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Eco-development of biocomposites from water hyacinth: A sustainable integral design proposal for Xochimilco, Mexico City

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Abstract

This work starts from the context of an environmental crisis that frames a growing trend of a search for alternatives of a sustainable nature as a proposal solution from the transdisciplinary approach of design. The objective of this work consists of planning an eco-development strategy to create biocomposite materials using water hyacinth (*eicchornia crassipes*) as raw material. The approach will be part of a collective research programme for future doctoral studies whose further objective is the sustainable integral community development of San Gregorio Atlapulco in Xochimilco, Mexico City. Theoretically, an approach is made from complex thinking and the sustainability paradigm, resulting in a vision of design as an integral sustainable activity, from the perspective of the formulation of new materials, appealing to movements like *Material Activism*, *Ecodesign* and *Material Designers,* in conjunction with a circular economy. Exploratory experimentation for bio bases and sustainable treatments for the water hyacinth fibre was carried out to establish the optimal formulations for the elaboration of biocomposites. From this, seven biocomposites with different properties were obtained that can be used with various low-impact processes for manufacturing sustainable design objects. By doing so, this stage ended with a prospective scenario that was proposed for further work with the community as the beginning of a social entrepreneurship initiative.

Keywords: Biocomposites, Integral sustainability, Water hyacinth, Eco-development

Introduction

The current situation of crisis in environmental, social, cultural, economic and health aspects is a consequence of the imbalance brought by industrial development, which has raised growth in terms of capital instead of ecological improvements. This is reflected for example, in accordance with sources like the Global Footprint Network (2020), which mentions that the planet has an average biocapacity of 1.63 global hectares (GHA) and that the ideal would be to have an ecological footprint that does not exceed that amount. However, the average per person is 2.75 GHA, which represents a deficit of 1.1 GHA. Today, humanity uses the equivalent of 1.6 Earth planets in terms of exploitation of resources and waste absorption; among them are deforestation and overfishing and carbon dioxide emissions, respectively. In a local context, we can think about specific problems in each community that can be added to the main ones. In this case study, the presence of water hyacinth with its impact on different areas and scales of Xochimilco is the main concern.

As a brief presentation, Xochimilco has an history of eco-development since ancient times, a balance between a wetland environment and anthropogenic activities. Nowadays, there is only a remnant of that antique land. Xochimilco "is a zone that includes a group of original towns, a net of water channels, lakes and the chinampas (which is a portion of land built on the water with soil and the help of the endemic ahuejote trees, with agricultural purposes) whose importance was recognised in 1987 by UNESCO when it was declared a historical and cultural heritage of humanity" (Soria, 2004, p. 261). Despite its natural tourist attraction, it has various problems in each of its neighbourhoods. With a population of 442,178 people

(INEGI, 2020), it expresses an environmental crisis promoted by water pollution, deforestation, irregular settlements in the protected area and in the socioeconomic dimension, due to abandonment of local activities such as agriculture, lack of opportunities, unemployment and migration, which together have returned to the town hall a very vulnerable area. One of the original neighbourhoods is called San Gregorio Atlapulco, a place that reunites a set of characteristics that led to proposing a project towards the sustainable development of the community from the design perspective. Beyond the political organisation of this town, San Gregorio has the characteristic of being well-organised through cooperatives with mainly commercial purposes. The people who work at chinampas defend their land, interests, customs and traditions, doing a very remarkable form of organisation in the zone.

It is proposed that a strategy for the eco-development of biocomposites with water hyacinth can be derived towards a proposal of sustainable integral design. For their part, these materials have properties that make them suitable for use in various design projects. At the same time, the strategy seeks to integrate a prospective proposal within comprehensive community development plans that can be adapted and adopted in areas with similarly vulnerable situations.

In the first place, the eco-development concept mentioned here is the one proposed by Ignacy Sachs (1974), which considers this form of development as an adaptation to the ecosystemic situations of each eco-region. The author mentions that one strategy for development will not fit all realities, given the complexity of the topic and multiplicity of operative variables. This concept aspires to define a development adapted mainly to third world rural regions, addressing specific solutions to specific problems, contemplating the ecological and cultural characteristics and the immediate and long-term needs. The eco-development then, is a reaction against the trend of universal solutions and master formulas.

