Chapter 12

Challenges and opportunities in the implementation of rainwater barrels. An analysis of usability for the Guadalajara Metropolitan Area, México

V. L. Díaz[1] and G. E. Muñoz[2]

[1]Universidad de Guadalajara, Urban Projects Department, Guadalajara, México

[2]Universidad Autónoma de Guadalajara, Architecture Department, Guadalajara, México

Keywords: rainwater barrels, usability, user evaluation

12.1 INTRODUCTION

The aim of this chapter is to provide a description an evaluation of the usability of rainwater barrels in the context of the Guadalajara Metropolitan Area, in order to present the challenges and opportunities regarding the implementation of rainwater barrels. The analysis is based on the end-user perspective, of those who decide to implement the rainwater harvesting system in their households. In order to attain this, we implement a usability measuring instrument adapted to the evaluation of ecotechnological objects. This evaluation seeks to present an approach towards the identification of key elements for the improvement in the design of rainwater barrels. They are conceived as eco-products for the betterment of the environment and society as well as an affordable innovation.

Water is a fundamental resource linked to health and sanitation, and according to the United Nations (UN) water is an essential human right. The UN points out that there are approximately 884 million people without access to drinking water and 1.5 million children under 5 years of age who die from water-related diseases

Editor(s): José Arturo Gleason Espíndola, César Augusto Casiano Flores, Raul Pacheco-Vega and Margarita Rosa Pacheco Montes
doi: 10.2166/9781789060584_0153

(ONU, 2010, p.2). Hence, it is essential to integrate initiatives, programs and resources to assist the most vulnerable population. This situation encouraged the creation of UN-Water, a mechanism that focuses on the exchange of information, technology transfer and the creation of inter-institutional networks (ONU-Agua, 2009). Under this perspective, water is firmly established as a right and, in an economic context, as a resource. It is estimated that 80% of jobs worldwide depend on access to water (UNESCO, 2016, p.V), favoring in turn the economic development of countries. Investment in water is thus fundamental and establishes a correlation between the level of investment in water and the income of countries; in a global context where water is scarce, the capacity of its storage is linked to economic growth.

Irrespective of the fundamental role of water and the precedents set by the UN in terms of its care and management, there are national agendas that have failed to address the issue. In Mexico, while severe floods caused by rainy seasons directly affect highly vulnerable segments of the population, the issue of shortage and access to water remains unattended. In addition to that, a number of factors compromise the access to fresh water in the country, these include the pollution of rivers, lakes and seas on the one hand, and high consumption, negligent waste, disregard of the hydrological cycle balance and climate change on the other. Inadequate governmental water management and lack of infrastructure largely contribute to exacerbate this.

Within the ranking of the world's top 10 rivers at risk, one is located in Mexico, the Rio Grande, also called Rio Bravo (WWF, 2007). While 70% of the country's bodies of water are contaminated (Greenpeace, 2012, p.5), there is also a high extraction of water per person ratio of 691.40 m^3/hab/year, compared to China's 409.90 m^3/hab/year, Brazil's 306 m^3/hab/year and only 80 m^3/hab/year in Ethiopia (FAO, 2013). Moreover, the average municipal wastewater produced in 2017 was 7.41 hm^3 per year (234.9 m^3/s), while the municipal wastewater treated was 4.28 hm^3 per year (135.6 m^3/s) (CONAGUA, 2018, p.125). In 2015, the amount of renewable water per person was 3692 m^3 per year and it is estimated that by 2030 it will be reduced to 3250 m^3 per year (CONAGUA, 2016, p.79).

Considering that both the shortage of water suitable for human consumption and the excess of rainwater result in severe urban problems, attention to the management and consumption of water in its different variants of use is a high priority. In the case of the domestic use, there are some technical proposals to address this problem, such as the rainwater collection systems. According to the manual of rainwater collection of Texas, three stages define the process: water collection, conveyance and storage (Krishna *et al*., 2005, p. 2). According to the United Nations Food and Agriculture Organization (FAO, 2013, p.9).

