Master's Degree in Energy Engineering
EEE Renewables and Environmental Sustainability

Reducing the packaging waste generated by the improvement of handwashing accessibility in a slum of Maputo (Mozambique)

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Sommario

Questo lavoro nasce come supporto per il progetto HANDS, uno studio di ricerca del Politecnico di Milano per lo sviluppo innovativo dei quartieri informali attraverso interventi multidisciplinari con visione a lungo termine, finalizzate alla promozione della salubrità nel quartiere informale di Chamanculo C, in Mozambico. Scopo del seguente lavoro è una proposta progettuale di un laboratorio sociale atto alla produzione e distribuzione sostenibile di Polichina, disinfettante per mani messo a disposizione dal Politecnico di Milano durante la pandemia da Covid-19, all'interno del quartiere. In Mozambico, il problema dell'accessibilità a strutture per il lavaggio mani è allarmante, ed osservato dal punto di vista sanitario, è causa di malattie e di una qualità di vita che lo rendono uno dei paesi meno vivibili al mondo, soprattutto per donne e bambini, come riportato dai programmi di monitoraggio volti al raggiungimento degli obiettivi posti dall'Agenda 2030. Altra faccia della stessa medaglia è il problema della gestione dei rifiuti, totalmente inadeguata e non pronta allo stravolgimento nel flusso dei rifiuti che la crescita economica in atto sta comportando. Di particolare interesse è il tema legato ai contenitori, con visione sulla sostenibilità di questi ultimi. La prima parte dell'elaborato consiste in un inquadramento della situazione globale, nei paesi a basso-reddito, sulla situazione di WASH e in generale sulla gestione dei rifiuti, con focus sull' incremento di percentuale che verrà inevitabilmente allocata a qualsiasi tipo di imballaggio durante la crescita economica, per poi focalizzarsi sul contesto mozambicano. Nella seconda parte, ampio spazio è dedicato alla parte di progetto, prendendo in analisi la compatibilità dei contenitori con il disinfettante, il dimensionamento fisico del centro e la fattibilità economica. Infine, con la consapevolezza del potenziale danno ambientale che l'incremento di contenitori di plastica nel quartiere può comportare, è presentata una proposta per l'incentivazione del ricircolo virtuoso, prendendo a modello l'efficiente sistema danese del vuoto a rendere.

Abstract

This work borns as support for the HANDS project, a research study of the Politecnico di Milano for the innovative development of informal neighbourhoods through multidisciplinary interventions with a long-term vision, aimed at promoting healthiness in the informal neighbourhood of Chamanculo C, in Mozambique. The purpose of the following is a design proposal for a social laboratory aimed at the production and distribution of Polichina, a hand disinfectant made available to society by Politecnico di Milano during the Covid-19 pandemic, within the district. In Mozambique, the problem of handwashing facilities accessibility is alarming and causes diseases and a quality of life that make it one of the least liveable countries in the world, especially for women and children, as reported by the monitoring programs aimed at achieving the objectives set by the 2030 Agenda. Another side of the same coin is the problem of waste management, totally inadequate and not ready for an upheaval in the waste stream that the current economic growth is causing. Of particular interest is the theme linked to containers, with a view on the sustainability of the latter. The first part of the paper consists of an overview of the global situation, in low-income countries, on the WASH situation and in general on waste management, with a focus on the percentage increase that will inevitably be allocated to any type of packaging during economic growth to then focus on the mozambican context. In the second part, wide space is dedicated to the project part, analysing the containers compatibility with the disinfectant, the physical sizing of the center and the economic feasibility. Finally, aware of the potential environmental damage that a sudden introduction of plastic containers in the neighbourhood can cause, a proposal to encourage the virtuous recycling, using the efficient danish returnable system as a model, is presented.

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Introduction

Despite significant progress in recent years, the world is falling short of meeting the global targets set in the United Nations Sustainable Development Goals (SDGs) for 2030. Ensuring access to affordable and reliable WASH – Water, Sanitation and Hygiene - services, coupled with an integrated and sustainable waste management system, for all by 2030 remains possible but will require more sustained efforts. In low-income countries, and especially in remote rural areas, access to basic services such as handwashing facilities or waste management remains a significant challenge. The spread of Coronavirus in 2020 has done nothing but bring to journalistic attention the, already existing, problem of accessibility of sanitation services in poorest countries. In Mozambique, the case study of the present elaborate, only half of the population have access to improved water supply with, in rural areas, accessibility equal to less than 20%. A more than valid alternative to hands washing with water and soap, considering the lack of water supply system, is the correct use of alcohol-based hands sanitizer, which may result in the abatement of almost totality of bacteria.

Most of the low-income countries are gripped by the waste emergency. Despite, in some cases, the existence of institutional frameworks for the creation of programs elected to the municipal solid waste management, there is no implementation of aforementioned practices, with a total absent interaction between involved stakeholders. Such situation leads to a solid waste management almost totally based on disposal, harmful habit for society and for the environment, with landfills such as mountain ranges of waste. In a vicious circle in which we lose sight of what is cause and what is effect, precarious conditions in water, sanitation and hygiene coupled with an inadequate solid waste management system, make a low-income country such as Mozambique one of the last in terms of quality of life.

This work is part of the HANDS project, a research study for the innovative development of the informal neighbourhoods, through a multidisciplinary approach, aimed at the healthiness in the informal district of Chamanculo C, combining both health and environmental projects driven by a strong social matrix. The project, whose acronym means Health and Urban Spaces, has been funded within the social engagement and responsibility programme of Politecnico di Milano (Polisocial).

Scope of the elaborate is a design proposal of a production and distribution centre in Chamanculo C, for the sustainable provision of Polichina to the population.

Polichina is a hands sanitizer produced by Politecnico di Milano during Covid-19 pandemic, thanks to the recipe published by the World Health Organization, with a purely social purpose, namely the one of making such a powerful tool accessible to everyone during a delicate moment. Furthermore, attention is reserved to the potential negative impact that, such a sudden introduction in the neighbourhood of thousands of plastic containers would have on the solid waste management flow. To

address this issue, a return system for the virtuous recirculation of Polichina containers is proposed, taking the highly efficient Danish system as a model.
Finally, in addition to concrete actions for the healthiness of the neighbourhood, expressed in the mere supply of hygienic products, this work has the objective to promote the culture of healthy behaviours, confident on how the aforementioned behaviours could become an integral part of the life of present and future generations.

Chapter 1 - A comprehensive approach to healthcare improvement projects, theoretical basis

1.1 Agenda 2030

In 2015, the United Nations adopted the Agenda 2030 for sustainable development, which includes 17 Sustainable Development Goals (SDGs) proposing themselves to be "the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace and justice", as sponsored by United Nations in their presentation of the Agenda 2030 in 2015 [1].

Figure 1 - Sustainable Development Goals (Source: United Nations, 2015)

“The 17 Sustainable Development Goals SDGs, and the 169 sub-goals associated with them, constitute the vital core of the 2030 Agenda. They take into account, in a balanced way, the three dimensions of sustainable development, namely economic, social and ecological. For the first time, a single policy document brings together sustainable development and the fight against poverty” [1]. The 2030 Agenda replaced the Millennium Development Goals (MDGs) adopted in September 2000, with deadline 2015, by 193 countries and achieved only partially. SDGs differs greatly from the Millenium ones basically over two aspects. Firstly, the SDGs are aimed at all states, regardless of the level of development they have reached, and secondly, while the MDGs have been "imposed" by the United Nations on the States, the SDGs have been defined through an active participation of the UN States in the work of creating the objectives themselves, ensuring widespread consensus.
Most of those goals have strict correlation with the issue of sanitation, hygiene and waste management, deficiencies which, in developing countries, are the cause of many fatal diseases, especially for women and children.

1.2 Water, sanitation and hygiene

Health is understood as a condition of harmonious functional, physical and mental balance of the individual, integrated into his natural and social environment.
Safe drinking-water, sanitation and hygiene are crucial to human health and well-being. Globally recognized and widely used by non-governmental organizations and aid agencies in developing countries, is the acronym WASH, standing, precisely, for water, santitation and hygiene. The World Health Organization, in its report on WASH theme published in 2022 [2], keens to emphasize how a safe and sufficient WASH is not only a prerequisite to health, but contributes to livelihoods, school attendance and dignity helping the creation of resilient communities living in healthy environments. During the Millenium development goals period, from 1990 to 2015, with the significant progress on water and sanitation provision, especially with an accent on the concept of WASH, were reported that Diarrhoeal deaths as a result of inadequate hygiene were reduced by half [2], but still, 829'000 people die each year because of this deadly infectious disease as a result of unsafe drinking-water, lack of accessibility to sanitation and hand hygiene, meaning that a lot of improvements have to be made yet.
More in general, a safe wash plays a key-role against the spreading of neglected tropical diseases, NTDs. As explained by WHO in 2021 [3], "NTDs are a diverse group of 20 conditions mostly prevalent in tropical areas, where they affect impoverished communities with a greater impact on women and children. These diseases cause devastating health, social and economic consequences to more than one billion people". They are mainly caused by severe environmental conditions in terms on personal hygiene. In spite of the gravity of this situation, the NTDs have always been almost absent from health policy agenda, and only with the advent of the Sustainable Development Goals, in 2015, start to gain recognition.
Especially, SDG3 "Ensure healthy lives and promote well-being for all at all ages" [1] can be achieved only if NTD goals are met.
What has to be clear is that the types of water supply and sanitation systems exploited in the high-income and industrialized countries are often not suitable for the low-income ones, since they are too expensive to be used in poor communities and because the water they need is not available or affordable. Furthermore, even if improved water supply systems and sanitation are put in place, sustained programs of hygiene education are necessary, in order for people to gain awareness on how to use them to maximize the benefits for their health. Despite COVID-19 putting the spotlight on the importance of hand hygiene to prevent the spread of disease, UNICEF in its 2022 WASH reported [4] highlighted how three billion people worldwide, including hundreds of millions of school-going children, do not have access to handwashing facilities with soap and that the portion of people living in rural areas, especially in low-income countries are the most vulnerable and most affected.

1.2.1 Prevention and health promotion against the spreading of diseases

The World Health Organizations, in an article published in 2022 “Health promotion and disease prevention through population-based interventions, including action to address social determinants and health inequity” [5], faced the topic of disease prevention in conjunction with the health promotion theme. WHO defines disease prevention as ”population-based and individual-based interventions for primary and secondary prevention, aiming to minimize the burden of diseases and associated risk factors“.
Two different levels of prevention are identified, a primary and a secondary. Primary prevention means the adoption of measures to prevent the onset of diseases, intervening on risk factors, acting on behavioural and environmental changes, while secondary one deals with early detection when this improves the chances for positive health outcomes, like for example evidence-based screening programs for early detection of diseases. Actually, also a third level of prevention should be taken into account, the one aimed at arresting already existing diseases and their effects. What also differentiates the most primary prevention between the other levels is the fact that its implementation is independent from capacity-building in other care services, as reported by WHO [5].
For what concerns health promotion, the World Health Organizations defines it “as the process of empowering people to increase control over their health and its determinants through health literacy efforts and multisectoral action to increase healthy behaviours” [5].
Even if from a concrete point of view they differ, there exists a consistent overlap between these two measures. In fact, conceptually speaking they share the final goal, even if belonging to different sectors. While health promotion is more related to social habits, disease prevention could usually be allocated to those services within the health care system structures.

1.2.1.1 Handwashing as primary measure for health promotion

Hand washing is one of the basic tools for primary prevention of infections, and one of the oldest as well, and represents a great example of bridge between primary prevention measure and health promotion. Every year, on the 15th October, through the Global Handwashing day, several non-governmental organization such as UNICEF or WHO do not miss the opportunity to remember how important this simple operation could be. In fact, washing hands with soap, or with alcohol disinfectant, is one of the cheapest ways to improve health and well-being. The results, in terms of reducing the spread of diseases, that accompany a daily hand

washing are astounding: CDC, the Center for Disease Control and Prevention reported that handwashing education to community can: reduce the people who get sick of diarrhea by about 23%–40%, reduce the number of school days children missed because of gastrointestinal illness by 29%–57% and respiratory illnesses, like colds, in the general population by about 16%–21% [6].
Astonishing results on the powerful of handwashing have been confirmed also by UNICEF in the 2022 Global Handwashing day, with a ‘’lowering of 30% diarrheal diseases, acute respiratory infections up to 20%, infant deaths from infections by 27% and the reduction of transmission of epidemics linked to pathogens such as cholera and ebola’’ [7].

Figure 2 - (Source: UNICEF, 2017)

Furthermore, Null et al. (2018) [8] in a cluster randomised control in Kenya, regarding effects of handwashing interventions on diarrhoea and child growth, show how the practice of handwashing reduce the presence of harmful bacteria by 92%, and the low-income world continues to struggle with high child mortality rates. Reiner et al. (2020) [9], reported how 11 children under age five died every minute in 2015.
Speaking of journalistic news, handwashing, coupled with adequate social distancing, is the key component of guidance to reduce transmission of the SARS-CoV-2 virus, responsible for the COVID-19 pandemic. Prior systematic reviews have indicated the effectiveness of handwashing to reduce transmission of respiratory viruses. In low-income countries, the reduction of transmission ratio is of paramount importance, and, considering the difficulty of ensuring social distancing because of several people living in high densities urban slums, handwashing seems to be the only safety net.
Several studies have investigated the correlation between the transmission of respiratory diseases with the frequency of hand washing and confirmed the astounding benefits resulting from this trivial operation.
Jefferson et al. (2009) [10] performed a systematic review of physical interventions adopted for the purpose of reducing the transmission of respiratory viruses. What emerged was handwashing to be effective, with an estimate of a 50% reduction in transmission. Furthermore, Saunders-Hastings et al. (2017) [11] analysed the effectiveness of personal protecting measures as prevention for H1N1 pandemic

influenza. Results show a reduction of transmission in human populations about 38%, with the use of masks found to be less effective with respect to handwashing. Finally, just for the records, Smith et al. (2015) [12], having taken into consideration influenza transmissions in adults, concluded that hand washing contribution is strong in reducing transmissions. Therefore, washing hands with soap is an essential resources of human health in preventing the spreading of diseases.

