

IMPLEMENTED MODELS OF CIRCULAR MANAGEMENT OF WATER

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Abstract: *Economy is part of our everyday life, whether it is present at a household level, regional level or global level. Albeit water is not considered a "commercial product like any other, but, rather a heritage which must be protected", as stated in the Water Framework Directive, released by the European Commission in 2000, practices involving the use of water around the globe are gravely damaging the availability of this resource in the future. [6] The purpose of this paper is to highlight a few of the solution implemented on the territory of Europe and India, regarding a circular approach to grey water, in order to reduce the stress exerted on this precious resource.*

With over 1,3 billion people and a GDP boom of 7% per year, India faces new demanding situation in phrases of resources and energy consumption. It has end up a need to govern Green House Gases emission, waste generation and pollution. That is why we suppose that the circular economy model is a possibility for India on the way to attain a long-term prosperity and economy. India is going through a water disaster and by 2025 it is expected that India's population could be stricken by intense water scarcity. Conventional groundwater and surface water sources are getting more and more prone to anthropogenic, industrial and natural pollution. The alternative and cost effective process in rural areas is the treatment of gray water to reuse it. One of the most effective approaches of conserving water in normal existence is graywater recycling.

Key words: *circular economy, water management, recycling water, greywater treatment*

INTRODUCTION

On Earth water is available in different forms, above and under the surface of the Earth. The mass of water on Earth is constant over time but the partitioning of water into ice, fresh water, saline water and atmospheric water fluctuates, depending on a wide range of climatic variables. To understand the circular economy, the study is focused on circular water management, and to understand the circular water management, knowledge of water cycle is must. The hydrological (water) cycle starts with the evaporation of water from the ocean surface. This air contains moist then rises and starts to cool; now the cooling water condenses and make clouds. Then in form of rains water from the clouds falls to the Earth and it is termed as precipitation. The precipitation may infiltrate the ground and be incorporated as ground water and or it may become runoff. Some water evaporates from the ground surface and some flows into streams and rivers and from there, back into the ocean where cycle starts again. Ground water perforates the surface and eventually enters back into the streams and rivers or back into the atmosphere through transpiration and again the cycle continues [1,2,7,8,11].

Making powerful coverage selections and enhancing water stewardship are important in coping with water risks for example, in minimizing risks to water components related to the poor affects of weather change. Countries can reply to contemporary and water shortages due to weather change through encouraging properly managed use of water, allocating water to excessive value uses, and through converting to greater efficient commercial and agricultural practices. Regions which are extraordinarily dry require far-accomplishing rules and policies to avoid inefficient use of water and to cope with the risks of water scarcity [1,2,7,8,11].

Reports of the United States Environmental Protection Agency (EPA) display that water-associated risks apply to all sectors of the economy [12].

CLOSED ECONOMY

The concept of “closed economy” transpired in the late 1960’s, when Kenneth Boulding first raised public awareness over the “open economy”, which uses unlimited inputs to produce unlimited outputs, that later end up being unlimited waste [10].

The first indicators of the certainty that the economic development of the humanity cannot be isolated from the degradation of the natural environment were made visible in the 1972 report named “The Limits to Growth” published by the Club of Rome. The conclusion of the report was that the model for development performed at that time is not sustainable for long term evolution [6].

The first UN Conference on Environment, held in Stockholm in 1972, raised the problem of the damaging relationship between human activities and environment, giving a voice to the international community’s concern. The Conference resulted in the establishment, in 1985, of the World Commission on Environment and Development.

Currently, the linear model of economy is the leader, but after many scientist raised awareness over the fact that it is not a sustainable model, many countries and governments choose to transition to a more sustainable approach to economy, directing their attention towards the circular model [6].

The fundamentals of the circular economy are based in the study of the natural living systems, which have the particularity of being non-linear and feedback-rich systems. The contemporary approach to circular economy relies on major contributions from a variety of scientific fields and concepts, as bio-mimicry, regenerative design, ecology, to name just a few [10].

A circular economy that has its basis in sustainability of water use, renewable substances are used in feasible manner, water is used sustainably, energy is supplied renewable sources in sustainable manner, natural structures are preserved and enhanced, and waste and negative effects are designed out. Materials, water, products and additives areas a substitute controlled in loops, retaining them at their maximum feasible intrinsic value [12].

MATERIALS AND METHODS

For this study on the efficacy of circular economy, the authors gathered data, information and statistics from studies and books specialized on the subject and the official web pages of the European Commission, European Parliament and European Council and Indian Government.