On the other hand, a biocomposites, as defined by Bootle et al. (2001) is a combination of two or more constituent materials, which are the matrix and reinforcing component, with at least one being naturally derived. This new material must show an improved performance over its individual components. The reinforcing material can be fibres, whiskers, particles or flakes; meanwhile, the matrix is the binder that provides mechanical support.

In the last two decades, there has been a great interest in the development of alternative materials around sustainable design, given the problems of environmental deterioration that have forced us to rethink how resources are extracted and exploited and how objects are produced and disposed of at the end of their useful life. Greater attention has been paid to the life cycle of both the products and the materials used. The present work proposes a contribution to the exploration of new material alternatives and the link between design and social innovation through a project leading to co-creation. As designers, is necessary to rethink the activity in terms of the impact of what we design and how, so the main question is: What can be done from the perspective of design to transform the situation of a community with social and environmental issues?

This work offers an approach to the potential that a developing country can have by visualising opportunities where they do not seem to be found, taking advantage of local resources to contribute to the transition towards a deeper ecology, following the concept of *Ecopuncture* proposed by Casagrande (2011) combining ecology and acupuncture, where a pin prick in a determined place will carry a revitalising effect to the point and its surroundings, i.e. a reaction of positive refeeding to have a bigger impact than expected with the initial move. In this case, San Gregorio is chosen as the *ecopunctural* site to have the incidence for further application of projects.

Literature review

Integral Sustainability

Sustainability, from its conceptualisation and foundation, is referred to as a complex paradigm, uniting scientific and technological, political and legal and social and cultural aspects to improve the global environmental situation through local plans, mainly in countries like Mexico, in growth. It is about substantiating pro-environmental actions that will lead to modifying the situation through changes on a small or large scale, involving very punctual or utopian actions that motivate a change of paradigm, implying "awareness, responsibility, ethical and cultural aspects, as well as patterns of consumption and lifestyles" (García, 2008, p. 73). For his part, Lopez (2004), in his essay on integral sustainability, mentions that "it is clear that the emancipatory mission, linked to arousing efforts and actions for the constant improvement of the quality of life of the population, cannot be left in charge of the only attention to the environment, but that it has to be given integrally, it must be assumed taking into account the social problem as a whole. In this case, we would talk about comprehensive sustainability". This paradigm implies recovering the transforming sense in different dimensions, since, in its practice, it tends to suffer different degrees of reductionism or, as mentioned above, it is easily manipulated in terms of convenience.

For Azamar and Matus (2019, p. 16), the challenge of building comprehensive sustainability involves two central aspects: 1. Thinking completely, considering the complex network of knowledge that a particular situation can summon; 2. Development of operational actions that merge science and practice into an interrelated whole. Sustainability, to face complexity, requires a degree of interdisciplinarity that needs material and logistical resources not currently provided for research. It implies not only the simple concurrence of disciplines but also an exercise in which situations are studied from articulated perspectives, linked to the processes that it defines and at the same time with those that integrate it (Tainter, 2006, as cited in Azamar and Matus, 2019). It will include the integration of productive, environmental, sociocultural, political, and technological processes, among others, that are evident on different spatial and temporal scales.