> '… Rainwater collection and use is understood as any type of technical effort, simple or complex, (…) meant to increase the amount of rainwater that is stored in the ground or in built structures, in such a way that it can later be used under conditions of water shortage'.

Although rainwater harvesting is not a new practice, going back to ancestral times all over the world, it is accepted that technological advances, combined with the idea of progress that supplied running water through complex hydraulic networks, were degrading this cultural practice to the point of disappearance. This can partially explain the reluctance of some society sectors to embrace this practice, since rainwater harvesting requires both an economic investment and a considerable change in habits. Currently, there are few commercial options in Mexico and a low perception of water vulnerability, these factors make the expansion of rainwater harvesting practices difficult.

This chapter takes elements from industrial design, evaluating the function of designed objects, in this case rainwater barrels. The benefits of this approach are described throughout this chapter, as well as the results of its application.

12.2 INDUSTRIAL DESIGN AS AN INTERVENTION TOOL

Industrial design is a fundamental tool to solve the problem of universal access to rainwater. Parsons (2015) states that, in order to achieve our objectives and perform our daily activities, we generate ideas, design and use our imagination to deal with specific problems or concrete needs, turning the act of designing into an underlying activity of life, one that is bound to all that man does. Papanek (1977), for his part, argues that through the conception of an object and, due to the impact it will generate in society, there is an unavoidable ethical and social responsibility on behalf of the designer towards humanity. Taking this into consideration, the conception of rainwater barrels demands their analysis as design objects which meet, through to their environmental, economic and social functions, the vital needs of man. In this regard, the notion of user-centered objects, a term and method developed by Donald A. Norman (2013) considers the position, characteristics, limitations and possible user responses as the center of decision-making within the entire design process, looking for products that are easy to use and comprehensible for the user through the identification of physical and cognitive interaction patterns while meeting the user's needs and wishes.

Within Nielsen's (1993) model of 'system acceptability', the perspective of the end user represents a basic condition to ensure the fulfillment of the interactivity functions of a product through the evaluation of a system or, in this case, a designed object. Centered on the needs and requirements of the user, Nielsen's diagram (Figure 12.1) branches off from the 'usefulness' attribute, which refers to the ability of the system to fulfill a desired objective, and is subdivided into 'utility', namely the system's ability to do what is needed based on its functionality, and 'usability', that is, how accessible that functionality is to the user.

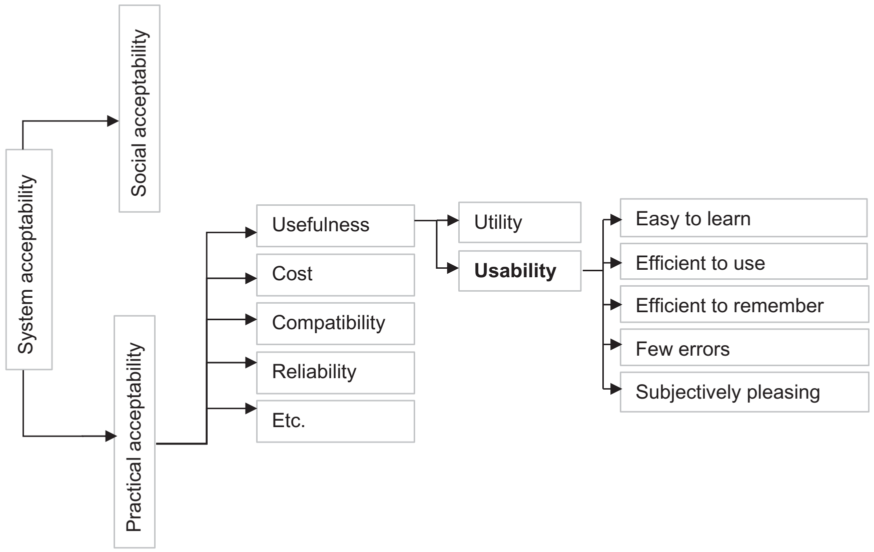

Figure 12.1 System Acceptability Model detailing the attributes with which 'usability' is assessed. (*Source*: Authors, adapted from Nielsen (1993)).