For the examples of implemented circular models, the authors gathered and interpreted the information available on the official web-pages of the respective enterprises that adopted and implemented the model in one or more aspects of their business.

The data collected from the aforementioned bibliographic sources were analyzed, synthesized, graphically represented, and conclusions were formulated, in order to provide an overview of the benefits a functional circular economy holds for the long-term sustainability of our ecosystem.

RESEARCH RESULTS

A circular economy is considered a closed system, aimed at eliminating waste and the unlimited use of resources, employing practices as reuse, repair, recycle, share. In a

closed loop, waste becomes material for another process, either as a by-product, recovered resource or regenerative resource [10].

Regarding the use of raw material, circular economy focuses on the basic 3-R:

- **Reduce** (use as little raw material as possible)
- **Reuse** (for as long and as many processes as viable)
- **Recycle** (high quality reuse of raw material)

At it's most basic level, it's considered that circular systems have three elements, although it is debated that a fourth- social inclusiveness, should also be considered:

- **Closed circle:** mimicking the way a natural ecosystem works, circular system seek to close the cycles of materials, considering every residual stream an opportunity for a new product. Producers ensure the repairs or recycling of used products in order to give them a new life.
- **Renewable energy:** because energy cannot be recycled, circular systems operate with “cascade type energy flows”, most of it coming from renewable energy sources.
- **System thinking:** in a circular system, every participant is connected to the others. The result is a network, in which every action one participant does influence the others. Therefore, every player in a circular system should take in consideration the impact their action has over the entire network [10].

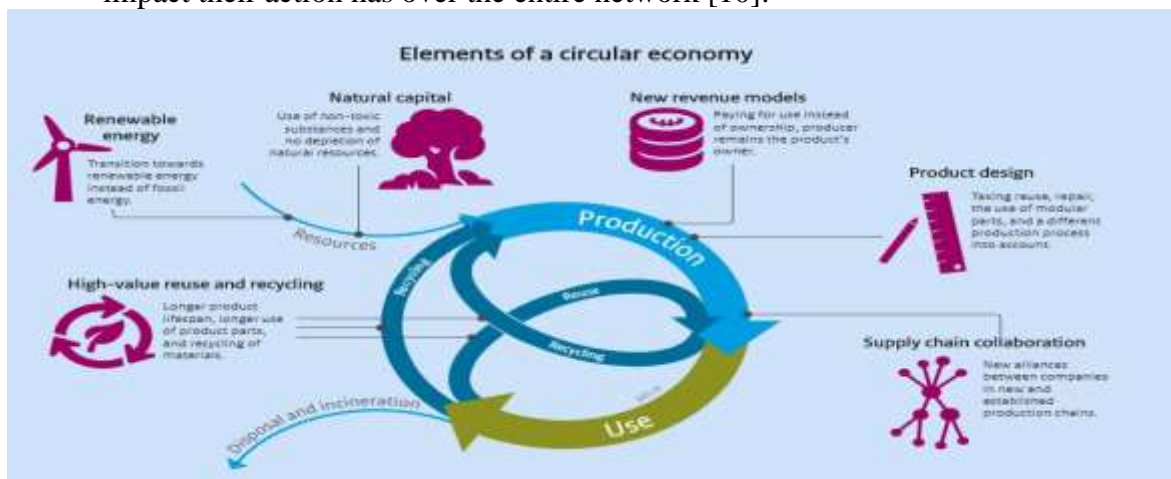


Figure 1. Elements of a circular economy

Source: <https://themasites.pbl.nl/o/circular-economy/> [21]

Until last decade, economic growth was strongly coupled with environmental degradation, every aspect of the economy being focused on monetary profit and not on the sustainability of the practices [6].

As mentioned in the Circular Economy Action Plan, published by the European Commission in March 2020, we are hardwired to consume as if we had trice the resources we have, and it is estimated that by 2070 the global consumption of fossil fuels, biomass, minerals and metals will double if we continue the actual trend [15].

This is highly related to the production of waste, with the annual waste generation increasing by 70% in the next thirty years. This trend is strongly conflictual to SDG12: Ensure sustainable consumption and production patterns, which aims to do more with less, by amplifying resource efficiency and stimulating the adoption of a sustainable lifestyle [16].

One specific aspect of our life that is particularly wasteful is water consumption. In 2016, the countries of the European Union consumed approximately 135,800 million cubic

meters of water, 655 million cubic meters of it being reused water, less than 0.5% of the total [17].