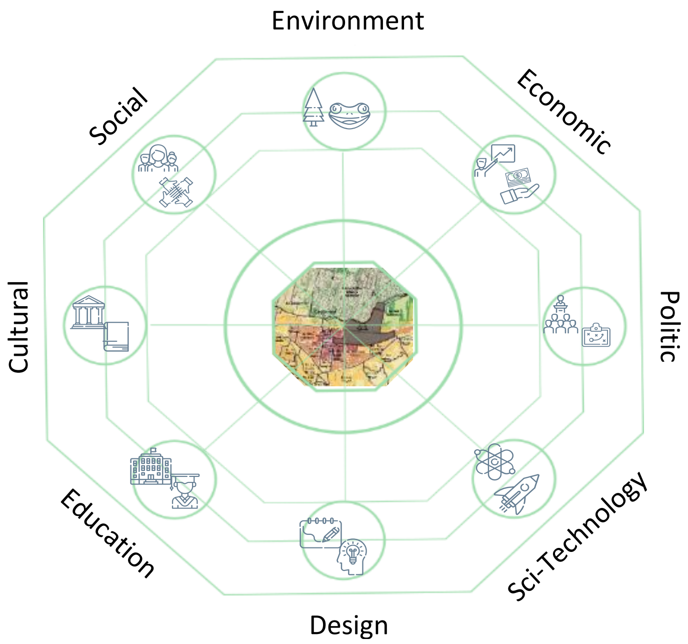

Image 1: Dimensions of Integral Sustainability.

Design in this context will play a vital role, being a determining factor through the points described in the work of García (2008, p. 25): "raw material extraction, selection of materials, determination of the production process, establishing how the product is used, distributed and discarded", that is, influencing each stage of the production of products. Sustainable design contemplates the other seven dimensions of the context in which it will be carried out, to transform reality.

Integral sustainable design through material creation

The role of the designer has come to be perceived as "an original conceptually deliberative thinker, who, through an active dialogue with manufacturers, fosters the development of new materials or production processes or develops them himself" (Bürdek & Eisele, 2011, as cited in Karana, 2013, p. 169). And in either case, the request is the same: production must be based on renewable raw materials and recyclable and/or biodegradable products. For this, the following five complementary proposals were considered:

Circularity

In a complex way of thinking, products must be understood as systems that are connected to other complex systems. These connections will allow waste streams from one system to be the raw material for another system. It is in the hands of the designer to apply this principle of circularity in the development of services and products, both by creating some that last longer, and by thinking about the future of the materials when they become waste (Cléries et al., 2018, p. 14).

Upcycling

Alternatives have been explored mainly in the last decade, such as upcycling, understood differently from recycling (recycling) as an upcycling that "provides an opportunity for waste or discarded products to be transformed into new, reconfigured, readapted and improved articles […] in some versions even being ephemeral like bags made of food waste […] and others that range from soaps, carpets, lamps, furniture and even entire constructions" (Bramston & Maycroft, as cited in Karana, 2015, p. 123). Beyond being a phenomenon of mass production, it came to reflect on whether it is possible to compete with local resources and techniques against industrial production. In time, more and more designers and experts from other disciplines such as biology joined the trend, products of this type entered the market, and material developments were increasingly elaborated based on this principle.

Material Activism

At the same time, there is another material concept called *material activism* (Ribul, 2013), whose purpose is to explore the democratisation of material production with do-it-yourself tools, in terms of materials and infrastructure that can be had at home and from there carry out experimentations. From this perspective, new materials can be developed with non-advanced technology, using the inputs at the discretion of each creator, but following some scientific guidelines that are shared “freely” on the Internet by activists ranging from bioplastics to biotextiles, from fungal or bacterial polymers for packaging to construction materials.

Material Designers

Recently, a proposal has been consolidated by the institutions Elisava Barcelona School of Design and Engineering, the Design Department of the Politecnico di Miano, and Ma-tt-er London. It is called Material Designers (Clèries et al., 2020), and it consists of a project, co-founded by the Creative Europe Programme of the European Union, whose objective is to promote talent towards circular economies on the continent. Material Designers consists of a platform, a training programme, an award and a series of events for the positive impact that material designers can have in all types of industry and the generation of an alternative that relates to the circular economy. According to Clèries et al. (2020), it is about empowering communities to search for alternatives applied to industry or the creation of activities from a creative sector, as it is through new explorations based on design and with the collaboration of other disciplines. The designer acts as a facilitator of materials derived from a reflection of the context, of the processes with which they can be created and of ideas for their application, since, based on the words of Manzini (1986), it has been understood that the designer not only can transform and create using the material for invention, but can invent the material itself.

Biocomposites

Nature has developed examples in countless presentations, according to García (2017), in wood, where lignin acts as a matrix and cellulose as a reinforcing fibre, bones made up of a calcium binder and collagen fibres, the nacre of molluscs, made up of calcium carbonate or aragonite and a conchiolin biopolymer. Now, in addition to proposing the manufacture of environmentally friendly materials, a more comprehensive approach is sought, so that these have relevant social, economic, aesthetic, scientific-technological and cultural impacts to contribute to the transformation of reality from design.