12.3 USABILITY AS AN EVALUATION TOOL OF DESIGNED OBJECTS

The assessment of usability as an evaluation tool can be traced back to the 1980s. It was, however, a decade later that Jacob Nielsen's (1993) works began to regard it as a substantial attribute that '(…) applies to all aspects of the system in which a human could interact, including installation and maintenance procedures' (Nielsen, 1993, p.25). As seen in Figure 12.1, this contemplates aspects such as ease of learning, efficiency of use, ease of remembrance, error tolerance and subjective satisfaction.

For the purpose of evaluating the usability of rainwater barrels, this work takes the four categories or techniques depicted by Nielsen and Molich's (1990) classification (Table 12.1) as point of reference, corresponding with the empirical type of evaluation for which further usability parameters were analyzed.

12.4 USABILITY MEASUREMENT PARAMETERS

According to the theoretical review carried out for this evaluation and, as condensed in a comparative revision of parameters (Table 12.2), it is evident that there are common variables in the measurement of usability. Among those 'ease of learning', 'attractiveness', 'efficiency', 'ease of use', 'persistence in memory', 'errors' and 'satisfaction' have served as the basis for the design of a usability evaluation instrument for rainwater collection barrels to be applied to our

Table 12.1 Types of evaluation

Formal evaluation	Assesses the user interface through some technical analysis. Formal analysis models are currently the object of extensive research applied primarily in software development projects.
Automatic evaluation	Computerized procedures for usability evaluation.
Empirical evaluation	Performs experimental user tests, with the aim of achieving a complete evaluation of the recipient. Currently most practical situations do not lead to empirical evaluations given the lack of time, specialization, inclination, or tradition to do so.
Heuristic evaluation	Performs the assessment of the user interface and generates a report according to the opinion itself (Ferrari & Mariño, 2014).

Source: Authors, adapted from (Nielsen & Molich, 1990).

Table 12.2 Usability measurement parameters comparison

Ferré-Grau (2001) and Alva (2005)	Jakob Nielsen (1993, p.26)	Norma ISO 9241-11 (1998)	España and Pederiva (2012)
Ease of learning	Learnability		Ease of learning
Understandability		Comfort and agreeability of use	Comprehensibility
Attractiveness			Measure of attraction
	Efficiency	Efficiency and effectiveness	Operativity
Remembrance in time	Memorability		
	Errors		
	Satisfaction	Satisfaction	Conformity

Source: Authors (2019).

case study in the municipality of Tonalá, Jalisco, a part of the Guadalajara Metropolitan Area.

Taking into account the application of usability parameters to the rainwater barrels' case study, some details are shown below. These contribute to their conceptualization as technological objects according to the categories of Ferré-Grau (2001) as well as the guide questions suggested by Jakob Nielsen (1993) and Nielsen (2012).

(a) Learnability: Ease of learning refers to the level of complexity represented by the use of the object, starting with the user's first contact, followed by the establishment of a self-generated knowledge peak caused by experience and interactive learning, up to the need for technical support. It addresses the question of 'How easy is it for users to accomplish basic tasks the first time they encounter the design?' (Nielsen, 2012).

(b) Memorability: Remembrance in time – this attribute considers the fact that users are not in permanent contact with the object in question, so that whenever a new interaction is necessary they are able to remember, without the need to learn 'from scratch', 'when users return to the design after a period of not using it, how easily can they reestablish proficiency?' (Nielsen, 2012).

(c) Understandability: This is based on the fact that users should be able to choose the product that best suits their needs and expectations, that is, to know the functions of the product and contrast them with what they need, in this case the input and output supply requirements of rainwater barrels. The language of the associated help documents must thus be simple, brief and in accordance with any potential user. The consideration of understandability is basic, so that false expectations among potential users are not raised. In its negative connotation, it would be linked to 'How many errors do users make, how severe are these errors, and how easily can they recover from the errors?' (Nielsen, 2012).