Table 1.

Water use in million cubic metres

Geographical area	FrW 2015	RuW 2015	FrW 2016	RuW 2016
EU Member States	118,665.775	744,761	135,738.007	654,063
European continent	162,713.827	744,761	200,315.628	654,063

FrW= Fresh surface and groundwater

RuW= Re-used water

Source: <https://ec.europa.eu/eurostat> [17]

In October 2000, European Commission and Council released the Water Framework Directive, stating in the first paragraph that “Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.”, the goal of the Directive being “to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater”. This legal framework provides the countries of the EU not only with the basic necessary measures that need to be implemented in order to ward off future deterioration of the aquatic ecosystem, but also to enhance and enrich said ecosystem [13].

The Directive sets the legal basis of water reuse policies and sustainable practices regarding the consumption of water, from household level, to municipal, to industrial use, in order to protect on the long term the available water resources. This includes surface water, groundwater, aquifers, coastal waters, inland waters and any other water body, on the surface or underground, natural or anthropogenic [13].

Although it is considered that Europe does not lack adequate water resources, the phenomenon of water scarcity and drought is more and more frequent in the European Union [13].



Figure 2. Water scarcity in Europe

Source: https://ec.europa.eu/environment/water/pdf/water_reuse_factsheet_en.pdf [13]

The Circular Economy Action Plan, part of the EU Green Deal, adopted by the European Commission in 2020, includes a section in Chapter 3, dedicated to The Water Reuse Regulation, encouraging circular approaches to water reuse in agriculture and not only. The European Commission also considers reviewing policies on water treatment, in order to facilitate the extraction of natural nutrients such as algae from sewage and greywater, as part of the Integrated Nutrient Management Plan [14].

This approach of the European Union is also aligned with the Sustainable Development Goal 6, part of which specifically targets a substantial increase in recycling and safe reuse globally by 2030 [14,16].

As mentioned above, less than 0.5% of the freshwater withdrawn in EU annually is reused, but the potential is estimated to be six times greater than the present volume. Multiple Member States already have in place initiatives regarding reuse of water for irrigation, nutrient extraction or industrial use. Some of these initiatives will be researched in the paragraphs below [14].

1. All-Gas, El Torno Chiclana, Spain

The All-Gas project, developed in 2011 by Aqualia, Europe's fourth largest private water company in terms of population served, focuses in reusing wastewater from El Torno, Chiclana to create bio-fuel extracted from algae.

The main concern in the creation of bio-fuels from organic materials as sugar cane is the use of arable land, raising the issue of fuel vs food regarding land use. As specified in the Report on the preliminary evaluation, the production of algae from wastewater has two major benefits: marginal land is used in order to avoid using arable land and the surface required is smaller, due to higher biomass yields/ ha, when compared to other bio-fuels. The approach of All-Gas, to use non-arable land, means that negative land transformation does not occur.

On the other hand, given the fact that the main space demanding process is the cultivation of algae in algae ponds, that occupy 13ha of land for 10ha of water surface, is estimated that this model of water treatment plant needs ten times more space than a conventional waste water treatment plant. The uptake of land use is that the value of the land used by All-Gas is very low and there are no other beneficial applications for that area [18].