For Dos Santos and Lenz (2013) the most environmentally friendly materials are those formulated from biodegradable polymers and reinforced with natural fibres, which can be composted at the end of their life cycle. However, the challenge here is the balance between life performance because of the physical properties and the biodegradability. For its part, the biodegradable polymers can be obtained from plants, such as cellulose, starch, pectin, soy derivates, polypeptides and polyphenols and from animals, such as silk, wool, polypeptides, chitin, chitosan and glycogen. The natural reinforcements are used to improve mechanical properties, giving stiffness and strength to the matrix, and the main source is the vegetable fibres. These have many advantages besides the environmental, like low costs, easy processing, lower density and lower energy consumption. The main lignocellulosic fibres are flax, hemp, henequen, jute and kenaf, among others, that have the best chemical compositions to work properly on biocomposites. Dahy (2017) mentions that natural fibres like flax, jute, hemp, etc. have a higher cost and are not available worldwide as they are obtained from agricultural residues, which are those fibres retrieved after the crops harvesting, also called *agro-fibres.* This has lead to a search for new sources other than the conventional ones to improve the production of material alternatives.

In recent years, there has been a great boom in the exploration of these types of material. To mention some that have inspired this work, we have The *paper pulp* by Debbie Wijskamp, a composite of newspaper and a bio binder, to fabricate furniture; the *ex-presso project* by Julian Lechner, taking coffee waste mixed with casein or bio resin to make cups and other receptacles, the *Zostera stool* by Carolin Pertsch, a stool fabricated with a composite made from aquatic plant waste and bio resin; *Sargablock* by Omar Vazquez, a brick made from sargasso and soil for the construction industry; *Coconut ecodesign* by Karina Sánchez, a composite developed from coconut waste and bioplastic made of starch; and the C*heer Project* by Gaurav Wali, a biocomposite that consists of pine needles and bioplastic made from starch.

As the main source of inspiration for this work, the *Cheer Project* of Gaurav (2019) and the thesis *Eco-regional Design for Xochimilco* by Reséndiz (2010) are the chosen works. These are examples of academic works with the intention of reaching another level for social innovation and entrepreneurship in developing countries. The *Cheer Project* for India and the *Eco-Regional* for Mexico are both proposals for organisation that starts with biocomposite materials in similar contexts, trying to take advantage of residual biomass that causes big environmental problems if it is ignored, so that a community takes part to solve the problem, and in a way, it turns out to be a cultural and productive activity. As with these examples, there have been so many more in recent years. Developing countries that count on natural fibres that also represent an environmental problem are looking for commercial exploitation in some industries. At this moment, most of the biocomposites projected are limited to lab-scale investigations. It is important to consider the role of government legislation and technology development to escalate the lab work.

Water hyacinth for biocomposites

Eicchornia crassipes is a floating perennial plant with green leaves that has a spiky bloom violet and yellow in colour and has a fibrous root that extends up to three metres. It belongs to the Pontederiaceae family, whch is native to South America. It is the only species of the genus *eicchornia* that is floating. The petioles have intercellular spaces filled with air, and the blades are raised above the water level and act as sails, which allow it to float freely and quickly spread its distribution until it becomes a plague (INECOL, n.d.). It has been lying in bodies of water in Mexico for more than a century, spreading to cause major problems in its early years and to this day. It is suggested that it was brought during the government of Porfirio Diaz, given the policies that were implemented in the economic sector to increase the development of agricultural and fishing activities. Due to this, it is thought that it could have arrived as green manure in chinampera agriculture, as an element of fish farming technology or as an ornamental plant, according to Cervantes and Rojas (2000). It has a wet weight of 11–51 kg per square metre, corresponding to 0.62–2.87 kg per square metre in dry weight. The biomass has a variable doubling rate of between 7.4 and 46.5 days (Juárez, 2011). Its use for material creation was not raised until a few years ago. Micro-enterprises are dedicated to its transformation into paper and derivative handicrafts woven from the stems, and more recently it has been proposed as fibre for the manufacture of composites and parts for the automotive sector. Great interest has been shown in the last two decades for the creation of a wide variety of projects of this type, both research and marketed, for the sustainable use of waste and weeds mainly aimed at their transformation into industrial/handcrafted materials.