(d) Satisfaction: Attractiveness – it is generally accepted the level of visual attraction of objects implies an improvement in the display of information that enables interaction with the user and, to a certain extent, the preference of choice between several options. In reference to the perception of satisfaction, this would link to Ferrari and Mariño's (2014) question over how nice it is to use the designed object. Follow Nielsen, 'How pleasant is it to use the design?' (Nielsen, 2012).

(e) Efficiency: Once users have learned how to use the designed object, 'how quickly can they perform tasks?' (Nielsen, 2012).

From this perspective, all artificial objects have the ability to signify, communicate and relate to their users; in other words, the meaning itself is read in the 'language of the object'. In its broadest sense, that signification must act as container of the cultural and social assumptions (Sarabia, 1995, p. 114–117). The true challenge is thus to attend the broadest 'social, ethical and political problems (…) the artefacts produced by Design not only serve functional, symbolic and aesthetic aims, but also play a more fundamental role in influencing human life' (Parsons, 2015). On the other hand, Feng (2000, p. 164) as cited in Parsons (2015), argues that "even if technology is in some part driven by 'internal forces', (…) social values and demands also play a crucial, if not always highly visible, role".

In this regard, the scenarios turn into 'critical processes of learning and anticipation', in continuous adaptation, derived from the analysis of the possibilities of their impact (Sarabia, 1995, p 68). It is important to mention that the usability evaluation used for this work contemplates a systemic model comprising.

12.5 STAGES OF THE SYSTEMIC MODEL

The systemic model developed by Saravia (2006) represents the foundation from which the usability of the rainwater barrels' case study was evaluated. The six stages of development contemplated by the process are conceptually described in Figure 12.2, from this delimitation and analytical phases to the so-called 'Assessment Matrix' carried out on the last stage.

The usability evaluation instrument was applied to residents of the municipality of Tonalá. With the intention of establishing conceptual proposals that contribute to the improvement of the design object by addressing a specific problem, people were asked to collect water through the use of rainwater barrels in order to find out their degree of satisfaction and how they evaluate their operation. Stress was put on the stage of the process that includes their installation and operation, measuring their efficiency and effectiveness through the application of surveys and interviews.

12.6 RAIN BARRELS AND THE SCALL

Before delving into the discussion of rainwater barrels and their implications as rainwater collection systems, the extents of SCALL (Rainwater Collection System, for its acronym in English) should be first clarified and put into context. According to the 2005 Texas Manual on Rainwater Harvesting SCALL can be described as follows:

> 'Rainwater harvesting is the capture, diversion, and storage of rainwater for a number of different purposes including landscape irrigation, drinking and domestic use, aquifer recharge, and stormwater abatement. In a residential or small-scale application, rainwater harvesting can be as simple as channeling rain running off an unguttered roof to a planted landscape area via contoured landscape (…). More complex systems include gutters, pipes, storage tanks or cisterns, filtering, pump(s), and water treatment for potable use.' (Krishna *et al.*, 2005).

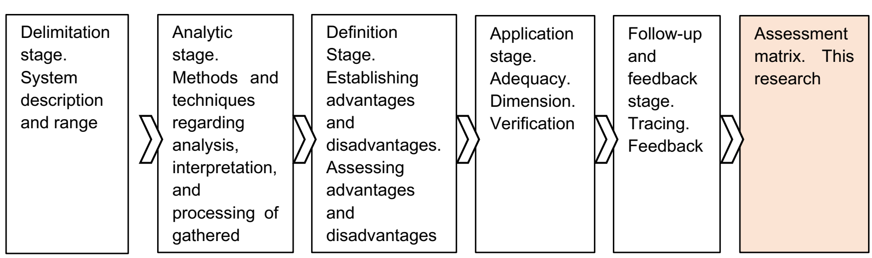

Figure 12.2 Systemic model applied to case study. (*Source*: Authors, adapted from Saravia (2006)).