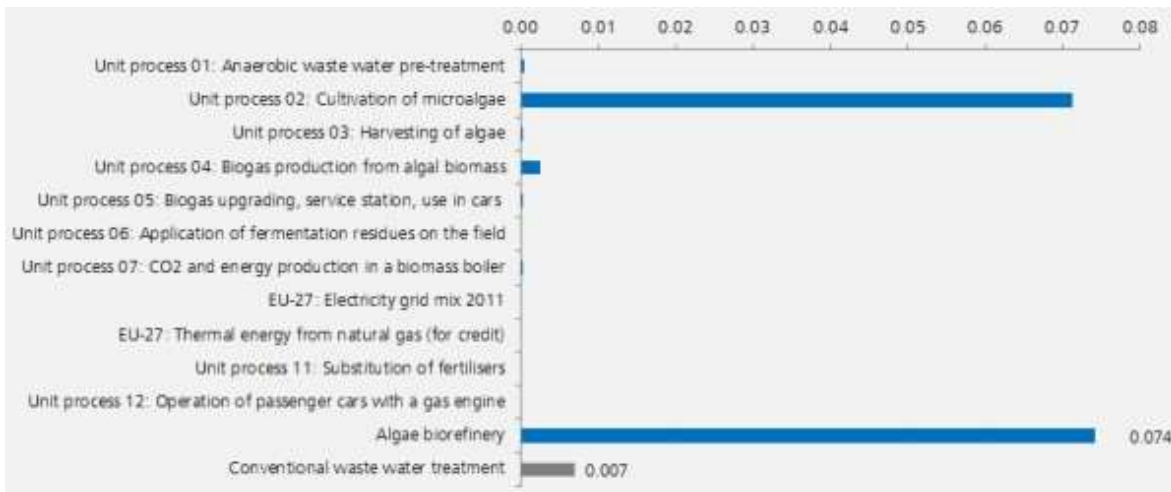


Figure 3. Comparison between All-Gas and a conventional WWTP related to land use in m² for 1 m³ of water treated annually

Source: <http://www.all-gas.eu/documents/1509955/2113404/D13.2+Report+on+the+preliminary+evaluation/ef18b661-90c2-75ae-5d7c-2c750abcbfd2> [18]

When considering EROI (energy return on investment), the data from the Report on the preliminary evaluation shows that the value of EROI is situated around 2, meaning that the system registers a positive energy balance. Compared to a conventional WWTP, which consumes energy in the process of treating the water, All-Gas produces 2 units of energy for every unit consumed, making it more attractive regarding the energetic expenses [18].

The first car fueled by All-Gas in 2016, provided by VW traveled around 80 km/day, reaching almost 30,000 km in the first year, in order to validate the quality of the gas, in concordance with the European Regulation EN 16723-2. In December 2016, Seat took over the mission to test in the long-term the reliability and the quality of the bio-methane.

Full scale results show that algae fuel is four times more efficient than the best conventional bio-fuels, with a capacity of 20 to 30 cars/ha, compared to sugar ethanol or palm oil diesel, that can power at most 5 cars/ha.

Another positive impact of the All-Gas is that compared to agricultural crops destined to become bio-fuels, it requires no arable land, no fresh water, no fertilizers. Even more, the wastewater is disinfected for reuse, with nutrient recovery and positive energy balance, all while creating sustainable fuel. It is estimated that in order to fuel the 30 million cars currently used in Spain, such a system would need to occupy an area of 15,000 km², 2.96% of the total area of Spain (505,990 km²) [18].



*20,000 km/year/car

Figure 4. Comparison between All-Gas and other bio-fuel production

Source: author's interpretation of data available at <http://www.all-gas.eu/documents/1509955/1612092/2018+Press+Clipping+All-gas+ENG.pdf/21d321d206cd-f099-f21d-c42ac24f0364> [18]

2. Aquaporin, Copenhagen, Denmark

Aquaporin is a water-tech company, situated in Denmark, dedicated to overcoming the problem of water scarcity around the Earth. Aquaporin works nationally and internationally, developing products and services for communities and companies that try to reduce water consumption and reuse what can be reused.

Their technology is based on the aquaporin protein, found in every living organism. This protein is shaped like a channel, forming pores on the surface of cells, in order to facilitate the transportation of water molecules between said cells. They were discovered by the American physician Peter Agre, who was awarded in 2003 with the Nobel Prize in Chemistry for his discovery.

Aquaporin S/A uses the discovery of the aquaporin protein to develop a natural membrane that can be employed in a wide range of water filtering devices, in household or industrial settings, with the capacity to facilitate safe and sustainable water reuse. In order to support the UN Sustainable Development Goals, Aquaporin S/A operates 100% on green energy, generated by wind turbines. Their solution for water purification and reuse is strongly aligned with SDG6: Ensure availability and sustainable management of water and sanitation for all, SDG12: Ensure sustainable consumption and production patterns and SDG14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development [3,16].

In contrast to traditional filtering membranes, mainly consisting of dense polymer films, the aquaporin membrane relies on bio-mimicry, using biological components to achieve water filtration and purification. The technology behind the membrane is called Forward Osmosis and can be used to draw clean water from a solution, without using any hydraulic pressure. It can be used to filter greywater with the recovery of clean water and dry residue that can be further transformed to be used as fertilizer. The membrane developed by Aquaporin S/A is certified by National Sanitation Foundation and was already implemented with great results in industrial products and household products.

The company is currently implicated in a project with BIOFOS, the largest water utility in Denmark, in order to develop a membrane that can filter the micro pollutant particles at industrial level, providing safe tap water for a wider range of the population. This membrane can also be used on the discharge circuit, in order to ensure that no micropollutants originated from human activities end up in the nature, thus protecting the aquatic environment.