1.2.1.2 The problem of accessibility

The apparent simplicity of the hand-washing gesture carries with it a major global burden, especially with regards to low-income countries, that is the one of accessibility to handwashing facilities. These facilities have been defined by UNICEF and WHO in 2017 [1], according to United Nations Sustainable Development Goal 6.2.1 as "a device to contain, transport or regulate the flow of water to facilitate handwashing".
In fact, despite huge improvements achieved in the last decades, Brauer et al. (2020) [13] reported that, in 2019, approximately 2 billion people lacked access to handwashing with soap and water, this means that 26% of population couldn't access this facility. Furthermore, reducing the radius on a low-income area such as Sub-Saharian Africa, [13] indicates how more than 50% of population has nowadays no accessibility at all to those services. The visual impact given by the figure below is tremendous. More than 2 billion of children lack resources to wash their hands at home and, in low-income countries, more than two thirds of people do not have basic hand washing facilities [7]. Of almost equal gravity, seems to be the lack of awareness of this problem considering that, at the current pace, 1.9 billion people will still not have the opportunity to wash their hands at home by the end of the era set by Sustainable Development Goals, in 2030.

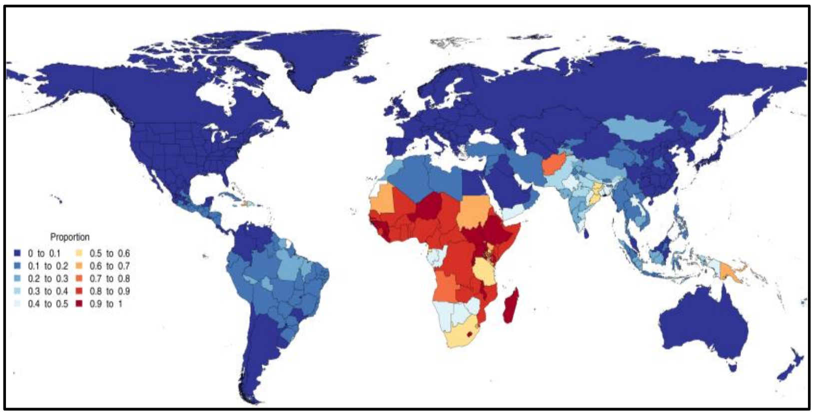

Figure 3 - Estimated population with no access to handwashing with soap and water (Source: EHP, 2019)

Unfortunately, this alarming picture is not just about housing. In fact, what has emerged from the the latest report “Progress on WASH in health care facilities 2000-2021: special focus on WASH and infection prevention and control” [14], published last year by the collaboration of UNICEF and WHO, is a worrying picture of the state of water systems and facilities, for washing hands, in health care facilities as well. Globally speaking, only 68% of health care facilities are provided of water systems and just 65% of hand washing with soap and water in bathrooms. If we are looking for the simoultaneous presence of these two services, the percentage drops to 51% [7]. Furthermore, UNICEF [7] report that one in eleven healthcare facilities globally does not have either services.

Finally, since limited access to handwashing facilities may promote the spread of the COVID-19 pandemic in LICs, governments may prioritize rapid deployment of access or alternatives such as alcohol-based solutions to those locations without accessibility to handwashing facilities. The project HANDS fits into this sense, as will be explained later in the thesis.

Chapter 2 – Waste generation and goods production

2.1 Waste management in low-income countries

Kaza et al. (2018) [15], in What a Waste 2.0, a cornerstone book which represents a global picture and prevision on the solid waste management at a global level, reported how, by analysing the recent years trends, "by 2030 the world is expected to generate 2.59 billion tonnes of waste annually and, by 2050 waste generation across the world is expected to reach 3.40 billion tonnes".
As can be seen in the figure below, high-income countries, albeit remaining the largest producers of waste per capita, are going to experience the least amount of waste generation growth by 2030. An increase of only 10% over the generations, will not particularly distort the waste flows for which the current managements systems have been designed for, making this growth a problem that is not so impactful for these countries.
In reverse, for the so-called low-income countries, [15] allocate the greatest amount of growth in economic activity as well as population with the consequent expectation of waste levels to more than triple by 2050. In fact, as countries develop from low-income to middle- high-income levels, their waste management situations dramatically evolve, in fact growth in prosperity and movement to urban areas inevitably carry with them increases in per capita waste generation.

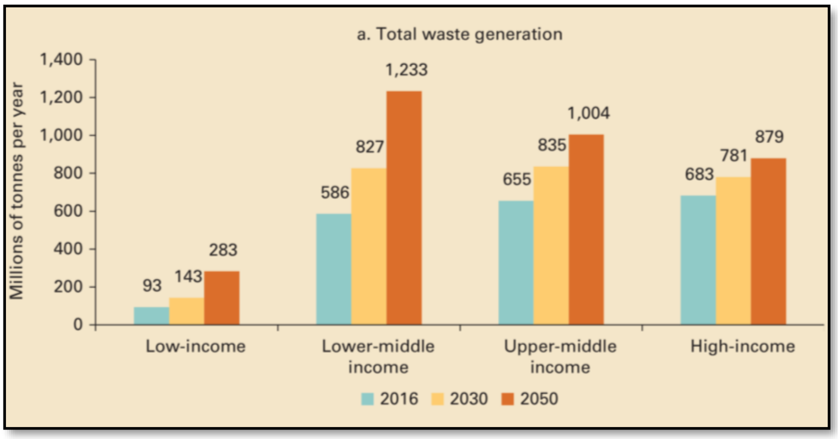

Figure 4 - Projected Waste Generation by Income Group (Source: World Bank)

Let's acknowledge that urban waste management is an expensive service to deliver, in fact it can be the single highest budget item for many local administrations in low-income countries, where it comprises nearly 20 percent of municipal budgets, on average. [15] Reported that, in middle-income countries, solid waste management typically accounts for more than 10 percent of municipal budgets, and it accounts for about 4 percent in high-income countries.

Still, having great financial resources is not enough to provide a sustainable and efficient waste management service, in fact it does not exist a universal solution, but rather a tailored one for each different situation according to the context needs.

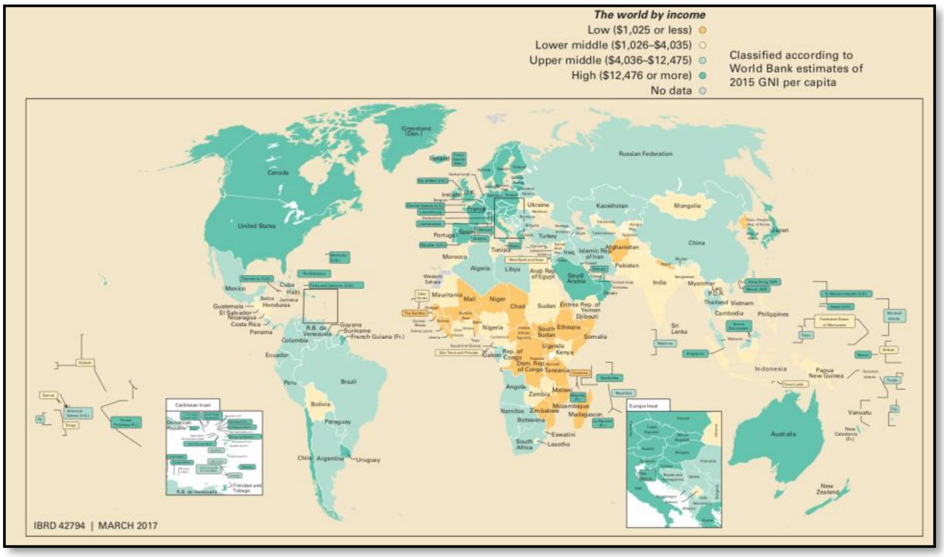

Figure 5 - Definition of Income levels in 2017 (Source: World Bank)

The income level is not only directly linked with the amount of waste generated , but also with its composition. Indeed, as a specific country move towards higher income level, the waste composition percentage that used to belong to organic waste dramatically decrease and consumed goods start to include more inorganic materials such as plastic, paper and cardboard, metals. The fact that low-income cities and countries are moving towards an economic growing without adequate systems in place to manage the changing waste compositions of citizens, is widely discussed by [15].

Income level	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metal (%)	Other (%)
Low income	64	5	8	3	3	17
Lower Middle Income	59	9	12	3	2	15
Upper Middle Income	54	14	11	5	3	13
High Income	28	31	11	7	6	17

Figure 6 - Waste composition by Income level (Source: World Bank, 2020)

Another dramatic correlation with the income level is the collection percentage coverage. As underlined by Fatemi et al. (2009) [16], the almost totality of the high-income countries have well organized collection systems with different coloured bins. In those countries each municipal authority has sent out a program for the waste management, and in particular the collection part. Each stakeholder involved in the systems knows the interrelationships among the others and each citizen is well informed on when and where he should locate his waste.

The main problem concerning low to middle-income countries is well captured by [16] when reporting that "in those countries, there is often a variety of formal and informal, public and private systems already operating, so the basis for a stable mixed system is already in place. What most low- and middle-income cities miss is organization, specifically, a clear and functioning institutional framework, a sustainable financial system, and the willing to aim at the well-being of the managed community, on the basis of which to bring together the individual interests of the actors involved". Furthermore "as long as there is no coordination and a clear interaction between the involved stakeholders, the mixture remains a cluster of separate parts that do not function well together, with severe consequences from an environmental, social and economic point of view".

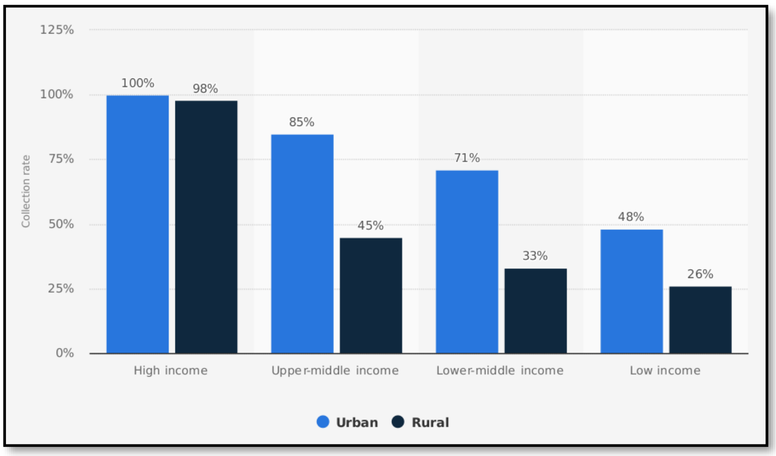

Figure 7 - Waste collection by Income level (Source: World Bank)

The last consideration, probably the most problematic, is upon the disposal methods linkage between the income level.

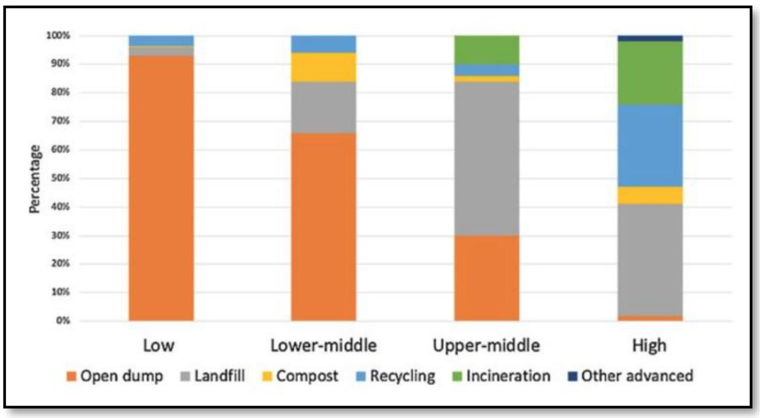

Figure 8 - Waste disposal methods by income level (Source: Kaza et al. 2018)

Figure 8 does not need further explanations. Yadav et al. (2019) [17], reported how, in low-income countries, more than 90% of waste generated is disposed of at uncontrolled dumpsites and landfills. Various hazards are associated with the waste dump sites such as, just to name a few, surface and ground water contamination, bad smell, release of greenhouse gases, and slope instability. Open dump sites in many countries, as we will see for our case study, have become a social plague even more than an environmental issue, with a lot of people living across or, in extreme cases, inside the landfills, making the latter as life resource. It is evident, simply by algebraically summing up the reality of events upcoming from above figures, how delicate is the problem and how dramatic will be the situation in those countries, if important upgrades in the waste management systems are not put in place. There is clearly a need to support waste management strategies for those poorer countries, where municipal authorities do not have the capacity to implement suitable policies. United Nations, in their environment program in 2019 [18], report that these countries are also among the biggest marine polluters: 90 per cent of the plastic in our oceans comes from just 10 rivers, with eight of those in Asia.

2.2 Integrated solid waste management system

Improving solid waste management is a major challenge in economically growing countries since, to deliver a good governance in solid waste, a strong and transparent institutional framework is essential. What has to be clear is that there are no perfect solutions, but also no absolute failures [19]. In fact, a winning strategy for a solid waste management system delivered in China, to name a country, may not work in another country or city. There is only one winning strategy, and that is to understand and build upon the strengths of each case study in order to identify the indigenous processes that are already working well. Each country, each city will have its own fitted solution, and we could see this by going through some examples of different applied, still efficient, solid waste management.

Although this crucial key concept, is important to have a basis above which create an efficient system for each situation. This important basis, is represented by the concept of integrated and sustainable waste management system.

As reported by Routledge et al. (2010) [19], integrated sustainable waste management, namely ISWM, is a framework that was first developed during the mid 1980s by WASTE, a Dutch non-governmental organization, and WASTE's South partner organizations, and further developed by the Collaborative Working Group on Solid Waste Management in Low- and Middle-Income Countries (CWG) in the mid 1990s [19].

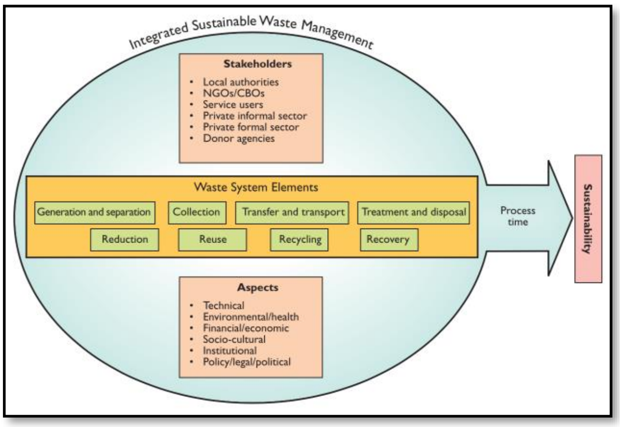

Figure 9 - ISWM framework (Source: WASTE, Gouda, the Netherlands)

The system approach lay its own foundations upon three important dimensions in waste management: First, the stakeholders involved in and affected by waste management, secondly, the practical and technical elements of the waste system and, thirdly, the sustainability aspects of the local context that should be taken into account when assessing and planning a waste management system.

