. Utiliza-se ouro para descontaminar esgotos e águas residuais. <http://novo.infojoia.com.br/uploads/arquivos/file/8abde-IBGM-Pesquisa-ind--stria---2013cor.pdf>. Accessed: 30/10/2015.
[30]. LEITE, M.; LIMA, A.; Silva, D.; GUIMARAES, J.; SABIA, R. Estudo da Concentração de Metais Pesados no Rio Salgado e a Contribuição da Indústria de Folheados do Cariri. In: XXXIII Encontro Nacional de Engenharia de Produção. 33., 2013. Salvador. Anais Salvador: Enegep, 2013.
[31]. CREBi. Mercado Brasileiro de Joias 2014. <http://www.crebi.com/materia/brazilian_market_jewelry_2014.pdf>. Accessed: 03/09/2015.

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