The rain barrels case study represents an initial approach towards a SCALL (Rainwater call) that entails greater complexity on the technical (system maintenance capabilities, equipment monitoring, filter replacement, among others), economic (adjustments to the property, system parts acquisition, replacement of filters) and especially cultural aspects (change of habits, responsibility for cleaning the surface of the roof in contact with water, constant review of system parts, cleaning of containers, programming to change filters in a timely manner, among others) while considering the quantity and quality of water available for more crucial uses such as human consumption. In this context, rainwater barrels, according to the Institute of Technological Research of Water (IITAAC), are defined as:

> '… small containers used to capture rainwater from the roofs of buildings through gutters or downspouts. During rainfall, the drainpipes move the rain towards the barrel. If the container is full and it continues to rain, water that is not stored in the device comes out through a pipe located in the upper part of the barrel. This water should ideally purge on a green area away from the foundations of the house … ' (IITAAC, 2019).

The use of rain barrels aims to reduce water consumption from the public network, thus contributing to the mitigation of urban floods while diminishing the waste of rainwater that becomes normally polluted as it incorporates to the municipal network. Their use fosters, therefore, the development of a sustainable society where new generations are taught a different way of relating to their environments.

12.7 CHARACTERISTICS OF THE RAINWATER COLLECTION BARRELS

When the users decide to install a rainwater collection barrel, a product sheet is provided explaining the object's nature as a 'pilot program', letting the user know that it is an experimental initiative developed by IITAAC (Technological Water Research Institute, for its acronym in Spanish) Lic. Arturo Gleason Santana AC to promote environmental care and the encouragement of sustainable technologies among the population through the collection of rainwater. The sheet includes the following: (1) A brief introduction on the topic of rainwater barrels; (2) The location and characteristics of the site, including the dimensions of the collection surface and information about the type of building and water supply, among other data; (3) An explanation about the use of the rainwater barrel and its design (parts and adaptations that make up the system); (4) Water needs of the user/owner (s) of the barrel and the domestic (non-drinkable) uses of the harvested water; (5) Household water consumption figures and calculation; (6) Design adaptation proposal;

Figure 12.3 Rainwater barrel parts. A: opening, B: Cover, C: nozzle, D filter, E: purge. (*Source*: Authors, 2019).

(7) Installation process; (8) Installation cost estimate; (9 & 10) Designation of the person responsible for filing, reviewing and approving the document; and (11) Literature on the subject.

As shown in Figure 12.3, the rainwater barrel requires a collection surface, where gutters are placed to direct the flow of water through a pipeline, or downpipes, which flow into a filter in the opening of the barrel (A), which, in turn, contains a further filter (D) to prevent the entry of contaminants of significant dimensions, greater than the size of dust and sand. Once it has reached its maximum capacity, the excess water is purged (E), ideally redirected towards a gardened or soil area in order to avoid further waste; additionally, the cover allows for the cleaning of the barrel. Finally, the nozzle (C) near the bottom of the barrel provides access to the collected rainwater.

The designed object is a high-density and high-molecular-weight polyethylene container with adaptations made by technical specialists, although the barrel's capacity may vary, the one used for the purpose of this analysis features a 114 liter capacity. It can be installed in different types of buildings, however, use in domestic environments remains the highest priority. In general terms, its efficiency and relevance depend on the average annual rainfall of the Guadalajara Metropolitan Area; according to the Municipal Statistical Notebook of Guadalajara, issued by INEGI (National Institute of Statistics and Geography, for its acronym in Spanish), the average rainfall in the 1954–2001 period was 983.1 mm, while the driest year registered 615.2 mm and the rainiest year 1349.1 mm (INEGI, 2002, p.10). Roughly speaking, this translates into a great potential for rainwater collection in the region.