ISWM is, first of all, about active participation of the stakeholders. The stakeholders always involved in the waste system are the municipalities, which has the duty to deliver a strategic plan for the urban cleaning and the citizens, who exploit the aforementioned system.

As underlined by [19], each city and country differ from each other and, in order to deliver an ISMW, is important to identify, in the local context, all the possible stakeholders and to make sure they are all involved and proactive in the waste management. In fact, [19] in their publication warn us on the possibility that unrecognized stakeholders include female street sweepers, male workers on collection trucks or dumpsite 'waste- pickers'. The inclusivity of the informal sector can be a life changing solution for a lot of people, living their life across landfills and working in precarious conditions. As we will see later, this is the case of the 'catadores'. There is the need to integrate them into society as an important figure in the waste management system, in order to stop seeing those people as a social plague. Integrated solid waste management system is an environmental issue as much as a social one.

The waste system elements represent the purely technical parts of the problem. Anschutz et al. (2004) [20], by putting ISWM into practice, underlined how most of them are also stages in the life cycle of materials. This life cycling or flow of materials begins with extraction of natural resources and continues through processing, production and consumption stage towards final treatment and disposal.

Finally, as reported by [19], for a waste management system to be sustainable, it needs to consider all of the operational aspects. These form the third dimension of the integrated system. In fact, without knowing the contexts where the system has to fit in, it is impossible to implement a successful waste management.

2.3 Hygienic products impact on waste generation

The World Health Organization, in its publication for the promotion of self-care as an effective part of national health system [21] defines self-care as the "ability of individuals, families, and communities to promote health, prevent disease, maintain health, and cope with illness and disability with or without the support of a healthcare provider".

Hygienic products are at the basis of protecting the health of the individual, and as awareness of the WASH concept increases even in low-income countries, a sharp increase in the production and consumption of these products is easily foreseeable.

Ash Pachauri et al. (2019) [22], in their article published in 2019 on the British Medical Journal 'Safe and sustainable waste management of self-care products', reported that, from 2013 to 2019, the global growth rate of self-care medical devices has arisen with a compound annual growth rate of 7.0%. Of course, this increase in the utilization rate leads to a direct growth in the quantity of disposables entering the waste streams. If we consider that half of the world's population is struggling with the waste managements of healthcare waste, especially in low-income countries, we understand the importance of the issue. [22] Stressed out the concept that the magnitude of waste arising from self-care products depends on the amount of user generated and segregated waste and the quality of treatment and disposal by the wider waste management system. For example, for what concerns condoms, as reported by [22] "they are mostly made of rubber-latex, which is bio-degradable, nevertheless condoms might contain polyurethane, which is non-biodegradable". Furthermore, their packaging also adds to the waste burden, with Ehiri et al. (2002) [23], in their study of the environmental impact of contraceptive use, reporting how "five billion packets of condoms sold annually contributing to beach litter and blockage of sewage systems".

Huge problems worldwide are also related to the management of waste deriving from menstrual hygiene products. Farz Edraki et al. (2017) [24], reported that women accessing menstrual hygienic products might use up to 12'000 during their lifetime, and biodegradation of plastic made sanitary pads could last over 800 years. The Menstrual Health Alliance estimates that 9000 tons of sanitary waste are generated annually in India. The actual problem is not the number of hygienic products consumed, in fact this is indispensable for the well-being of a person, rather the problem is the management of the waste related to those health services. Typically, this is disposed of with household waste, with consequent disposal is often improperly managing by local authorities, with sanitary products ending up in the oceans and waterways [25].

One of the main reasons regarding the failures in the waste management of such hygienic products, is accountability. Accountability has to be established by analysing each stakeholder's role during all the stages of a product. For instance, United Nations Population Fund's (UNPFA) [26] replicable green procurement strategy involved collaboration with donors, governments, beneficiaries, and suppliers, and by having clearly communicated details of the plan, has led to savings of 7.8 metric tons of CO_2, 11.8 million kg of solid waste, and 587’598 mc of water in 2010. Similarly, [22] reported that, a study evaluating the effect of syringe acquisition on syringe disposal, showed how providing syringes safely to HIV patients increases the likelihood of the products to be disposed in a sustainable way.

Self-care will form an important part of healthcare systems as governments strive to achieve universal health coverage by 2030, as part of the sustainable development goals. However, waste management of self-care products cannot be ignored, especially for low-income countries, coming to experience greater awareness in the importance of the hygienic products utilization, the problem of uncontrolled self-care products waste appears to be dramatically growing. An integrated approach, with clear accountability between the involved stakeholders, is necessary in order to ensure an efficient healthcare system to the population, without disastrous impacts on the waste management and consequentially on the environment.

2.3.1 The impact of containers and packaging

In 2022, the United States Environmental Protection Agency, EPA, published a study in order to deepen the containers and packaging impact on municipal solid waste generation [27]. In this analysis, containers and packaging are defined as "products assumed to be discarded the same year the products they contain are purchased". Unsurprisingly, these elements represent a huge portion in the solid waste generation, with approximately 82 tons in 2018, representing 28% of the total municipal solid waste. In order to simulate what is going to happen in low-income countries and how containers and packaging introduction in the waste fluxes will be relevant in the next years of economic growing, let's report the results of the study trend reported by EPA. Precisely, of particular interest for our case study is the trend of plastic containers and packaging, included of different plastic resins such as PET, HDPE and LDPE. The agency analyze the trend, in terms of percentage, within waste generation from 1960 to 2018. Furthermore, they have been able to address the respective waste management of such components. Figures below show what has emerged. Of particular matter is the trend of plastic containers landfilled, in fact in 2018, of the 14,5 tons generated, the 69% ended up disposed of in landfills, a practice that should gradually be eliminated, making way for a more sustainable circular economy.

Management Pathway	1960	1970	1980	1990	2000	2005	2010	2015	2017	2018
Generation	120	2,090	3,400	6,900	11,190	12,420	13,680	14,680	14,490	14,530
Recycled	-	-	10	260	1,030	1,280	1,850	2,150	1,890	1,980
Composted	-	-	-	-	-	-	-	-	-	-
Combustion with Energy Recovery	-	-	70	1,130	1,960	2,020	2,090	2,460	2,470	2,460
Landfilled	120	2,090	3,320	5,510	8,200	9,120	9,740	10,070	10,130	10,090

Figure 10 - Plastic Containers and Packaging MSW by Weight in the U.S. (Source: EPA, 2022)

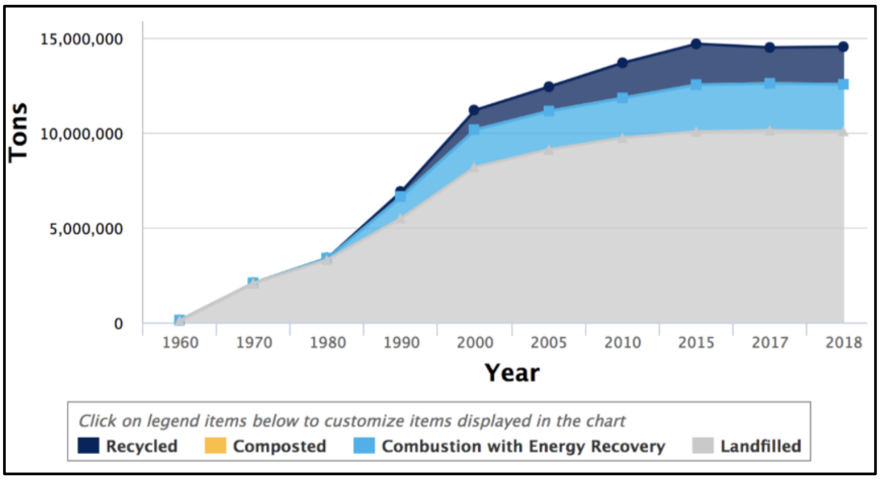

Figure 11 - Plastic Containers and Packaging waste management: 1960-2018 in the U.S. (Source: EPA, 2022)

2.4 Sustainable packaging product

Santi et al. (2022) [28] in their article "Sustainable food packaging: an integrated framework" analysed the concept of sustainability addressed to packaging product. The authors are keen to emphasize how a packaging product may be referred to as sustainable in a plurality of instances, for example, if it is made of recyclable, reusable or compostable materials or if it makes accessible a product or a service to disadvantages geographical areas in order to improve the wellbeing of the individuals. All these solutions could legitimately be defined as sustainable since they deliver different benefits for the environment, economy, and society. To cite the scope of this work, to the plastic containers used for the distribution of the hand sanitizer, even before analyzing the chemical component linked to the material and its potential environmental impact, a strong sustainable component can be allocated as they are used to make up for the lack of handwashing facilities in the Chamanculo C district.

Given that, Geyer et al. (2017) [29], reported how the packaging sector alone generates nearly 150 million tons of plastic in a year, with 95% disposed of in the same year, with consequent concern over ocean pollution and soil contamination, especially for what regards low-income countries. This is to underline that there are different declinations of sustainability associated with a packaging, starting from the purpose for which that specific packaging is used, passing through its management within a concept of reuse or recycling, up to the mere chemical compatibility with the environment, in terms of biological process.

Therefore, in a logic of initiative or sustainable process, all these variations must be taken into account. Let’s conclude by reporting an extract from [29], which summarizes very efficiently what just said:

"Traditionally packaging is defined sustainable if:

1. it is effective in containing and protecting products throughout the supply chain and by supporting informed and responsible consumption (effectiveness);
2. it uses materials and energy efficiently throughout its life cycle (resource efficiency);
3. its materials are cycled continuously through natural or technical systems (recyclability);
4. it does not pose any risks to human health or ecosystems (safety)"

2.5 Approach for the mitigation of waste containers generation

In an intervention aimed at promoting healthiness, the management of packaging or containers deriving from hygienic products used for personal hygiene is a topic of strong impact. In fact, for a low-income nation moving towards economic growth, the percentage of waste dedicated to any type of packaging or container, be it plastic or glass, is destined to increase dramatically as shown in previous chapters. Especially in the field of hygienic products aimed at improving personal well-being, promoting healthiness presupposes the insertion of various containers into the waste stream.

As an example, in this work we addressed the lack of water systems and therefore handwashing facilities, opting for the distribution of hand sanitizer through plastic containers. It is therefore important to consider the issue in all its aspects, so as to be able to make the right decisions. The following chapter will deal with the mitigation of the impact that derives from the introduction of containers into society, mentioning shortly a deposit-return scheme that symbolizes the chosen approach. With the aim of helping those who make decisions, the concept of functional unit will be brought to light, with an example that presents itself more as a provocation than a solution to the propaganda debate between plastic and glass, paying more attention to the analysis approach rather than to a resolutive choice limited to a specific theme.

In conclusion, this chapter, in addition to being of help for the choice of containers to be inserted in the virtuous recirculation object of the work and their management, is a clarifying mouthpiece on how the best solution can only be found with a complete analysis of the life cycle of a packaging.

2.5.1 Plastic or Glass? The concept of Functional Unit

According to a recent estimate by the Ellen Macarthur foundation [30], plastic waste pollutes the oceans more and more every day, and by 2050 the weight of the plastics present in the seas will be higher than that of fishes. Just to give some numbers, the European Parliament [31], in 2021 confirmed that 730 tons of waste are thrown into the Mediterranean Sea every day.

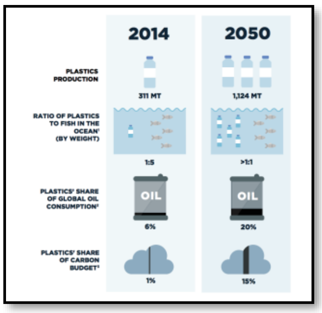

Figure 12 - Plastics in the Oceans projection (Source: European Parliament, 2021)

In our society, it is given for granted that plastic is way more potentially harmful than glass. This is due to some scientific basis, but in some cases also to misleading information and propaganda.
First of all, referring to plastic as a single product and therefore as a single type of waste is uncorrect. There are different types of plastics, each of these with different structures and with different impact on the waste management system and on the environment.
However, to, at least try, to analize this difficult dilemma there is the need to see with a more complete point of view. In particular analyzing it in its entirety through the analysis of the life cycle. As defined by Wikipedia [32], "LCA is a structured and standardized method at international level that allows to quantify the potential impacts on the environment and human health associated with a good or service, starting from the respective consumption of resources and emissions. In its traditional conception, it considers the entire life cycle of the system being analyzed starting from the acquisition of raw materials until management at the end of its useful life, including the manufacturing, distribution and use phases". A concept LCA cannot ignore is that of functional unit. To explain this concept, let’s exploit the example reported by European Parliament [31]. Let's imagine we have to decide which type of transportation to use in order to take a trip between Rome and Milan: we don't know whether to travel by bus or car, and we want to check which is the most sustainable option. Before any comparison, we must make a fundamental consideration: the bus carries out sixty people, the car only five. We will therefore not be able to compare a journey by car with one by bus (a comparison from which, of course, the bus would be defeated in terms of polluting emissions), but we will have to compare the transport of 60 people, which by car corresponds to about 30 journeys, considering the outward and return journey, while by bus only to one. In the case of the Milan-Rome route, we would therefore be comparing 570 km traveled by bus, with about 17,000 km by car. This is what is defined functional unit [31], the product, service or function on which to set the life cycle analysis and the comparison with the possible alternatives (bus or machine, plastic or glass): in the case of a bottle of water, for example, we could consider the amount of plastic or glass necessary to store a liter of water, and not how much pollutions coming from a kilogram of plastic compared to the same amount of glass. Hujibregts et al. (2009) [33] reported how the recipe method is one of the best known for evaluating the life cycle impact of a material. [33] Report how this method takes into account several factors, including the effect of the production of a material on climate change, CO2 emissions, and the consumption of fossil resources and water.
Several studies, including a life-cycle assessment performed by Accorsi et al. (2015) [34] of extra-virgin oil bottles, have confirmed the thesis that plastic is less harmful for the environment than glass. In fact, as confirmed also by [31], glass loses both due to its greater specific weight and to the energy consumed during its life cycle. To those who object that glass bottles can be reused, replies a study published in The international Journal of Lice Cycle Assessment by Amienyo et al.(2013) [35], which

states that "reusing a glass bottle three times lowers its carbon footprint to the level of that of a bottle disposable plastic; if, however, the plastic bottle is recycled or reused, then the glass bottle will have to be reused at least twenty times in order, for its carbon footprint, to drop to the levels of plastic".
In conclusion, the main issue related to plastic is not its life cycle but rather its "death" cycle: in Europe, for example, only 30% of it is recycled; the remaining 70% is incinerated (39%) or disposed of in landfills (31%), releasing toxic substances into the air and into the earth.