This plant has been proposed as raw material, for example, due to its absorbent quality, to retain contaminants resulting from spills. Vargas (2017) mentions a variety of existing and possible derivative products, such as compost, paper, handicrafts, toxin absorbers, construction materials, paint texturisers, oven supplies, fodder, soil remediation, some produced as a biocomposite, with the addition of chemical or biological matrices. Ajithram (2020) evaluates its use in compounds with epoxy resin, showing characteristics very similar to those provided by synthetic fibres. This is oriented to industries such as the automotive industry. Non-woven textile production has been proposed by Bhuvaneshwari and Sangeetha (2017) through a defibration process and combined with another fibre (hemp) that has greater cohesion power.

Fiber	Cellulose (wt. %)	Lignin (wt. %)	Hemi cellulose (wt. %)	Pectin (wt. %)	Wax (wt. %)	Moisture (wt. %)
Jute	61–71.5	12–13	13.6–20.4	0.4	0.5	12.6
Hemp	70–74.4	3.7–5.7	17.4–22.7	0.9	0.8	10
Kenaf	31–39	15–19	21.5	–	–	–
Flax	71	2.2	18.6–20.6	2.3	1.7	10
Sisal	67–78	8–11	10–14.2	10	2	11
Coir	36–43	41–45	10–20	3–4	–	–
Banana	63–67	5	19	–	–	8.7
Water hyacinth	61.63	3.78	16.26	–	–	11.8

Table 1: Physical properties of water hyacinth fibre compared with others. (Ajithram et al., 2020).

Methodology

To implement an ecological production system for biocomposites in coherence with the context and the objective of comprehensive sustainability defined from the documentary review, a search was carried out for processes with the least impact on both environmental and human health, drifting towards simplified processes that are feasible to be carried out in vulnerable communities with a lack of services, reduced spaces and low investment level, using the most accessible tools and machinery in terms of use and costs, the least possible use of substances or additives both renewable and non-renewable, as well as an optimal use of energy and in the same way, the least possible, whether electricity or from fuel. In this way, a strategy of strategies emerged that occurred four stages before social entrepreneurship.

1) Theoretical foundation. Relevance of the proposal. 2) Strategy where the methods of preparation of the fibre and other inputs for the material creation were planned. 3) Strategy of experimentation in the creation of materials. 4) Proposal for the future for obtaining materials and the creation of design objects aimed at a social enterprise.

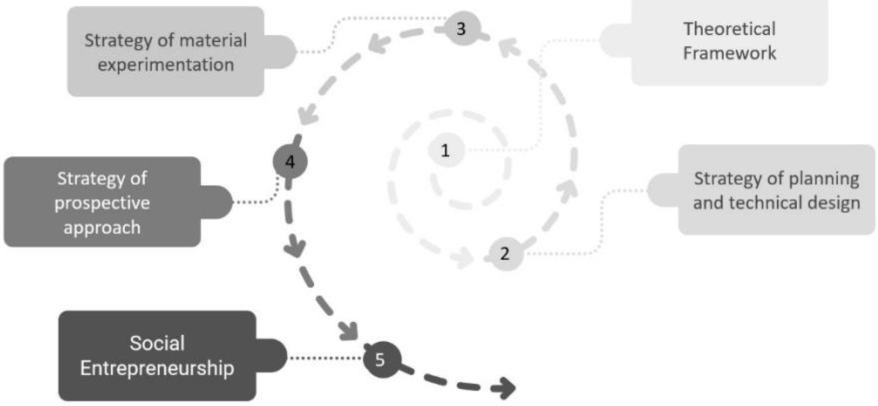

Image 2: Strategy phases of the proposed methodology for eco-development of biocomposites in San Gregorio.