12.8 CHALLENGES AND OPPORTUNITIES IN THE IMPLEMENTATION OF RAINWATER BARRELS

The commercial availability of rain barrels as a product is relatively new, those evaluated throughout this study are therefore still in an experimental stage and access to users is limited, this, however, implies the opportunity for in-depth analyses by means of interviews. The instrument consisted of 35 questions related to the following categories: context, ease of learning, remembrance over time, understandability, attractiveness, efficiency (of use), satisfaction and errors. As mentioned earlier, every case-study barrel is located in the municipality of Tonalá.

Drawing on the results obtained, the use of the barrels appears to respond to a context of social relationships of trust, suggesting that the way in which the users became familiar with the designed object was through talks and recommendations by friends or acquaintances, establishing a base of trust regarding the rain barrels, which in turn encouraged the users to the acquisition and subsequent use of the product. Some stated that the most interesting aspect of the system is the self-created link to concepts such as 'ecology' and 'sustainability' and their latent interest in addressing these issues from the domestic sphere. Regarding the motive that triggered the transition from being interested in the subject to taking action, we found that, for most users, the economic aspect was key. According to the perception of users, the acquisition of the barrel represented a smart investment considering the high benefits expected in return; as a general rule, the obtainment of a container represents a first stage to then adjust, in a short to medium term, to a full system of rainwater collection.

As summarized, evaluation over usability concepts allowed us to establish a set of variables and measurement parameters which can be used for the assessment of the rain water barrels' case study. For the particular case of this work, we have considered to address the perspective of Saravia's (2006), the specific part of the process of his systemic model with an emphasis on its final stage, evaluated through the application of a survey and interview in order to understand the user's experience in regard to the operation of rain barrels with a focus on its qualitative aspects.

In terms of the **learnability** attribute, the system is generally regarded by users as one that allows the effortless collection of rainwater and is easy to install. However, concerns over the need for specialized technicians and adequate tools for this purpose were raised, noting that an improvised installation carried out by inexperienced hands might derive into problems that could confuse and discourage other people contemplating the purchase of such ecotechnology. Learning how to use it and how to perform simple maintenance actions was generally considered to be of low difficulty.

Being a utility that does not need frequent interaction with its user, in terms of **memorability in time**, details on the functioning of rain barrels could represent an obstacle for their correct operation. Likewise, problems would arise if constant preparation was required to be able to use the system or to keep it in good conditions. However, the users were able to report the characteristics, parts, and maintenance requirements of the system without requiring the re-reading of the manual that was delivered to them along with the rain barrel. Despite informing that they had to turn to the supplier for technical support, it was not on account of forgetting how to carry out an activity, but due to the requirements for adaptation to the installation.

In regard to **understandability**, as foreseen on the of ease of learning and remembrance over time attributes, the rain barrel system represents a simple-use ecotechnology, which is therefore easy to understand. Something important regarding this aspect is the impact that the dissemination of information exerts. As mentioned before, the socialization process that triggered the interest of the users, was sparked by recommendations of friends and by word of mouth. It is thus inferred that the person who recommended it in the first place understood the essence of the system, had formed expectations, and was subsequently able to explain and describe it before others.

The main expectations constructed around the usefulness of the rainwater barrel at the domestic scale lie on activities like garden irrigation, garage cleaning, laundry and vehicle washing. This is consistent with the expected level of water quality and it is assumed that its level of understandability is high. A further element that allows evaluation of this understanding is the instruction manual that was delivered to the users, observing that the high level of specificity and technical language used in it hinders and confuses the reader and might discourage its further use. This category is linked to the amount and type of errors in which users may incur as a result of an inadequate understanding of the system; since the errors reported by most of these users are limited to details regarding the installation process, a positive understandability of the overall process can be assumed.