2.5.2 Returnable and reuse, then recycling

To guarantee sustainable consumption and production models is one of the 17 global goals adopted in 2030 Agenda for Sustainable Development [1]. A fundamental requirement for this global turning point is the release of the economic growth from the resources availability, resulting in a circular economy.
The action plan for the circular economy to be put in place, as underlined by European Commission in 2015, specifies that the products, materials and resources values should be kept within the economy chain value as much as possible and the generation of waste should be minimized. Essential concepts moving from a linear towards a circular economy are those of returnable, reuse and recycling. The difference between the terms 'reuse' and 'recycling' is substantial: we reuse an asset that has not yet become waste and we recycle what it already is a waste and which apparently is no longer functional to the purpose for which it has been produced. The two are not mutually exclusive, but have just a well-defined temporal succession. In fact, it is well known the benefits of the reuse and the recycle process, and it is clear how the coupling of the two might be the turning point to achieve the concept of circular economy, leading to a minimization of the waste to be managed. You reuse a material until the material itself, compatibly with its sector of use, allows you to do it. Then when reuse is not possible anymore, your recycle it turning it into another material with a different purpose.
The 'Returnable' concept goes in the same direction. In its primitive state, it implies that a container, once emptied of what it contained it is returned to the supplier. Everything could be returnable and reused several times before going to recycling processes. At least forty times for glass bottles, twenty for PET ones. All this also translates into energy savings: Galdo et al. (2021) [36] reported how the reuse of a PET bottle twenty times means a lower consumption of 76% of energy to produce it in the different versions.

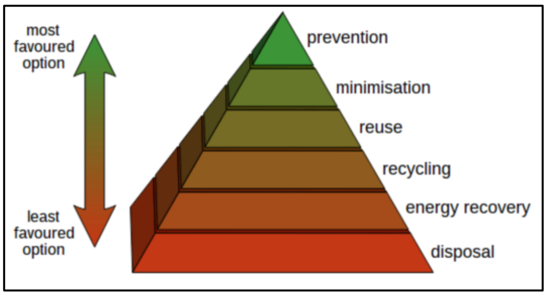

Figure 13 - Pyramid of Preferences (Sources: Google, 2018)

2.5.3 The case of Denmark: Dansk Retursystem

As defined by itself, Dansk Retursystem is a non-profit company owned by Danish Breweries, regulated by the Danish Environmental Protection Agency. Founded in 2000, it manages the national system for the deposit and return of bottles and cans of beverages with the aim of recycling as many materials as possible. All profits are reinvested in the business in order to improve the system and ensure that the high return rate is maintained or further increased [37]. Dansk Retursystem is an excellent example of successful collaboration between the private and public sectors. Its business model creates a circular economy that involves the entire chain: beverage packaging manufacturers, breweries, retailers, consumers, transport and recycling companies.


Figure 14 - Dansk Retursystem (Source: Danskretursystem, 2021)

Dansk Retursystem collects bottles and cans from automatic empty return machines located in 3,000 outlets across the country, from retailers, shops, offices, cafes and restaurants, or through deposit return points located in 12 cities. It separates down all collected packaging into glass bottles, plastic bottles and aluminum cans, which are recycled and transformed into new packaging. The result of this highly effective system is that 9 out of 10 bottles are returned and recycled, with an important reduction in the waste streams. The functioning of the system is very simple.

Basically, when a citizen goes to the supermarket to buy, for example, a coca-cola, he has to pay a small deposit to the store. Each container, depending on its functionality and its material, has a small ticket on the back distinguishing its category of belonging, as shown in figure below.

Figure 15 - Dansk Retursystem Category (Source: Youtube, 2021)

For each category, there exists respectively a deposit, the latter will be gained back once returned the container.

DANSK RETURSYSTEM		
Pant A	DKK 1.00	Glass bottles and aluminium cans less than 1lt
Pant B	DKK 1.50	Plastic bottles less than 1lt
Pant C	DKK 3.00	All bottles and cans of 1-20lt

Table 1 - Dansk Retursystem Category Deposit (Source: Youtube, 2021)

Once the user has emptied the containers, he can return it to the Dansk Return System through several machines located either inside either outside the supermarkets. On each machines, there are two buttons in order to choose what to do with the return deposit.

Figure 16 - Final user returning a plastic bottle to the Dansk Return System (Source: Danskretursystem, 2021)

In fact, you can either take the deposit back, or you can decide to donate it. Once you have returned all the bottles and cans, the machine calculate, scanning and weighting each of those, how much you gained, based on the value of table above, and it prints out a receipt through which the user can get his deposit money back. As previously said, this system has obtained great result in Denmark in recycling percentage and in reducing the waste streams. In an international context, Denmark is the unique country being able to collect more than 90 percent of packaging and recycle it for new bottles and cans. The expansion of the deposit system makes sense because it means including more products in a well-functioning closed cycle. Furthermore, off the records, this system creates a parallel economy. In fact, especially during summer and in touristy areas of the country, homeless people with low-income can collect bottles and cans, take them to the machine and redeem the money.

Chapter 3 - Mozambique: The case study

3.1 Presentation of Mozambique

Mozambique, officially Republic of Mozambique, is a State situated in the Southern-East Africa. Its borders are at East with the Indian Ocean, North with the Tanzania, North-West with Zambia and Malawi, West with Zimbawe and at South-West with South Africa and Swaziland. The country is very wide : in terms of extension, it rates 14th out of 54th African states, with its surface of 801’590 kmq and overlooks the Indian Ocean with a coastline 2’470 km long.

Figure 17 - Mozambigue on the Globe (Source: Wikipedia)

Based on the latest Census (2020), the Mozambique population settles around 31 millions inhabitants, with a density population around 39 in/kmq. As reported by Trading Economics [38], in the last decade the number of inhabitants of Mozambique experienced an increase of nearly 50 percent, with a 2,9 percent annual variation, as reported by World Bank in 2021 [39].

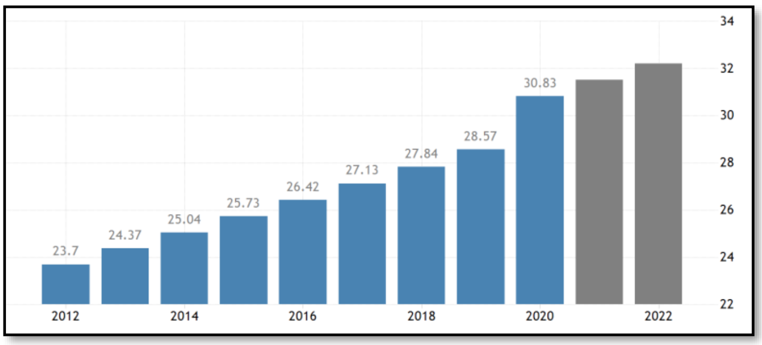

Figure 18 - The Mozambican population trend (Source: World Bank, 2020)

Mozambique is administratively divided into 10 provinces and 1 city district, that of the capital and the only metropolis of the country, Maputo, a city located in a very decentralized position, in the southern extremity of the territory, counting around 1'128'000 inhabitants.
Matola, Nampula and beira are the other main centers of the country, with a respective population of 1’032’000, 760’000 and 592’000.
The urbanization rate of Mozambique settles, in 2021, around 37% [40].
What must to be noted is that, compared to the last decade, the inhabitants of the cities have grown by 39 percent, as reported by CAM in 2017 [41].
The problems posed by such an accelerated urbanization are well summarized in the notes accompanying the Sustainable Development Goals. These are problems that arise from the fact that urbanization is not synonymous with poverty alleviation, as a matter of fact the population living in the slums increases, leading to more suffocating pressure on city administrations, not structured to manage such growth. "The result is an uncontrolled extension of cities, associated with a dramatic growing lack of services and a deterioration in environmental conditions due, in particular, to inadequate management of municipal solid waste. It should be added that the population that is in poverty often ends up occupying swampy areas or in conditions of environmental risk" [41].
In terms of Human Development Index, an indicator of progress that a country is making in fields such as standards of living and access to knowledge, Mozambique rates 180th out of 187 world countries.
From a political point of view, in the last decades the country has been subject to several tensions, also militaries, and civil wars between the government and the oppositions.
Starting from 2016, until the signing of a final peace agreement in August 2019, the country has experienced a sort of political stability and a climate of peace.
The presidential and legislative elections of 15 October 2019 recorded a clear victory of the party in power, FRELIMO. President Nyusi was re-elected with 73% of the votes and FRELIMO won 184 parliamentary seats, surpassing the 2/3 majority in the Assembly of the Republic, winning also provincial elections across the country.
Frelimo, literally Frente de Libertação de Moçambique, is a political party of socialist matrix. Without a political stability had been impossible for the country to follow the trend of the growing population in terms of modernization. Now that stability has occured, it is time for Mozambique to a new beginning.

3.2 WASH situation in Mozambique

The JMP, precisely Joint Monitoring Programme, is an initiative held since 1990 from the collaboration of UNICEF and the World Health Organization (WHO), which aims to report country, regional and global estimates of progress on drinking water, sanitation and hygiene (WASH). The 2015 update marked the end of the Millennium Development Goal period and the 2017 update established baseline estimates for monitoring the new Sustainable Development Goal (SDG) targets. In 2017 JMP, the first monitoring the objectives set by the Agenda 2030, the WASH situation in Mozambique has been reported as dramatic, with an overall access to health facilities very low. In fact, "despite significant progress over the years, only half of Mozambicans have access to improved water supply and less than a quarter use improved sanitation facilities'' reported WHO and UNICEF in their monitoring programm [14]. Furthermore, evident difference in water supply services persist if comparing urban and rural areas. To quantify this disparity, let's report the percentage difference in coverage for improved water sources, 64% in the urban areas and 17% in rural areas, with a 49% overall for Mozambicans [14].
World Bank [42], in 2015, reported that the percentage of Mozambicans people living in households that have a handwashing facility with soap and water available settled around 12%.
The Sub-Saharian country has also one of the highest globally open defecation rate, 36%. The Mozambican situation is dramatic also for what concerns children and women. In fact young children are most at risk from poor WASH conditions with diarrhoeal diseases remaining amongst the leading causes of death among children and women and girls are especially affected by poor access to water and sanitation. In fact as reported by [43] "poor access to WASH for girls threatens their security and contributes to a loss of dignity and threat of sexual assault due to a lack of toilets". This dramatic numbers regarding health conditions translated, in 2020, into a life expectancy at birth of 61%, as reported by [42]. Following table summarizes the results reported in the 2017 Joint Monitoing Programm regarding Mozambique.

People with access to improved water sources nationally	61%
People with access to improved water sources in urban areas	88 %
People with access to improved water sources in rural areas	49%
Open defecation rate	36%
People who do not have or do not use improved sanitation facilities	76%
Access and using improved sanitation in rural areas	12%
Access and using improved sanitation in urban and peri-urban areas	47%

Figure 19 - Water, sanitation and hygiene in Mozambique at a glance (Source: JMP, 2017)

3.3 MSWM In Maputo City: Responabilities, fluxes and state of the art.

3.3.1 Responsibilities

Dealing with Municipal Solid Waste Management is something relatively new for Mozambique, a country that gained its political and administrative independence in 1975. Langa et al. (2014) [44], in his extract "GESTÃO DE RESÍDUOS SÓLIDOS URBANOS EM MOÇAMBIQUE, RESPONSABILIDADE DE QUEM?", published by Revista Nacional De Gerenciamento de Cidades, reported that iIn Mozambique, decree Law No. 13/2006 of 15th June, which approves the regulation on Solid Waste Management, defines solid waste as follows: "waste is any substances or objects that are disposed of or that are intended to be disposed of or even that if required by law to dispose of, defined-as garbage ('lixo')".
Garbage in Maputo city, as in many African cities, is not only an environmental issue, but also a social one. In fact, rapid urbanization resulted in a dramatic growth of neighborhoods without any basic services, and the consequent internal migratory flows, without planning among other basic services, have challenged the public administration to face new realities.
[44] Reported how in Mozambique, with Law 2/97, of 18 February – Law of Local Authorities – which enshrines the legal framework for the implementation of local authorities, was established that the municipality is responsible for legislating above local interest matters. In its article 6, this law establishes that the municipal authorities are responsible for guarantee the urban cleaning.
Therefore, in Maputo City the Municipal Council is the one who should think about the strategy for a sustainable municipal solid waste management and for its implementation. Every issue regarding "Gestão de Resíduos sólidos Urbanos" has to be addressed to municipal power, in particular it has to ensure that all different steps, from collection to recycling processes, are clearly allocated, the stakeholders involved are aware of their roles inside the systems and transport and disposal happen in a sustainable way.
Municipalities are led by an elected Mayor and his cabinet (*Conselho Municipal*), accountable to an elected Municipal Assembly. The problem is that, while the administrative structure and formal responsibilities of the municipalities are clearly defined, all municipalities suffer from a severe shortage of human and economic resources.
Responsability of the Municipalities is also the education of the citizens above the symbols that will give meaning to the Muncipal Council's strategy with regard to the MSWM. In fact, even the most efficient solid waste management system, without an adequate system for promoting dialog among stakeholders, will happen to fail.