The main contribution of this methodology is to find a way to make an impactful project in the San Gregorio region, going little by little, given the cultural characteristics of the communities. This work frames the first steps where a posture of eco-development is taken through the theoretical investigation and materials are obtained, so is possible to offer workshops with actors of the community to have an approach from the perspective of design and other fields like biology, architecture, chemistry, among others, with social entrepreneurship aimed at since the beginning. This is the first estimated bridge between the community and a group of work that will carry a whole project of sustainable restoration called *Master plan of sustainable development for San Gregorio Atlapulco*, in which professors, investigators and students from different disciplines like those mentioned before meet. With a complete map of stakeholders, we can formulate a complex strategy for the estimated project to the integral sustainable transformation of San Gregorio Atlapulco.

Case study

San Gregorio Atlapulco is chosen as a strategic site within the Xochimilco demarcation. It is made up of different zones: rural chinampera, wetlands (remnants of Lake Xochimilco) and urban and hilly. This area shares the typical characteristics of Xochimilco; it consists of an average altitude of 2,240 metres above sea level with an average 669 mm annual rainfall and temperature of 16.4°C (Torres-Lima & Conway., 2018). The lake system is made up of 277.8 km^2, where an estimated volume of 2622 cubic metres of water is contained in 160 ha. There is a channel network of 203 km in total length. The agroecological production area has decreased from 9,000 ha registered at the beginning of the 20th century to 1,200 ha. Torres-Lima and Conway also mention a series of problems that affect the sustainability of the San Gregorio Atlapulco wetlands (Table2):

Indicator	Socio-environmental Impact
Socioeconomic	Use of modified or transgenic seeds Use of chemical fertilisers and pesticides Replacing traditional chinampas techniques with greenhouses Construction of stables Construction of bridges between canals Introduction of a sanitary hydraulic network in chinampas Improvised rubbish tips Loss of trade with local markets
Environmental	Construction of locks and weirs Closure of canals and ditches Destruction of dykes Drainage of sewage into canals Deforestation of native ahuejotes trees (Salix Bomplandiana L.) **Invasion of water hyacinth (*Eicchornia crassipes*)** Removal of wild plants and animals Use of motorised aquatic vehicles
Regional	Abandonment of piers Transformation of chinampas into housing Conversion of canals into streets No intervention on the part of institutions and government officials

Table 2: Indicators and variables of socio-environmental impacts that negatively affect wetland sustainability in San Gregorio Atlapulco (Torres-Lima et al., 2018).

The aforementioned has motivated the generation of a proposal that articulates the use of the water hyacinth plague that shows an average yield of 120 tons per hectare yearly (D'Agua et al., 2014) and an approximate cost of 70,000 Mexican pesos per hectare to remove it from the waters (Juárez, 2011), causing an economic, environmental and social impacts that affect the water ecosystems and productive activities. With the strategy of utilisation as fibre, this can be profitable, through value-added products created by the community members in workshops.

Strategy of planning and technical design

The processes for the preparation of the water hyacinth as a raw material for the manufacture of biocomposites are established, starting from the theoretical basis of the treatment of fibres for their use as reinforcement in biobases. A general approach to the treatment of the plant is provided by Ajithram (2020) with a sequence of extraction, cutting of roots and leaves (which are discarded), drying and crushing. In addition, implements for these processes were designed and manufactured. Subsequently, experiments were carried out with the manufacture of biobases using starches, vegetable glue, pine resin and gelatin.

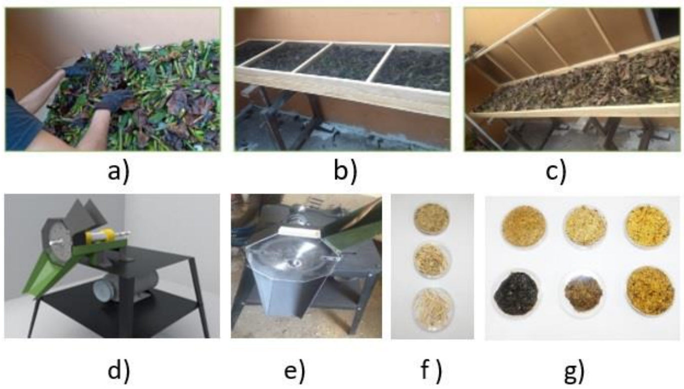

Image 3: Preparation of biomass for utilisation in biocomposites experimentation. a)–c): Drying process in net panels; d), e): designed low cost shredding machine; f) particle sizes obtained from shredding; g) experimental biobases of starch, gelatin, mucilague + fibre.