The attribute of **attractiveness** reflects an overall poor perception; the rain barrel is considered unattractive and also not very adaptable to the aesthetics or character of the houses at which it was installed. However, when asked what they liked most about the rain barrel as a designed object, the answers had a utilitarian tone; the fact that it allows for the collection of rainwater is granted a greater value than aesthetics and attractiveness themselves. This reinforces the argument that barrels represent an initial approach towards the widespread of sustainable ecotechnologies that allows a gradual establishment and growth of the system, offering the opportunity to progressively tend to their aesthetic attributes.

In broad terms, levels of **satisfaction** among users point to their contentment in terms of the decision they took in order to carry out a concrete action to tackle the sustainability issue at a domestic level through the acquisition of the rain barrel. However, some details and inconsistencies between the expectations formed in the user and the perception of what has been obtained, tend to have a negative impact on their sense of satisfaction. Disappointment is perceived in regard to installation defects and inconveniences such as the lack of a stable base, or to the difficulty to extract water due to the position of the nozzle. Interestingly, the size of the rain water barrel is perceived as small, based on the initial expectation of the users derived from photos that they had seen before.

Considering that the **efficiency** category refers to the usability attribute and does not deal with performance nor specific tasks, the evaluation results reflect an acceptable level according to users, leaving room for improvement in terms of technical details. An example of this is the location of the nozzle, which makes it impossible to place a bucket under it. Likewise, given the high subsidies and low tariffs, the economic savings in regard to regular water expenditure are not considerable; within this context, rain barrels are not likely to be qualified as objects of efficient use.

The results obtained depict areas of opportunity where it is not difficult to adjust and improve technical aspects of the rain barrel and its installation process. These do not necessarily involve user interaction with ecotechnology and therefore do not reflect usability problems, but rather adjustments required by any technological object that goes through an experimental stage. Irrespective of this, some users mentioned that they would be willing to recommend the collection of rainwater through this product, as long as the technical aspects mentioned above are taken care of. Despite being an eye-catching, strange, colorful object, which is placed (mostly) on the front of their houses, users reported that barrels spark little or no curiosity among neighbors and relatives.

12.9 RECOMMENDATIONS

The main challenges and opportunities that were detected throughout the development of this study can be summarized as follows.

(1) Education acts a key element for the development of an environmental awareness that involves taking care of water and rainwater collection as sustainable and environmentally friendly alternatives;
(2) Adjustments to the existing Mexican legislation in terms of water protection are required in order to regard it as a living cycle to be respected and taken care of in the urban and domestic environments;
(3) Provide economic incentives to the people that implement the Rainwater Collection System in their homes or businesses while enforcing its application in diverse scales and variations for new housing developments in order to promote the protection of the water cycle in Mexico;
(4) Promote institutional programs that enable the dissemination of the benefits obtained through the existing rainwater collection barrel model and the creation of fiscal incentives for those who implement it; and
(5) Encourage and support the design and development of new affordable and scalable alternatives for rainwater collection while including them as part of public environmental policies to be prioritized by the government.

These suggest that rain barrels are an appropriate option to introduce society to issues of responsible water consumption, rain collection and other topics related to sustainability and environmental care, as they have a level of usability that allows users to upgrade to more complex systems. As in any experimental stage, the rain water barrel case study, as a system, requires certain adjustments that go from quality control of the installation and of its components, to revising the contents of the user manual in order to avoid hindering its comprehension. Figure 12.4 shows the location of the rain water barrel in front of the family house that implemented it in Tonalá.

It is worth noting that people who have acquired this product manifest their individual interest to address environmental problems, which in turn reveals the construction of a type of idiosyncrasy that is posited in favor of the environment and natural resources, one that has found an echo in initiatives such as this. Likewise, a broad dissemination of the pertinence and benefits of the domestic installation of Rainwater Collection Systems is needed, since this suggests the emergence of a segment within society that, despite having already developed the motivation to take action towards sustainability in the urban habitat, find a lack or scarcity of options in the market.

Assuming that the attribute of usability is indispensable, albeit not the only one, for an ecotechnological designed object to successfully find its niche in society, especially in the domestic sphere, the results obtained so far are positive showing that the rain barrels are perceived as an easy- to-use system of low complexity, inexpensive and beneficial to the environment.