3.3.2 Waste generation and composition in Maputo

The amount of Municipal solid waste generated is following the trend of population growing, while the composition is following the growing in terms of income, due to higher levels of consumption and greater use of packaging by industry. As we have already underlined, in low-income countries waste management is caused of severe health conditions. Dos Muchangos et al. (2014) [45] reported how sanitation problems caused by poor solid waste management ’’resulted in significant occurrence of malaria, 1’500 deaths from 1996 to 2000, and cholera, with 250 deaths between1997–2000’’, just for the records. The fact that Municipalities use to struggle also in other issues such as hunger, water shortages and civil war, does not help waste management system to obtain the priority it would need.
Therefore, as underlined by Dos Muchangos et al. (2014) [45] "most municipalities have proven unable to solve or even mitigate causes and effects of urban environmental issues, and Maputo City is an example of the general environmental situation in Mozambique".
Sallwey et al. (2017) [46] reported that the capital stands out as the city with the highest production of waste in Mozambique, with a generation in the inner city up to 1kg per day per person, set against 0.56kg per day per person in suburban areas. Dos Muchangos et al. (2016) [47]performed a material flow analysis to the city of Maputo, and revealed that waste generation increased from 397 milion kilogram in 2007 to 437 million kilogram in 2014.
Dzeco et al. (2020) [48], in their purpose to use the municipal solid waste as source of energy in Maputo City, to reduce the environmental impact derived from open dumpsites, assumed an average of 0.75 kg per person per day to determine and forecast the quantity of Municipal solid waste. Table below provide the evaluation of the population and the municipal solid waste in the last years and the forecast.

Year (census)	Population	MSW ton/day	MSW ton/month	MSW ton/year
1997	801 449	401	12 021	146 365
2007	1 205 709	603	18 086	220 095
2017	1 908 078	954	28 622	348 210
2027	3 015 997	1 508	45 240	550 420
2037	4 881 714	2 442	73 227	890 912
2047	7 808 371	3 904	117 125	1 425 028

Figure 20 - Population and MSW: Maputo Projection (Source: World Bank, 2020)

Considering the trend of this amount of waste, it is clear how Municipalities not able to manage their duty on waste management led to dramatic situation.
Regarding the composition of the waste streams, not much information are found in literature upon the Mozambique in general. The only information are found for the capital, reported by Tas et al. (2014) [49], underlining a clear difference in composition between the inner city and the suburbs, as expected.

	City	Suburbs
Organics	68	29
Paper	12	4
Plastic	10	4
Metals	4	1
Glass	2	–
Fine Fraction	–	57
Other	4	5

Figure 21 - Composition of municipal solid waste from Maputo, Weight % (Source: Tas et al. 2014)

In the city center the majority of waste is composed of organics, while in the suburban areas 57% of the MSW collected is fine fraction.

3.3.3 State of art

As most of the Mozambican cities, Maputo has a planned central core sorrounded by largely unplanned neighbourhoods, called bairros, characterized mainly by self-built houses, difficult vehicular access and low levels of public services. Therefore, as underlined by Dos Muchangos et al. (2014) [45] "the state of the art for the collection system contains different solutions for the different characteristics of the inner city and suburban areas".
Private companies provide most of the services, along with the municipality. [45] Report that the inner city has one big contractor to collect either plastic bags in the residential areas or 1.10 m3 containers located on the streets. This collection is made twice a week from the municipality van. In rural neighborhoods, instead, there is distinction between primary and secondary collection. Primary one is sub-contracted to small-scale enterprise which collect the waste twice a week from households with a door-to door concept, they use the so called 'tchovas' to transport the collected waste to large containers, usually of the volume of 6 to 12 mc, as reported by [45].

Figure 22 - Tchovas for primary collection in Maputo City (Source: MICOA, 2012)

The containers are then replaced with empty ones and transported, by the Municipality, to the Hulene landfill every day at 10pm.
Finally, [45] reported how, for what concerns the outer suburban areas, municipal waste collection is totally absent and households have to burn or bury their waste, or feed it to animals. The costs of the waste management service are paid by the users in the electricity bill to the EDM, electricidade do Mozambique. It is not clear from the literature but it seems that EDM retains 5% of the bill, with the rest going to the municipality.
So, depending on the area, especially based on the economics, there might be different ways of collecting.
Unfortunately, what does not change is the final destination of the municipal solid waste collected in Maputo City. In fact, it is directly transported to the municipal waste final disposal site called Hulene dump, an open dump located 10 kilometres away from the city centre in a suburban neighbourhood, Hulene, surrounded by many basic infrastructures. [45] reported how this open dump "has a total area of 17 hectares with heights that vary from 6 to 15 meters, the site is open 24 hours a day, receiving municipal solid wastes unloaded with minimal control and compaction, and only covered if there is soil available". The common practice in this facility is burning wastes without any control.

Figure 23 - The Hulene dump site (Source: AMOR, 2019)

In the last decade, the MSW generation significantly increased from 397'000 tonnes per year to almost the double, along with the amount of material recovery to 3'000 tonnes to almost triple as well, however the rates of waste processing for recycling and composting are far below the existing potential.

3.3.3.1 Catadores do lixo: an opportunity not to waste

One of the most underestimated, uncensed and potentially successfull stakeholder in the waste management system of Maputo City, and several low-income realities, is the figure of the waste scavengers, the so called 'Catadores' in the local language of

Mozambique. Those actors are the maximaum expression of the fact that waste management system has to be considered also as a social issue. The Catadores are those fraction of society who, normally without work, in order to survive endanger their health by making garbage the source of their lives. Along with other initiatives, these figures represent the only quote addressing recycling in the country.
"We arrived with nothing and we could not find a job. When we found out that we could make profit from plastic and metals, we started collecting it". This is the witness of Paulo Tomas, a catador driving one of the trucks that transport plastic bales to the city for resale to recycling factories. This is how these figures were born. Inside the walls of the landfills on the outskirts of Maputo they are tolerated, while outside they live on the margins of society, invisible to the eyes of politicians: "They see us as poor failures. But we actually serve the city. We recycle and clean-up" [50]. Those are seen as a social plague, living their life across the Hulene Dumpsites looking for recycling materials to sell out at recycling enterprises.

Figure 24 - Catadores do lixo (Source: MICOA, 2019)

In Beira, the most important port city of Mozambique, once the Catadores reach a sufficient amount of waste picked, usually once a month, they take the collected material, plastic and other recyclable materials, to the collecting point to the Latrer enterprise or other Indians and Chinese enterprise [51]. Through a dynanometer the amount of recyclables is weighted, they pay to catadores the respective Metical and place the material on the recycling market. [50] Reported that plastic price is generally around 1 to 3 Metical per kilogram, while the iron settles around 5 Metical for kg. As is easily understood, the Catadores have no negotiating power at all. An interesting idea to protect them, could be to impose a minimum market value and associate them with micro-enterprises. The average monthly income for a waste scavenger is around 3'000 Metical per month. An office employee income settles around 25'000 Metical per month, 8'000 for a driver, for the record [51].
The informal sector is active in many African cities and is largely responsible for recycling. As we have already discussed, all the waste collected from the formal

sector is disposed at the Hulene dumpsites. This should be even more underlined the importance of the Catadores for the City of Maputo, since they are the only quote addressing recycling.
AMOR, the Mozambican Association of recycling, was established in September 2009 to promote and organize the recycling of waste while struggling against urban poverty in Mozambique. So far, the actual profit of recycling in Mozambique had been maintained abroad, with the recycling value mostly going to China.
In the City of Maputo and Matola, AMOR has been implementing Eco-point Networks. The 'Eco-Points' are points of collection and purchase of recyclable materials where everyone can bring its recyclable waste. In parallel they offer waste collection service with mobile collectors who collect the recyclables directly in homes, public or private institutions and organizations, bringing them afterwards in the Eco-point network. This initiative could be linked with the problem of marginality of the catadores by formalizing them as cleaning agents.
The formal integration of waste scavengers within the waste recovery activity is dramatically needed from every point of view.
As a reference, there are well-known cases of fruitful partnerships and successful integration of scavengers in the municipal solid waste systems, such as in Belo-Horizonte, Quezon City, Pume and Lima. Burcea et al. (2015) [52] reported how the the results of such inclusion was followed by "increased recycling rates, avoided collection costs, social inclusion, job creation and income generation".
A study by Mertanen et al. 2013 [53], assessing the scavengers identity in Maputo City, indicates that more than 30% of the MSW generated in the city does not reach the local dumpsite, mainly due to the Catadores interventions combined with the existing material recovery initiatives. This shows how important would be to integrate them as formal agents within the material recovery activities.

3.4.3 Barriers to an ISWM in Maputo

There are different reasons because of the actual failures in solid waste management system in Mozambique, and especially in Maputo City. For sure, the rapid growing in population and economical, with the consequent change in waste composition and generation are some of the main ones.
Actually, rather than reasons, those are what have brought out already existing problems, from any point of view. It would be interesting to analyse the real obstacles not allowing an efficient policy implementation, regarding waste management, to be successful in such a low-income city like Maputo. In fact, in addition to focusing on the work context, it would also be a starting point for other situations, as dynamics are very similar in other low-income areas.
Dos Muchangos et Al. (2015) [54] analysed the structure of barriers to municipal solid waste management policy planning in the capital of Mozambique.

In order to do that, they exploit the combinations of two different structural modeling methods, the Interpretive Structural Modeling (ISM) and Decision-Making Trial and Evaluation Laboratory (DEMATEL).
As briefly explained by [54], "ISM is a computer-assisted process that enables individuals or groups to develop a map of the complex relationships among many elements involved in a complex decision situation, while DEMATEL is a comprehensive tool for building and analyzing a structural model involving causal relationships between complex elements".
They first identified the barriers, therefore, through coupling of these two analytical methods, analysed the interrelationships between the main factors involved in order to identify the most influential barriers to ISWM implementation. Such results could be valuable also for different realities, considering the parallelism intercorring between different low-income countries. The main objective is to provide to decision policy makers a clear mirror of the most influential barriers, to help overcome those.
[54] Concluded that the failures related to the waste management policy can be attributed to a total of 26 barriers. The latter can be divided into two different groups, a causal one, inclusive of the most crucial barriers, and a group called ‘dependent’ composed of the barriers which exist as consequence of the first ones. Figure 25 reports the first group, representing those who should receive more attention.

B1 Lack of control over legal content by those responsible for its implementation
B2 Reduced law enforcement
B3 Excessive subordination of legislative power to political power
B4 Weak framework for promoting dialogue among stakeholders
B5 General perception that the government is solely responsible for MSWM
B11 Weak political will
B12 Ineffective education programs and dissemination of good MSWM practices
B18 Conflicts of interest and corruption
B26 Ineffective representation of communities in decision making bodies

Figure 25 - ISWM Barries (Source: Dos Muchangos et al. 2015)

Mutual characteristic of all the most influential barriers is the relation with weak institutional frameworks and the absence of a mechanism able to encourage the active participation of the different actors involved, leading to a not implementation of waste management programs which, in some cases, have been deliberated.
Especially barrier B4, underlining the difficult relations among different stakeholders, is particularly important. This could be linked also with the figure of

Catadores, one of the main stakeholders in the SWM system, let isolated with no integration and valorization of their contribution to waste management.
Also barrier B5 is pretty significative, underlining how the main problem is not much that a government policy is missing, in fact in Mozambique is clear who should legislate among environmental and social issue. What is missing is an education of the citizens regarding the actual policies, and the delivery of instructions for the management plan to be put in place.

Chapter 4 - Health and Urban Space in Chamanculo C

4.1 HANDS

HANDS, namely Health and Urban Space, project is a research study for the innovative development of informal neighborhoods, through a multidisciplinary experimentation of long-term actions, aimed at promoting healthiness in the informal district of Chamanculo C. The aim of the project is the design of a social laboratory dedicated to the production and sustainable distribution of Polichina, an hands disinfectant produced by Polictecnico di Milano, associated with the design of a management system for medical waste generated by the COVID-19 pandemic. The project's approach is not strictly related to the emergency situation, but rather to favor a long-term vision, in which Polichina represents the tool through which promote the culture of healthiness within the neighborhood. The greatest challenge is to make the project self-sufficient, sustainable and replicable.
The HANDS project is funded by Politecnico di Milano as part of the Polisocial program and it is characterized by a multidisciplinary approach, favoring collaboration between several departments of University. Precisely, five departments are involved: Department of Architecture and Urban Studies (DAStU), Department of Architecture, Construction Engineering and Built Environment (DABC), Department of Civil and Environmental Engineering (DICA), Department of Energy (DENG) and Department of Chemistry, Materials and Chemical Engineering "Giulio Natta"(CMIC).

4.2 Project: Social laboratory in Chamanculo C

Figure 26 - Satellite photo of Chamanculo C (Source: Google Maps, 2022)

The goal of the work integrates itself within the appendix of HANDS, correlated with the severe health crisis caused by the covid 19 pandemic in Chamanculo C, a rural suburb on the outskirts of Maputo City. The entire district has 150’000 inhabitants and in the Barrio C live around 26’000 inhabitants. The latter is one of the oldest slums in the capital, characterized by a dramatic high percentage of informal settlements. Because of that, the neighborhood is characterized by overcrowding with limited presence of infrastructures, and almost absent accessibility to basic services such as water systems, healthcare facilities and waste management programs. Furthermore, as shown in figure below taken during HANDS field mission in 2021, the majority of streets are not paved, with a very high probability of flooding during frequent rains in such a tropical zone.

Figure 27 - Chamanculo C (Source: Hands Field Missions, photo by Francesca Villa, 2021)

The Covid-19 pandemic has put a strain on this backward neighborhood. First of all from a health point of view, combining a pandemic with the already precarious conditions, without the necessary tools to deal with it, has brought to light all the inadequacies within the suburb. Mainly two interconnected problems came up with the spread of Coronavirus. First of all, the supply of protective devices such as masks and hands disinfectant, and secondly their management once they become a waste. In fact, as previous unrolled, Chamanculo fits itself into a low-income neighbourhood and, without an adequate waste management system, the sudden introduction of those protective devices within the waste chain could be potentially dramatic from an environmental, social and economic point of view.

Under these premises, the project Health and Urban Space in Chamanculo aims at the promotion of the culture of healthiness in Barrio C.

As reported by Martinez et al. (2021) [55], Semmelweis and Wendell, in their several studies, came to the conclusion that diseases into the hospital were transmitted via hands. Semmelweis, in particular, has been the forerunner for what concerns hand hygiene, and he was the first provider of evidence that cleansing heavily contaminated hands with an antiseptic agent can reduce the transmission of virus and germs more efficaciously than handwashing with soap and water. In fact, Semmerleis, as reported by [55] discovered that alcohol present in the gel-hand sanitizer kills the 99.99% of bacteria.

Therefore, using an antibacterial hand gel has many benefits when soap and water are not available. In addition to being a simple, cheap, effective measure and within the reach of most of the population, it not only reduces the risk of infection, but also decrease the transmission of germs to other people. Nowadays, disinfection with alcohol-based products is the most quickly and effectively way to deactivating a variety of potentially harmful germs and virus in hands.