To obtain the optimal biobases for fibre binding, it was considered a design of experiments with mixtures proposed by Gutiérrez y De la Vara (2008). Guided by the geometric representation, the vertexes represent pure mixtures, the edges represent binary mixtures, the faces correspond to tertiary mixtures. and the interior points to quaternary mixtures.

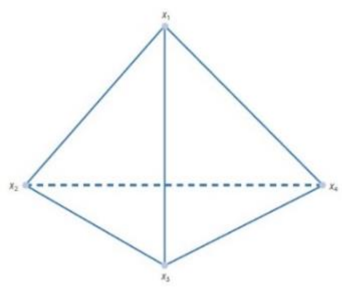

Image 4: Geometric representation of design of experiments with mixtures by Gutiérrez y De la Vara (2008).

Strategy of material experimentation

With the selected formulas, the material tests were carried out to obtain seven different presentations of fibre and combined biobases, using, as mentioned, simple processes, friendly for the user and the environment:

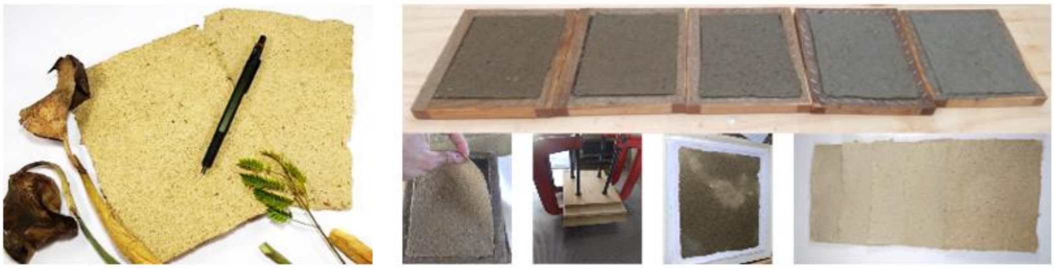

Image 5: Paper. A laminate from a mixture of 80% water hyacinth fibre and 20% recycled newspaper, both previously treated with water immersion of 7 days to soften the fibre.

Image 6: Agglomerate. Material made of 100% fibre, previously treated with water immersion of 7 days, only subjected to pressure in a mould to take form and expel most of the water. This presentation of bars was weak in its face, but very strong when it was resting on its edges.

Image 7: Agglomerate with starch bioplastic. The optimal matrix was composed by a 4:1:1:1: 1/5 formula: water 30 g, starch 7.5 g, vinegar 7.5 g, glycerin 7.5 g, with 1.5 g of dried fibre. The difference between this material and the previous one is that this were not subjected to pressure to give form. It was just cast into the mould and left to dry. It takes around 4 days to be completely dry.

Image 8: Vinyl of gelatin and starch bioplastic with fibre. The optimal formula for the matrix was 10:3/4:2:1, which entails 100 g water, 7.5 g of gelatin, 20 g of glycerin and 10 g of vinegar for the mould used. The optimal amount of fibre added was 3 g dried or 20 g wet. It solidifies in 15 minutes, but to be completely dry takes approximately 96 hours.

Image 9: Bioplastic of pine resin. This material consists of three components: pine resin, beeswax and fibre. The wax is added to give fluency to the mixture. The optimal amount was 15 g resin, 15 g wax and 3 g dried fibre. The matrix is heated until it melts and then is cast in a mould with the fibre already inside it, stirred for a few seconds and left to dry.

Image 10: Bio-laminated weave. This material consists of a piece of woven stems and a process of bio-laminate with starch bioplastic. First, the hyacinth stems are set in the sunlight for drying, then the air is removed by pressure with the hand. Once the stems are flat, the weaving starts. The bio-laminated weave consists of mechanical pressure applied to the piece of woven stems. Once it is flat, it is coated with layers of starch bioplastic, then is subjected to pressure again, with a source of heat supplying hot air to dry and harden the piece.