Aquaporin also created a membrane for industrial use, destined to companies in the pharmaceutical and medical industry, breweries, food industry and not only. The

membrane facilitate the filtration and re-circulation of the used water, in order to achieve zero liquid discharge and zero water waste, reducing the costs for the industry and the stress for the planet. This membrane is also tested by the Danish Aerospace Company and NASA, in search for solution to clean water in space, the goal being to replace the current multifiltration beds, which are high maintenance and heavy [19].

3. Hydraloop, Leeuwarden, Netherlands

Hydraloop International B.V. is an innovative company situated in Leeuwarden Netherlands, which took upon itself the mission to stimulate people to save water by offering smart and affordable water & energy recycling products. Founded in 2016, after years of research and development on systems that are affordable, easy to use and low maintenance, Hydraloop launched its first product on the market of Netherlands in December 2017 [20].

In January 2020, Hydraloop launched their global product in Las Vegas, during the Consumer and Electronics Show, being awarded “Best of Innovation” in the category “Sustainability, Eco-design and Smart Energy”.

According to their official web-site, the most effective and economical source of water inside a building comes from reusing the greywater, through a decentralized water recycling system. Through their product, Hydraloop contributes to the achievement of SDG6 (Clean water and sanitation), SDG11 (Sustainable cities and communities) and SDG12 (Responsible consumption and production) [16,20].

The water filtration system developed by Hydraloop is different than any other developed before, regarding the technology used in the process of purifying the water. Instead of using filters and membranes, that are subjected to clogging and require frequent maintenance, Hydraloop combines six innovative technologies in the water treatment: Sedimentation, Flotation, Dissolved Air Flotation, Foam fractionation, an Aerobic Bioreactor and UV light, the final treatment, for disinfection.

The Hydraloop unit can be configured in different ways, depending on the way customers want to use the recycled water. With a maximum capacity of 530 L/day, the system can be designed to direct the recycled water inside the house- to the wash basin, washing machine or toilet, or outside the house, for irrigation or pool top-up.

Another configuration, destined for entire buildings or hotels, implies the use of Hydraloop Cascade system, which is simply more than one unit, installed together.



Figure 5. Hydraloop Home and Hydraloop Cascade

Source: <https://www.hydraloop.com/technical> [20]

The Hydraloop system is self cleaning and monitored on-line 24/7. If a component of the system fails, it automatically shuts off and switches to the backup water facility. A notification is sent to the phone app, with detailed specifics, and the installer responsible

for the unit is noticed too. The team behind the project recommends an overall preventive maintenance check once every year.

One unit can filter between 300L and 520L day, from a household with 4 to 5 person. According to their data, one unit can save around 78,138 l/year, or 85% of the total domestic water use. Also, the recycled water is certified by PIA GmbH and KIWA Netherlands B.V. and meets the criteria of DIN EN:1717 “Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow” [20].

Example of annual Hydraloop water recycling for 4 person family in liters									
Capita 4	liters	persons	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Shower (morning)	45	4	180	180	180	180	180	180	180
Shower (evening)	55	1	55	55	55	55	55	55	55
Collected greywater			235	235	235	235	235	235	235
Available HYDRALOOOP recycled water		95%	223	223	223	223	223	223	223
	liter								
Toilet flushes (5 flushes/day/person)	6,0		120	120	120	120	120	120	120
Washing machine (1/day)	42,2		42,2	42,24	42,24	42,24	42,24	42,24	42,24
Garden, pool or carwash			61,0	61,01	61,01	61,01	61,01	61,01	61,01
Recycled water usage per day			223	223	223	223	223	223	223
Mains water saved per year			78.138 liters						

Figure 6. Water savings using Hydraloop

Source: <https://www.hydraloop.com/technical> [20]

In India: As per the document of Ellen MacArthur Foundation in 2016, adopting circular economy standard might place India on a direction to positive, regenerative, and value-developing improvement, with annual benefits of ₹40 lakh crores (US\$ 624 billion) in 2050 [5] as compared with the current development path – equivalent to 30% of India’s current GDP. In addition to developing financial savings for businesses and households, following a circular economy development direction would reduce negative externalities: greenhouse gas emissions might be reduced 44% in 2050 as in comparison to the present scenario, and congestion and pollutants might fall significantly, leading to health and financial benefits to Indian citizens. One of the most effective approaches of conserving water in normal existence is greywater recycling [9].