Concretely, the final goal is the design of a sustainable center for the production and distribution of Polichina. Issues to be addressed are therefore the sizing and the management, especially the promotion of a virtuous recirculation of the disinfectant containers, in order to incentivize in the Barrio the important concepts of reuse, recycle and personal hygiene, further than, in concrete, provide hands sanitizer to the population.

4.3 LCA of antibacterial gel production in Mexico

During the Covid-19 spread in Mexico, the demand for preventive hygienic products against the pandemic increased suddenly by 50%. In fact, not only for the internal provision, but Mexico ranked fifth country for exporting products against Covid-19 worldwide. Of course, people and production houses started to be worried about the potential environmental impacts this sudden massive increase in production and distribution may have. However, the evolution was so rapid there was no time to allocate this type of related problems. The consequences to be addressed concerns mainly climate change, human toxicity and waste management.
V. Enríquez-Martínez et al. (2021) [55], with the will to address the issues related to the chain production, performed a Life Cycle Assessment analysis, LCA, of antibacterial gel production, to evaluate the negative potentially environmental impacts associated with the products or services.
The aforementioned LCA study, analyzing the production chain of the hands disinfectant in Mexico, consider transportation of raw material, production of the substance, pack and distribution.
The reference flow considered for the results is 450'000 bottles in one day of production and the chosen functional unit is 1 bottle of 120 ml of antibacterial gel manufactured and packaged.
[55] Concluded how climate change is one of the categories with the highest values in the process, mainly due to the data on the amount of energy consumed directly by the trucks and the machines in the chain production. A relevant fraction of the emissions sources is allocated to the machines for the production stage as well, underlining that simplicity of operation and searching for low-energy requirements methods must be of primary importance when designing such a center.
Below a summarize of the results reported by [55] in their publications.

No	Impact category		Value
1	Climate change, incl biogenic carbon	[kg CO2 eq.]	4.9E+00
2	Fine Particulate Matter Formation	[kg PM2.5 eq.]	4.26E−3
3	Fossil depletion	[kg oil eq.]	1.94E+00
4	Freshwater ecotoxicity	[kg 1,4 DB eq.]	1.69E−4
5	Freshwater Eutrophication	[kg P eq.]	1.42E−2
6	Human toxicity, cancer	[kg 1,4-DB eq.]	1.0425E +00
7	Human toxicity, non-cancer	[kg 1,4-DB eq.]	1.83E+00
8	Land use	[Annual crop eq.y]	1.7E−01
9	Marine ecotoxicity	[kg 1,4-DB eq.]	3.95E−4
10	Marine Eutrophication	[kg N eq.]	3.86E−3
11	Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	1.30E−01
12	Photochemical Ozone Formation, Human Health	[kg NOx eq.]	1.15E−01
13	Stratospheric Ozone Depletion	[kg CFC-11 eq.]	2.2E +00
14	Terrestrial Acidification	[kg SO2 eq.]	8.52E−3
15	Terrestrial ecotoxicity	[kg 1,4-DB eq.]	1.11E−3

Figure 28 - Impact categories in Mexico (Source: V. Enríquez-Martínez et al. 2021)

The limitations of the study are mainly the lack of inclusion in the analysis of the steps after the production stage, the impact of the operative steps such as alcohol evaporation into the atmosphere, contaminations of the water flow after the hands washing and, mostly, where the waste ends up. Nevertheless, I have decided to report this study since, first of all it has been one of the first in literature to life-cycle assess the production of hand sanitizer, and secondly for the preciousness of the results. In fact, by knowing the most impacting steps, would be easier to focus right away on those aforementioned ones in order to reduce the footprint.

4.4 Location of the Laboratory

An important aspect of the project is the location of the Polichina center. Several field missions have been performed from the Politecnico di Milano group of the project HANDS in order to get in touch with the neighborhood of Chamanculo C and its peculiarities. One of the main objectives of the research was to evaluate selected public spaces, among the existing ones, where it could be possible to maximise the effects of an efficient distribution of the Polichina sanitizer to the local inhabitants, with the purpose of improving health conditions of the people.
For that scope, 3 hubs have been taken into consideration : An ex-health center, Mercado Sumaio and the primary school of Chamanculo C.
As shown in figure 4.3.2, the three locations considered are very close to each other, making the choice, at this level, a purely social one.

Figure 29 - Proposal for the Polichina center location (Source: Hands report field mission, 2022)

In Proposal 1, the ex-health center, Polichina production would be integrated into a larger project dedicated to the healthiness of the place.
Proposal 2 stands for placing the laboratory in the Mercado Sumaio, the largest market in the neighbourhood. Considering the overcrowding of the Mercado and the necessity of people to reach it for their primary needs, such as food, this could be an interest strategy. In fact, inserting the distribution of an asset, not yet seen as primary by society, within a context in which all inhabitants regularly go to buy basic necessities, could be the winning choice to promote the habit of inserting a health product aimed at personal well-being in everyday life. Furthermore, there would also be a question of convenience, for the inhabitants, in finding both food and protective equipment for their health in the same market. From field missions report also

emerged the possibility to redevelop / reconstruct a range of services at the edge of the market: new bathrooms, cistern for water collection and, precisely, a point of diffusion of Polichina managed by the many female organization of the neighborhood.
Finally, Proposal 3 would place the laboratory in the primary school. Could be a good option, to insert in the school the habit of the personal health and WASH and the one of the virtuous recirculation of the containers. In fact, in school, with children, little input could be enough to achieve great results in the future generations. Let's conclude by saying that proposal 3, other than the mere supply of the hand sanitizer to the population, carries a strong social impact on the future generations of Chamanculo.

Figure 30 - Satellite photo of the laboratory area (Source: Google Maps, 2022)

4.5 Compatibility with Polichina

Polichina is a hands sanitizer produced by the personnel of the Department of Chemistry, Materials and Chemical Engineering at Politecnico di Milano to face the COVID-19 outbreak in 2020. Due to the severe shortage of disinfectants, students and professors of the Department spontaneously decided to use their knowledge to produce some basic formulas. Considering the success of the experiment, after the emergency the University decided to officially register the sanitizer, with the name of Polichina, combining 'Poli' as Politecnico and 'china' as the traditional deponent of chemical disinfectants.
Polichina is produced in two different formulas, both of them officially published by the World Health Organization [56]. Figure 32 shows the two chemical compositions, both having a secure efficiency.

WHO Formula 1	
Ingredient	**ml**
Ethanol 98%	833.3
Demi Water	110.5
Hydrogen Peroxide 3%	41.7
Glycerin 98%	14.5
Total	1000

WHO Formula 2	
Ingredient	**ml**
Isopropanol 99,8%	751.5
Demi Water	192.3
Hydrogen Peroxide 3%	41.7
Glycerin 98%	14.5
	1000

Figure 31 - Polichina Formula (Source: World Health Organization, 2010)

The aim of the project is to place a continuous and fully automated device for the production of Polichina, and to distribute it in a sustainable way to the community of Chamanculo. Priority for the implementation of such center is the choice of the containers.
In fact, in order to promote a virtuous recirculation, the material containers must have certain characteristics in terms of durability, heat exposure and recyclability.

The idea behind sustainability and healthiness of the project is to reuse Polichina container until its characteristics make it possible in terms of health for the community; once its life cycle will end, the containers will be sent to recycling-process.
Reusing containers is one of the most effective and inexpensive ways to reduce the environmental impact of packaging. Some plastic containers can be made durable enough to be refilled and reused about 25 times before becoming too damaged for reuse, as confirmed also by ecology center [57]. Refilling and reusing plastic containers directly reduces the demand for disposable plastic. Accordingly [58], lowering the demand for single-use containers reduces waste and energy consumption. Ecology Center reported how, based on 1990 data, if glass and PET bottles were refilled and reused 25–35 times, the overall weight of beer and soft drink container waste would be reduced by 73.6% [57]. Significant reductions in waste and energy consumption can be achieved with just 7–8 reuses of a single bottle.
Under these premises, the choice of the material is of primary attention, in particular its compatibility with the chemical components of Polichina and with the contexts elements must to fit in.
Several plastics have been taken into consideration for the material containers, also by looking at the actual state of art for the containers.
Globally plastics are recognized through seven codes, as shown in figure 33.

#1	polyethylene terephthalate (PET or PETE)
#2	high-density polyethylene (HDPE)
#3	polyvinyl chloride (PVC)
#4	low-density polyethylene (LDPE)
#5	polypropylene (PP)
#6	polystyrene (PS)
#7	other

Figure 32 - Types of plastic codes (Sources: Plastic Oceans, 2021)

PET is usually used for water bottles and, although the Food and Drug Administration [FDA] has approved PET bottles for single use and for reuse, it is not the most suitable for reuse. In fact, the production of PET requires the use of a toxic catalyst, Antimony trioxide, and in several studies including Xu et al. (2021) [59], Antimony has been found to leach out from plastic bottles into the liquid they contain when the bottle is submitted to heat exposure.
PVC is one of the most used plastic in the world, and is also used as material container for hand sanitizer such as Amuchina due to its high hardness and its resistance to chemicals and weathering, [60]. On the other side, we must note that PVC is the most dangerous plastic to human health, known to leach dangerous toxins

throughout its entire lifecycle (eg: lead, dioxins, vinyl chloride) [60]. After having taken into consideration all types of plastics, the circle has tightened up to Polyethylene, the High-Density HDPE, one of the most common plastics in the world. HDPEs is strong and resistant to moisture and chemicals, which makes it ideal for containers. In addition HDPE bottles are almost 100% recyclable, so material can be used over and over again, as confirmed by Dahlbo et al. (2018) [61].
Furthermore, CPLabSafety in 2021 [62] tested the compatibility of HDPE with different chemicals, in order to create its compatibility chart [62]. What has emerged from the laboratory is that Polyethylene has a very good compatibility rating with most chemicals and is resistant to strong acids and bases, as well as gentle oxidants and reducing agents. The chemical compatibility have been tested at 20 and 50°C, for 7 days and 30 days (if applicable) with constant exposure, and a Ployethylene resistance chart by chemical has been implemented.

Chromic acid 50%	LDPE / HDPE at 20°C-50°C: little or no damage after 30 days.
Citric acid 10%	LDPE / HDPE at 20°C-50°C: little or no damage after 30 days.
Cresol	HDPE at 20°C: shows some effect after 7 days. LDPE at 20°C-50°C & HDPE at 50°C: show immediate damage. Not recommended for continuous use.
Cyclohexane	LDPE / HDPE at 50°C: immediate damage may occur. LDPE / HDPE at 20°C: show some effect after 7 days.
Diethyl ketone	LDPE / HDPE at 20°C-50°C: damage may occur. Not recommended for continuous use.
Dimethylsulfoxide	LDPE / HDPE at 20°C-50°C: little or no damage after 30 days.
Ethanol 95%	LDPE / HDPE at 20°C-50°C: little or no damage after 30 days.
Ethyl acetate	LDPE / HDPE at 20°C-50°C: little or no damage after 30 days.
Ethyl benzene	HDPE at 20°C: shows some effect after 7 days. LDPE at 20°C-50°C & HDPE at 50°C: show immediate damage. Not recommended for continuous use.
Ethylene glycol	LDPE / HDPE at 20°C-50°C: little or no damage after 30 days.
Ethylene oxide	HDPE at 20°C: shows little or no damage after 30 days. LDPE at 20°C: and LDPE/ HDPE at 50°C: show some effect after 7 days.

Figure 33 - HDPE resistance listed by chemicals (Source: CPLabSafety, 2022)

One of the chemical compatibilities analyzed have been with Ethanol, the main component of Polichina, and what came up from the results was reassuring: HDPE shows little or no damage after 30 days [62].
Therefore, HDPE has been selected to be the material for the hands sanitizer containers virtuous recirculation.

4.6 Washing of the Containers

A relevant issue to be addressed in the organization of the laboratory is the washing of the containers, a crucial part of the process in order to ensure healthy conditions to the final users. Lopez et al. (2022) [63] conducted an observation study about the use of hands sanitizer during a pandemic and report that reusable bottles should never be refilled until they have been completely emptied, cleansed and disinfected. WHO, in its book "WHO Guidelines on Hand Hygiene in Health Care" [64] published in 2009 in the National Library of Medicine, delivers some basic guidelines regarding cleaning procedures before distribution of reusable containers.
WHO reported there might be different cleaning and disinfection processes for reusable handrub bottles, mostly thermal and chemical ones. If they are heat-resistant, thermal disinfection by boiling in water is preferable, since it is less expensive in terms of costs and water consumption. For what concerns chemical cleaning, most likely to be the one chosen for the project of the elaborate, should include soaking the bottles in a solution containing 1000 ppm of chlorine and then rinsing with cooled boiled water. WHO [64] report that "after disinfection, bottles should be left to dry completely upside-down. Dry bottles should, finally, be closed with a lid and stored, protected from dust until the next use".
In a virtuous recirculation of the containers, which would want to demonstrate itself as a dynamic one, the laboratory must have the capacity to wash at the same time several number of containers, in order to be able to meet the needs of the neighbourhood. Furthermore, what must be taken into consideration, is the context where the washing method has to fit in. In fact, in a rural neighbourhood inserted in a low-income country, the simplicity of operation must be a priority. Moreover, the washing method must be a process with very little energy requirements and waste generation. In one word, it has to be a sustainable process from an environmental and economic point of view.

4.6.1 The method

In choosing the washing method, the proposal of Trabold, 2019 [65] has been taken as reference. He built an easily replicable home-made bottle washer able to wash simoultaneously several containers, with very little energy requirements.
The figure below shows a graphic representation of the trivial, but still efficient technology proposed for the containers washing in the laboratory. In that case, is shown the contemporaneity washing of 24 containers performed by [65], the quantity of washables can be modulated according to needs.
Basically, a utility pump is used to pump water, mixed with specific soap, inside a basic circuit created with pipes.

All of this is hand built and so it can be regulated for each needs. The pipes are spaced depending on the containers size, and as many holes are made as there are containers to be washed at the same time. In the holes, pens are fasten to be used as bottle nozzles, as shown in figure below.

Figure 34 - Bottle washer (Source: Trabold, 2019)

The structure is hence inserted in a batch of the necessary dimensions, always depending on the needs of the containers to be washed at the same time, full of water mixed with soap, as shown in figure below. The pump keeps recirculating the same water, nozzling it into the containers at a velocity depending on the pump power and on the pipe diameters. A problem that may occur with light HDPE containers is just the fact that, the nozzled spray water may let the containers fly away, this issue can just be addressed by fasten with a simple homemade hook the containers to the pipes structure.