Image 11: Bio-panel. A combination of the last two materials: agglomerate + bio-laminated weave. The agglomerate is glued by the faces with starch bioplastic and subjected to pressure. Then, two pieces of laminate are set under and over the agglomerates and glued with starch bioplastic applying pressure too. The result is a light and hard piece of a sandwich of water hyacinth that supports large amounts of weight.

Strategy of prospective approach
This section proposes an application of the development of materials and the manufacture of design objects in a community environment that contributes to its integral sustainable development. It is intended that from this research a complex strategy arises, where the materials function as a means through which a community such as San Gregorio Atlapulco can provide solutions to the identified problems and solve needs, improving the current situation without causing further environmental deterioration, and alluding to environmental education and awareness.

How the project is planned to be carried out in the next stage is in a co-creation space where the community inhabitants interact with the material to explore design alternatives or applications for each material likely to be marketed to generate a social enterprise. This implies empowering the members of a community to achieve independence based on the self-production of materials, using simple transformation processes with local and circular inputs.

1 2 3 4 5

6 7 8

Image 12: Examples of applications for the developed materials in this work. 1) Biovinyl applications. 2) BioVinyl objects. 3) Paper for art. 4) Biovinyl lampshade. 5) Bio-laminated veneer on PDF. 6) Paper dog poop collector. 7 & 8) Bioplastic from hand-moulded starch.

The main contribution of this work is a extensive exploration of the material possibilities with water hyacinth, working with austerity, thinking about taking the processes to a rural environment, with the possibility to make a manual for developing this kind of biocomposite to use with groups in workshops. Another contribution is that when the work was showed to the public, mainly academic experts on the region of Xochimilco, it generated great interest as a project applying social innovation, whereby this project has been considered the more feasible way to approximate to the communities of San Gregorio, to carry then a greater project that covers another area and requires more actors.

In the context of developing the project proposal as social entrepreneurship, it is expected that there will be attention to each of situation that needs solutions, as follows:

Dimension	Development
Environmental	Water hyacinth control; inculcate ecological awareness; the barrier between the protected area and irregular settlements
Social	Improve quality of life; creation of new organisations; improve health
Economic	Improve navigation in channels; offer job opportunities
Bio-cultural	Heritage revaluation; landscape conservation; inculcate values and environmental care
Political	Agreements between stakeholders; support networks; proposal of new regulations and policies
Scientific-Technologic	Research and technological development (materials, processes); implementation of eco-technologies;
Educational	Form a socio-environmental criterion; educate for family planning
Fields of design	Sustainable alternatives of creation; aimed at socio-environmental benefit; investigation to and from design; create a regional product identity

Table 3: Developments for each dimension of integral sustainability.

Final considerations: Limitations and scope

The objective is to create an eco-development strategy aimed at the production of materials in an environment of scarce resources and infrastructure. The methodology will entail an approach to a technical manual for the eco-development of biocomposites with water hyacinth. Aspects of feasibility will aim at a circular economy that contributes to community development through innovation and social entrepreneurship, which in turn, contributes to its control in the tributaries that are plagued by water hyacinth. Finally, due to the restrictions of the COVID-19 pandemic, the study of the community was carried out through document review and participation in seminars and talks with academics who have worked in the area.

Conclusions

A realistic scenario is proposed to carry out the eco-development strategy in the community of San Gregorio Atlapulco. Through a subsequent multidisciplinary, in-depth study with various actors (research community and authorities) and with a definitive structure, a pilot project with desirable scenarios will be developed.

The sustainability paradigm is perceived integrally, trying to contemplate the complexity, in this case, of the object of transformation, and thus responding with a proposal from complexity to provide solutions for social change. However, this approach is nothing more than a viable transition for the moment, towards a paradigm of deep ecology.

Future investigation will explore the optimisation of materials using other sustainable inputs – biobased or synthetic – and greater self-produced technological development. There will be execution of quantitative tests, such as mechanical, use and end of cycle like degradability and compostability. In addition, an impact matrix with social, cultural, economic and aesthetic indicators will be developed. Finally, a survey methodology will be implemented in the community on the receptivity of social entrepreneurship initiatives from design.

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