In India, 20 percent of groundwater blocks are critical or overexploited, while untreated sewage flows amount to 37,000 MLD. By 2050, the freshwater abstraction by industries will be 10.1 percent. All these factors make a strong case for a circular economy pathway in the wastewater sector. In a conventional economy, everything is linear, from cradle to grave: extraction, production and disposal. In the circular economy, consumption patterns are designed to mirror the cyclical approach of natural ecosystems.

Initiatives regarding reuse of water in India are presented in the following examples.

4. VA Tech Wabag Ltd., Chennai, India

Their technology is based on Tertiary Treated Reverse Osmosis in plant they are setting up in Chennai, India [22]. The TTRO plant, with a capacity of 45 MLD, was constructed in 2018 in partnership with of IDE Technologies Israel, in order to produce non-potable recycled water for industrial use. The IDE Technologies declares specialty in the development, engineering, construction and operation of enhanced small to mega-size, sea and brackish water desalination facilities; industrial water treatment and water reuse plants, based on the most advanced technologies. As per the official website of company, it has been developing a growing portfolio of economic, green water treatment solutions for municipalities and industrial needs – especially in the areas of desalination, industrial

water and wastewater treatment. This industrial-grade water supply helps relieve some of the immense water demand generated through the industrial activity in the area, and permits a bigger part of the local potable water reasserts to be allotted for the municipal use.

Tertiary treatment is the last cleaning process that improves wastewater quality before being reused, recycled or discharged to the environment. The treatment discards remaining inorganic compounds, and substances, consisting of the nitrogen and phosphorus.



Figure 7. Types of filtration

Use of membrane-based technology will make sure that smaller particles that have been overlooked within the previous stages can be taken care of, particularly total dissolved solids (TDS).

The IDE-WABAG consortium has been decided on through the consumer due to their adequate experience in RO and Industrial Reuse technologies, flexible financing skills and strong local presence. As a part of the consortium, the technologies included in this project included Gravity Sand Filters, Ultra Filtration (UF) and Reuse Reverse Osmosis treatment, so that it will deal with the very poor quality of the Wastewater Treatment Plant effluent.

5. Greywater (Jaldhara Technologies Pvt. Ltd.) - Member of Indian Green Building Council, Maharashtra, India

This company offers a unique range of highly compact, modular products under the Grewa brand [23]. The Grewa range is appropriate for residential and commercial buildings, hospitality and industrial sectors. As per the official website of this company, they install products with minimal on-site civil/fabrication work and offer significant reduction in space and operating costs compared to conventional solutions. They use biodegradable bags for automatic collection of sludge. Minimal man power is needed in the installation of the plant.

Basically, in India cost effective solution is required, so, the companies are trying to provide cost effective solutions, like: **Jalconserve Technologies Pvt, Mumbai, India**: This enterprise is an Indian start-up based in Navi Mumbai, India. 'Jalsewak' was founded in the year 2016; mission of this enterprise is to provide remedy to all water problems. As per the website of this firm, their initiative includes conservation of natural resources, reducing liquid waste, substantially and reducing cost. They are providing customized solutions for the treatment of the grey water. They are using filtration technology and chemical treatment chamber to treat the grey water. The grey water treatment plant is cost effective.

CONCLUSIONS

Circularity is the nature's way of self regulating and self sustaining. Human activities have been for a long time in contradiction with the natural way of using the resources and disposing the waste. Unlimited extraction of raw material and disposal of waste product resulted in a polluted environment, threatening human health and future life on Earth. But not to despair, abundant solutions are to be found if we learn to look closely in the nature. The examples above are only one small part of the innovations happening all over the planet, innovations that shift our behavior towards a mindful approach to the available resources, responsible consumption and waste disposal.

In developing countries like India, for example, the total sewage generation in 2015 was 61,754 millions of litre per day. About sixty two percent of total sewage, however, becomes discharged without delay, directly into nearby water bodies due to the prevailing incompatibility of the sewage treatment plants. Going through those numbers, it is evident that there is ample scope and need to recycle grey water. While consciousness has increased, clients are not open to installing costly solutions. There is a massive demand for cost-effective and compact answers that require minimal re-plumbing.

Indeed after adopting the water re-use policy, India is entering in what Christopher Gasson, publisher of Global Water Intelligence [4], has called the golden decade of water reuse.

As pointed by the European Commission, United Nations and other governmental and non-governmental organizations, a circular economy has the potential to reverse the damage sustained by human activities on the planet and to reduce the health risks associated with over-consumption, with the ultimate goal of creating a sustainable future for the generations that follow.

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