Figure 35 - Bottle washer in the batch (Source: Trabold, 2019)

4.6.2 Energy requirements

Low-energy requirements must be a characteristic of the selected washing method. For the proposed solution, mainly there are two types of operative costs related to energy consumption: electricity and water.
In this small section, starting from a real and proven application of the technology, we have estimated the energy [kWh] and the water [liters] consumption in term of single container washed. In fact, by obtaining those values, [kWh/container] and [liters/container], it would be possible to estimate the energy consumptions whether 1, 10 or 100 containers has to be washed at the same time.
[65] Applied those washing method in order to wash at the same time 24 glass bottles of 250 ml volume. During the process, he used a 0,25 HP utility pump, the equivalent of approximately 200 Wel. This means that an electrical pump power of about 10W can be considered to wash a single glass bottle. Furthermore, the volume of water inside the batch in order to wash the 24 bottles is around 8 liters, bringing the water factor of 0,3 [lt/container]. This is clarified with the example below.

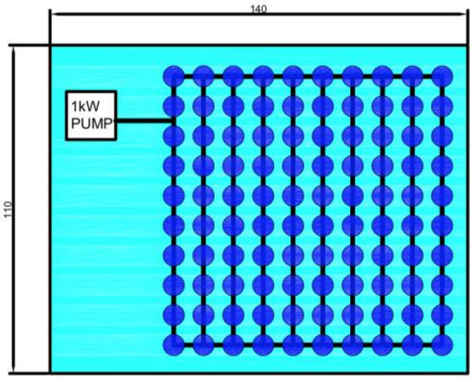

Figure 36 - Bottle washer in the batch, simulation

In the figure above, the contemporary washing of 100 containers is performed. Following the above reasoning, 1 kWel utility pump would be sufficient to wash all of them at the same time. Let's imagine to wash the containers, so to make the water recirculating, for 5 minutes, this means our energy consumption would be around 0,08 kWh, or 80 Wh. Finally, the energy factor necessary to wash a single container for 5 minutes is 0,08 [Wh/container]. Besides, the water consumption for the simultaneous washing of 100 containers would be around 30 liters.
The Table below summarizes the energy consumption results for a single container.

Energy consumption for 5 mins washing	0,8	[Wh/container]
Water consumption	0,3	[lt/container]

Table 2 - Energy requirements for single container

To be noted how those values have been calculated considering the washing of glass bottles of 330ml volumes [65].

4.7 Design of the social laboratory

The following chapter will be dedicated to the purely design of the laboratory. The scenario considered is the distribution of Polichina to a 4 minutes walking distance circling the center. For the results, a reasonable daily Polichina production of 100lt will be considered, with 100ml containers volume. For the scenario, the center will be sized and the economic feasibility will be brought to attention, with 1-week trial period, as shown in table below. For sake of simplicity, will be consider that, at the same time, each family of the Barrio can keep one single container. This hypothesis is also reasonable if we consider that, scope of the initiative is the possibility to supply hand sanitizer to as many people as possible. Regarding the promotion of the virtuous recirculation of the containers, this is incentivized with a return system inspired by the Danish one.

DESIGN PREMISES	
Polichina daily production [lt/day]	100
Containers volume [ml]	100
Trial period [week]	1

Table 3 - Design Hypothetis

4.7.1 Polichina consumption in the project area

In sizing an appropriate hands sanitizer distribution center, the first knot we have to untie is: How much Polichina will be consumed within the project area?
Considering the unavailability of this information, for many reasons such as the social outcastity of the neighbourhood combined with a too much recent tragedy such as Covid-19 pandemic for literature to be available, we have to estimate a daily Polichina consumption. Step by step, adding reasonable assumptions to official data we will obtain this important number.
By analyzing several globally commercialized hand sanitizer containers, turns out that a single person consumes approximately 0,002 liters per single hand washing. This is confirmed by the fact that usually the pumps above the containers have that flow rate in terms of liters per stroke, as reported by Lopez et al. (2022) [63]. So now, moving towards our reasoning, we have to assume a reasonable number of times a single person disinfects his hands. Coupling this information with the Chamanculo C census will provide us a reasonable assumption for the daily Polichina consumption.
Recently, [63]conducted an observation study concerning the use of hand sanitizer during a pandemic was published in the Journal of Exposure Science & Environmental Epidemiology.

To better understand the impact of this recommendation, hand sanitizer use, including the frequency and amount handled, was examined among adults in a non-occupational setting and children in both the home and school/childcare settings.
[63] Report that an online survey of Canadians (conducted from September to October 2021) was employed to estimate use frequency, amount, and pattern of hand sanitizer use.
Of particular interest, as shown in figure 38, has been the comparison of frequency of hand sanitizer use before and after the pandemic. For our case study, we consider the number of times per day averaged on a situation before and during a pandemic. In fact it would be too oversized to consider a context of pandemic, on the other side, it would be undersized not to consider the aftermath left by the pandemic. Therefore, a number of 5 washing per person per single day will be considered.

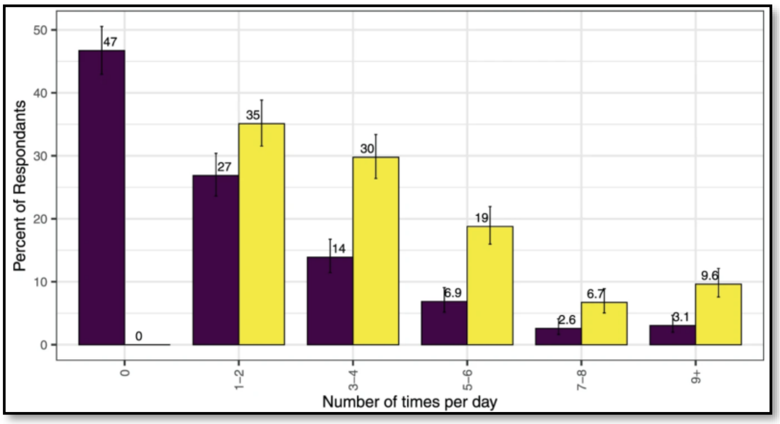

Figure 37 - Frequency of hand sanitizer before and during the pandemic (Source: Lopez et al., 2022)

Therefore, exploiting the assumptions made over the quantity of Polichina for single use and the reasonable number of disinfections performed by a single person, Table 4 shows the results obtained coupling those assumptions with Census data from the 4 minutes walking distance of Chamanculo C.
In order to obtain the number of persons per family, we have used the data from 2017 Census: 129’306 inhabitants in Chamanculo, with 29’031 families.

Appendix
To obtain the daily Polichina consumption, this steps has been performed:
*0,002[lt/washing]*4,45[person/family]*5[washing/person/day]= 0,04[lt/day/family]*
*And then: [lt/day/family] * [N° family] = [lt/day]*

	inhabitant	person/family	N° Families	liters/day/family	lt/day
4-min walking	6’482	4,45	1’456	0,04	**64**
Chamanculo C	26’000	4,45	5’842	0,04	**260**

Table 4 - Daily Polichina consumption in the project area

The results from table 4 will be the guide numbers for the sizing of the laboratory.

4.7.2 4 minutes walking distance area

The project scenario represents the supply of Polichina to a portion of Chamanculo C, precisely to a number of 6’482 inhabitants, as shown in table 5. Starting from the design premises, the maximum number of containers which can be filled everyday is evicted. Furthermore, having estimated the Polichina daily consumption of a family of the Barrio, we can make conjectures on how many times, on a weekly basis, a family member will go to the center to buy a new container. Obviously, due to a contemporary factor, it will never happen that all households go to the distribution center at the same time to get a new container. We know that each household consumes about 50mL per day, which means that, assumed the container volume of 100ml, every 2 days they will go to the center to have a container filled. Let's put ourselves in a realistic situation: all families, at least 3 times a week, will go to the center to have a container filled. So, by coupling the design premises with the results obtained in table 5, we know the number of containers that the project area demands. The following table summarizes what has been said above.

WEEKLY BASIS	
Number of containers demanded from the 4 min walking distance [#]	4370
Number of containers the laboratory is able to refill [#]	5000

Table 5 - Laboratory Demand and Supply

4.7.2.1 Design of the laboratory

The center will consist of different areas, each of which will carry out a specific task. It will be organized mainly in three departments: acceptance, production and washing area. In the competent department also the storing of the containers coming from the previous one will be set.

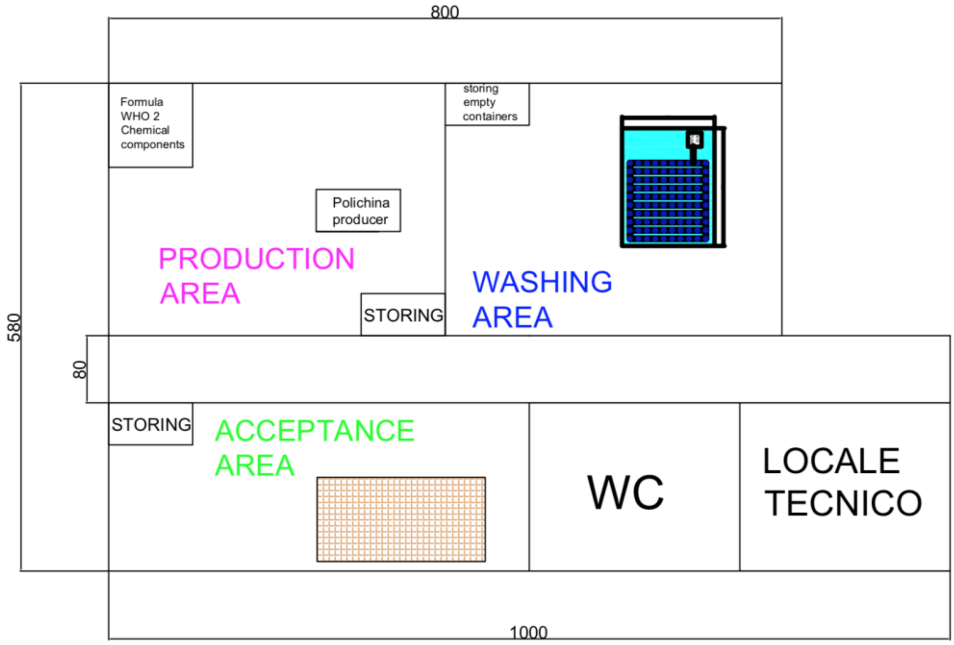

Figure 38 - Social Laboratory Design

4.7.2.1.1 Acceptance area

The acceptance area has been designed for one person, working as a back office. The employee will be the only one interface with the customers. His job will be to deliver the filled container to the final user and manage finances. He will be also in charge of redeeming the money to the final user for the return system mechanism. The back-office clerk will place the empty container in the storing area of the washing department. It will also be duty of the back-office employee, every time he hands a filled container to a customer, verify that it has the date of first use written. If this date is not present, it means that it is a container that has never been used, so will be necessary to write the expiry date with an indelible marker. This action is of primary importance in ensuring that a container is not reused and does not remain in circulation any longer than the prescribed time. Finally there will be a shelf containing the filled containers arrived directly from the production area.
Therefore, the acceptance area is composed of a front desk and a shelf for the storing of the filled containers, which will develop vertically, as will be explained in chapter 4.7.2.1.3:

ACCEPTANCE AREA SIZING		
Front desk	2	m^2
Storing shelf	0,5	m^2
Maneuver room	7,5	m^2
TOT	**10**	m^2

Table 6 - Acceptance area sizing

4.7.2.1.2 Production area

This section represents the core of the laboratory. In the production area is allocated the producer of Polichina and the storage of the chemical components that make up the formula. The Polichina producer is a parallelepiped, for the sizing we consider a volume of 0,75mc distributing on a base 0,5mq times a height of 1,5mq.

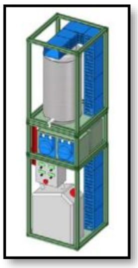

Figure 39 - Polichina producer (Source: Politecnico di Milano)

For what concerns the storage of the chemical components, the space necessary for storing Formula 2 chemical components has been esitmated for the one-week trial period. So, a stock of 500lt Polichina_2 is necessary.

WHO FORMULA 2 – WEEKLY PRODUCTION		
Ingredient	**[lt]**	**[m^3]**
Isopropanol	375,75	0,37575
Demi water	96,15	0,09615
Hydrogen Peroxide	20,85	0,02085
Glycerin	7,25	0,00725
TOT	**500**	**0,5**

Table 7 - WHO Formula2_Weekly chemicals (Source, WHO)

So the one week storage for the chemical components of formula 2, as was easily guessed, takes up 0.5 cubic meters. Actually, the various components are divided into many small containers, it is therefore likely to consider a necessary space double than the calculated one. Therefore, for the storage of the chemical components we consider a parallelepiped with a surface of 1 m^2 for a height of 1 m.
It follows the design of the production and storing area.

PRODUCTION AREA SIZING		
Stock formula 2 [WHO]	1	m^2
Polichina Producer	1	m^2
Maneuver room	10	m^2
TOT	**12**	m^2

Table 8 - Production area sizing

4.7.2.1.3 Washing area

This area would be dedicated to the containers washing and to the storage of the empty ones which need disinfection. Two physical components will be present in the department, the washing batch and a storing shelf.
The first is designed based on the possiblity to wash, at the same time, 100 containers of 100 ml volume each. The technology is composed of a grid system of pipe sticking up, soaked in a batch containing a solution of water and Chlorine, with a 1 kW utility pump circulating the solution into the system.
For the washing batch, let's allocate a surface of 1.55 m^2. This is reasonable, in fact by considering a diameter of 5cm for a single container, the square of 10x10 containers, adding the spaces between each containers, will lead to an area approximately of 0.5 m^2. Plus, considering the space occupied by the pump and maneuvre space, it is reasonable to allocate 1.55 m^2.

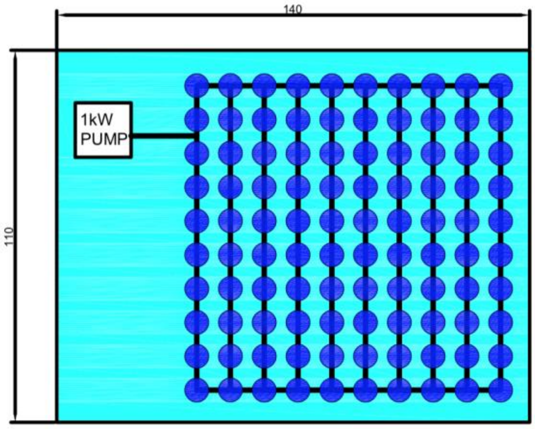

Figure 40 - 100 containers washing batch

A little in-depth analysis should be made on the space to be allocated for storing the empty containers. As decribed above, this is the destination area, in a dynamic operation of the laboratory, of the empty containers coming from the 4 minutes walking distance of Barrio C. For storing sizing, we consider that every time an empty container enters the laboratory, through the acceptance area, a filled one goes out. In fact, if a customer brings back an empty container, it is to buy a filled one. The sizing is done considering the initial situation, represented by a container for each family container, therefore 1'456 containers.
The worst case scenario is used for the sizing of the storing components, that is, at the same time 1'456 families come to collect a filled container and deposit an empty one.
It means that the storing of empty containers in the washing area and the storing of filled containers in the acceptance area will have the same capacity. Therefore, for the storing shelf, 1'456 containers of 0,0001mc each, considering the space almost doubled for the fact that those 0,1456 m^3 are divided in small containers with air space between them, a project volume of 0,5 m^3 is finally allocated. The shelf dimensions are 0.5 m base and 1 m height.

WASHING AREA SIZING		
Washing batch	1,55	m^2
Storing shelf	0,5	m^2
Maneuver room	9,95	m^2
TOT	**12**	m^2

Table 9 - Washing area sizing

4.7.2.2 Economic feasibility

Any initiative, even with a predominant social and environmental inspiration, must be solid from a financial point of view. Considering the project matrix, the final goal might not be an insured satisfying annual economic profit, rather than that, the laboratory should be at least self-sustainable. This means a little insight into the possible costs and revenues must be analyzed, in order also to be able to guarantee to the final users, the inhabitants of Chamanculo C, a competitive price for the Polichina.

Figure 41 - Profit vs Loss Balance (Source: Google)

The possible revenues are represented solely by the commercial sale of the hand sanitizer. Instead, the costs are divided into two components: the CAPEX and the OPEX. Capital expenditures are major purchases designed to be used over the long term, while operating ones are day-to-day expenses incurs to keep the business operational.

4.7.2.2.1 Capital costs

In the laboratory, mainly we can identify two different capital costs. The first one is the core business, therefore the Polichina producer. In the following cost analysis, this capital cost will not be included, in fact in the wondering of this social initiative, the production system is a donation, from Politecnico di Milano, to the neighbourhood of Chamanculo. The second relevant capital expenditures are the washing components. It is therefore necessary to give a brief insight into the costs to be incurred for the washing of the containers, the final goal is to obtain a factor in terms of cost per containers to be washed simultaneously.
The first premise is that the components are designed in order to be capable of washing, at the same time, 100 containers.
The main component is the 1 kW utility pump, for the pumping of the chemical solution inside the grid pipe systems. By peeking on Alibaba, a cost of 9’000 Mozambican Meticais (MZN) is allocated for the component, equivalent to about 150 euros. For the nozzles, simply made by pens, have been allocated a price of 30 MZN per pen, 3000MZN for the 100 containers.

For what concerns all the other components like glue, plastic pipe systems, plastic 'T', the batch etc, it has been considered a cost of 4'000 MZN, comparing the costs to what has been achieved by [65]for washing 24 containers. By adding all the components together, is obtained the capital cost of 16'000 Mozambican Meticais for the simultaneous washing of 100 containers. As highlighted in table 10, the final parameter is the capital cost necessary to wash a single container, so that, depending on the needs, will be sufficient to multiply that value for the number of containers to be washed at the same time, to obtain the corresponding capex.

WASHING	**CAPEX per100 containers** [MZN]	**CAPEX per container** [MZN/container]
1kW utility pump	9'000	90
Pens	3'000	30
Components	4'000	40
TOT	16'000	**16**

Table 10 - Washing Capital Exprenditures

4.7.2.2.2 Operative costs

Operative costs are the ongoing expenses incurred from the normal day-to-day of running the Polichina distribution center. They include both costs of goods sold and other operating expenses, often called selling, general, and administrative expenses. In our analysis, we have identified the following operative expenditures: public space rental, formula 2 WHO components, electricity and water, containers and salary operators.
Concerning the public space rental, this is a variable still not well defined, since the location of the laboratory, as previously discussed, is more of a social matrix. However, at this preliminary step, in order not to leave this cost unallocated, we use as a reference the cost of a rent in Maputo, for an apartment of 50-60 square meters.
By searching on several real estate sites in the area, we have allocated a cost of 12'500 MZN per week, our period of trial.
For what concerns Formula 2 cost, we use as reference the knowledge of the cost per liter of the chemical components of the Polichina. We consider the formula 2 [WHO] since it is cheaper, and we would like to provide the disinfectant at the lowest possible price.

Ingredients	Quantity (liter/liter)	Cost (MTZ/liter)	Cost (MTZ/liter) Waterless
WHS Formula 1			
Ethanol 98%	0.8333	473	473
Demi Water	0.1105	85	0
Hydrogen Peroxide 3%	0.0417	36	36
Glycerin 98%	0.0145	11	11
Total	1	**606**	**520**
WHS Formula 2			
Isopropanol 99,8%	0.7515	308	308
Demi Water	0.1923	148	0
Hydrogen Peroxide 3%	0.0417	36	36
Glycerin 98%	0.0145	11	11
Total	1	**503**	**355**

Figure 42 - Polichina components costs (Source: Politecnico di Milano, 2021)

A weekly productivity of 5 days, with 100lt/day production, leads to a weekly cost of 177’500 Mozambican Meticais.
Regarding bills, mainly we have two components: electricity and water.
We know that for the simulatenous washing of 100 containers, for 5 minutes, we electrically consume 0,083kWh. Considering the weekly demand of the 4 minutes walking distance, we would perfom 44 washing of 100 containers at the same time, consuming 3,65kWhel. In Mozambique, the electrical price in March 2022, was set around 8,2kWh [66], leading to a weekly operative cost of 30 MZN.
Anyway, for sake of simplicity, as bills comprehensive of electricity, water supply, waste management etc, let’s take as a reference an average monthly bill for the city of Maputo. [67] Sets out a monthly expense of 5’000 MZN for an apartment of 80 m^2. By using this as reference, we allocate a weekly operative cost of 1’250 MZN.
For what concerns the salary operators, the center is designed for three operators to fit in, one for each department. One would be working in the acceptance area, interacting with the final customer and manage the finances. This figure, as already explained, will also have the duty to retire the empty containers and deliver to the customer a new one, writing on the containers, if not written yet, the expiry date. Then, a person would be in the washing area and a last one in the production area.
To allocate this operative cost, let’s take as reference the average monthly salary for the city of Maputo, this value sets around 46’500 Mozambican Meticais per month. Therefore, considering 3 operators, the weekly cost would set at about 34’500 MZN/week. Finally, the operating cost of the HDPE containers. As said in previous chapters, the laboratory is able to fill, weekly, 5000 containers. Therefore, let’s assume to insert into virtuous recirculation 5000 HDME containers of 100ml each. On Alibaba [68], as a reference cost for HDPE 100ml containers, is set a price of 5,74 MZN per piece, if you buy 5’000 pieces, that is our case study. As suggested by UNICEF, the life of the HDPE recirculated containers, would set around the 90 days [7]. This means, every 90 days, 5’000 containers would expire towards recycling process, and new 5’000s containers will enter the circle. The data of the 90 days is sufficiently aligned with the re-use of 25 times proposed by the HANDS group.

In fact, by considering an average of 2 refill at week, 90 days of use would involve approximately 25-30 reuses.
Given that, the weekly operative cost of the containers is just obtained by dividing the cost of the 5'000 by 12, the number of weeks in three months. Finally, the allocated weekly opex for the containers sets around 2'391 MZN/week.
To the final algebric sum of these 5 components for the operative costs to run the laboratory, is added a reasonable 10%, in order to insert operating costs difficult to quantify at this level, such as transport and logistics

WEEKLY OPEX	**[MZN/week]**
Public space rental	12'500
Formula 2 components	177'500
Bills	1'250
Salary operators	34'500
HDME containers	2'391
Transport and logistic factor	+10%
TOT	**250'955**

Table 11 - Operative Exprenditures

4.7.2.2.3 Polichina commercial sale

After having analyzed the costs, now we have to take into consideration the incomes given by the commercial sale of the Polichina to the neighborhood of Chamanculo C. The question we need to answer is: at what price do we sell the polichina? As we said, we want the laboratory to be, at least, financially self-sustainable, so the weekly income should be at least equal to the weekly operative costs. Figure 44 shows some prices per liter of some of the most popular hands sanitizer on the market.

Trade Name	Volume (ml)	Price (MTZ)	Price STD (MTZ/liter)
Aqua Vera	100	106	1060
Papillon	500	395	790
Papillon	250	199	796
Voi Antibacterial	500	475	950
Voi Antibacterial	100	172	1720
Voi Antibacterial	50	75	1500
Bactigel	250	189	756
Dettol	200	650	3250
Dettol	100	110	1100
Dettol Spray	50	195	3900
Mistolin	125	165	1320
Procare	100	125	1250
Procare	1000	499	499
Germex	5000	1699	340
Germex	250	189	756
Germex	50	119	2380
AlcoolGel	200	299	1495
Sivoderm	100	79	790
Amalfi	80	180	2250
Amalfi Spray	60	225	3750
Enlinven Strob.	100	129	1290
Enliven	100	130	1300
GreenWord	100	115	1150
GreenWord	50	79	1580
Care	100	169	1690
Identity Hand	150	95	633
Clerè	250	375	1500
BioGlow	250	260	1040
Quicksan	250	290	1160

Figure 43 - Hands sanitizer costs on the market (Source: Politecnico di Milano, 2021)

Polichina was born from researchers of Politecnico di Milano with the idea of providing a service to society, therefore the price of the product would be aligned with the mindset of the original idea. Given that, also by looking at the price of the others commercialized hands sanitizer, an initial price of 750 MNZ per liter is set for the sale of the product. Therefore, a 100 ml container is sell to the neighborhood at a price of 75 MNZ.
The weekly operative income, considered the expected sell of 4'370 containers, sets around 327'741 MNZ.
Finally, having calculated the operative costs and the incomes, we calculate the operative margin, the financial parameter indicating the rates of profitability of the business.

ECONOMIC ANALYSIS (weekly trial period)	
Polichina price [MZN/lt]	750
Operative costs [MZN]	250'955
Operative incomes [MZN]	327'741
OPERATING MARGIN [%]	**23.42**

Table 12 - 4 minutes walking distance Economical analysis

The operating margin will be used for improvements in the social laboratory, or in any case it will be used for social initiatives aimed at promoting healthiness in the Chamanculo C district

4.7.2.2.4 HANDS return systems

As per the premise, priority of the laboratory is not only the distribution of the hands sanitizer to the neighbourhood. In fact, if this were the only scope of the initiative, the consequences on the environment would be potentially harmful. In effect, as previously discussed, would be irresponsible to insert in a low-income country rural neighbourhood the commercialization of thousands of plastic containers without an adequate waste management system. What needs to be done is to exercise a sort of control over the containers circulating in the neighbourhood. And this is done by economically incentivizing the virtuous recirculation of the containers, by taking as a model the successful Danish return system.
The user, when buying a container, will be charged of a small deposit for the return system. The aforementioned deposit will be returned to the user, once he will take back the empty container to the center. The advantages of the return system, as demonstrated from the results obtained in Denmark, is threefold. First, a virtous recirculation of the containers is clearly incentivised, therefore we are sure to be able

to excercise a control on the waste streams related to the plastic containers. Secondly, we ensure the fact that a user does not keep an unused container at home, in fact it is likely to think that, even if the user is not interested in buy new Polichina, will take back the container to redeem his deposit. Finally, a parallel economy is, off the records, originating. The so-called ‘Catadores’, when waste picking around the district, can collect the not yet returned containers, bring those to the center and redeem the money.
As deposit, a surplus of 10 MZN, 13%, is added to the standard container cost. In conclusion, the final cost of the 100ml container is 85 MZN, with the possibility, by bringing back the empty container, to recover 13% of the cost.

HANDS RETURN SYSTEMS	
Standard 100ml container price [MZN]	75
Deposit for the Return system [MZN]	+10
Return system 100ml container price [MZN]	**85**

Table 13 - Hands Return System

Chapter 5 – Conclusions

This work was born as support for the HANDS project, a research study of Politecnico di Milano aimed at promoting healthiness within the Chamanculo C district in Mozambique, on the outskirts of the capital Maputo City, through the sustainable distribution of Polichina, a hand sanitizer produced by the institute during the Covid-19 pandemic. The goal was to create a preliminary sizing proposal for the social laboratory, intended for the production and distribution of Polichina, with an eye on the strong, social and environmental impact that the sudden introduction of thousands of containers could have on a low-income neighborhood characterized by an inadequate municipal solid waste management system.

For the physical sizing, one-week trial period and a 100 liters daily production of disinfectant have been hypothesized and it has been considered to supply a 4-minutes walking distance area surrounding the center.

In order to estimate a plausible Polichina consumption within the project area, starting from census data, the number of families has been evicted. Furthermore, by logical reasonings and based on studies found in literature ,considering a pre and post pandemic situation, a reasonable number of daily hand washing operations has been allocated.

Hence, coupling the aforementioned data with the spray capacity of the containers, it has been possible to obtain a reasonable daily consumption. Finally, by crossing the project area demand, supply and the volume of containers, it has been easy to size the physical space of the centre. In addition to making a hygienic product accessible that would otherwise be difficult to reach for such a marginalized neighborhood, the work has focused on the environmental impact that this business could have been created. After bringing back the working principles of the danish returnable system, active for some years with excellent results, a similar system has been proposed for the Chamanculo district, with the aim of encouraging the virtuous recirculation of the containers. To do this, a deposit equal to 13% of the sale price has been assumed.

To conclude, this work, in addition to the practical aim of making accessible a service otherwise not possible with the current situation in terms of hand washing facilities, and to promote the containers virtuous recirculation in such a low-income neighbourhood with a lack in waste management, has always been inspired by a strong social connotation. It is, in fact, hoped that this it can contribute, even if only for a small part, first of all to the effective implementation of the social laboratory, and furthermore to somehow promote certain healthy habits among future generations, reinforcing the concept of integration between social and environmental well-being, which has by now become essential.

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