Figure 12.4 Family using rain water barrel. (*Source*: Authors, 2019).

REFERENCES

Alva M. (2005). Metodología de medición y evaluación de la usabilidad de sitios web educativos. Universidad de Oviedo, Oviedo, Spain.

CONAGUA. (2016). *Numeragua México 2016*. México: CONAGUA.

CONAGUA. (2018). Estadísticas del agua en México. Government of Mexico, Mexico.

España S. and Pederiva I. (2012). Evaluación de la Usabilidad en un entorno de Arquitecturas Orientadas a Modelos. Valencia. Retrieved on February, 2019 from http://personales.upv.es/jopana/Files/Conferences/Evaluacion_de_la_usabilidad.pdf.

FAO. (2013). Captación y almacenamiento de agua de lluvia. Opciones técnicas para la agricultura familiar en América Latina y el Caribe. Santiago de Chile. Retrieved February, 2019 from http://www.fao.org/docrep/019/i3247s/i3247s.pdf and http://www.fao.org/nr/water/aquastat/maps/World-Map.ww.cap_esp.htm.

Feng, P. (2000) Rethinking technology, revitalizing ethics: overcoming barriers to ethical design. *Science and Engineering Ethics*, **6**, 207–220.

Ferrari S. and Mariño S. (2014). Guía de evaluación de la usabilidad para herramientas de minería de datos. No Solo Usabilidad. Revista Sobre Personas, Diseño y Tecnología, **13**, 1–10. Retrieved February, 2019 from http://www.nosolousabilidad.com/ articulos/usabilidad_mineria_datos.htm.

Ferré-Grau X. (2001). Principios Básicos de Usabilidad para Ingenieros Software. V Jornadas Ingeniería de Software y Bases de Datos (JISBD 2000), Madrid, Spain.

Greenpeace. (2012). Ríos Tóxicos. Greenpeace, México.

INEGI. (2002). Anuario Estadístico Jalisco. Aguascalientes. Government of Mexico, Mexico.

IITAAC. (2019). http://www.iitaac.org.mx/proyectos/barriles/.

ISO. (1998). Ergonomic requirements for office work with visual display terminals, ISO 9241-11. ISO, Geneva, Switzerland.

Krishna H., Brown C., Gerston J. and Colley S. (2005). The Texas Manual on Rainwater Harvesting. Texas Water Development Board (Vol. 1), Austin. Retrieved July, 2019 from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+Texas+Manual+on+Rainwater+Harvesting#0.

Nielsen J. (1993). Usability Engineering. Morgan Kaufmann, San Francisco, USA.

Nielsen J. (2012). Usability 101: Introduction to Usability, https://www.nngroup.com/articles/usability-101-introduction-to-usability/ (Retrieved February 21, 2019).

Nielsen J. and Molich R. (1990). Heuristic evaluation of user interfaces. CHI ’90 Proceedings, (April), 249–256, http://doi.org/10.1145/97243.97281.

Norman D. (2013). The Design of Everyday Things. Basic Books, New Jersey, USA.

ONU-Agua. (2009). Guía sobre ONU-Agua. Retrieved February, 2019 from http://cenca.imta.mx/index.php?option=com_content&view=article&id=1844:guia-sobre-onu-agua&catid=89&Itemid=29.

ONU. (2010). Resolución aprobada por la Asamblea General el 28 de julio de 2010. Vol. **660**. ONU/United Nations, New York, USA.

Papanek V. (1977). Diseñar para el mundo real: ecología humana y cambio social. H. Blume Ediciones, Madrid, Spain.

Parsons G. (2015). The Philosophy of Design. Polity Press, Cambridge, UK.

Sarabia A. A. (1995). La teoría general de sistemas. Isdefe Ingenierìa de sistemas, Madrid, Spain.

Saravia M. H. (2006). Ergonomía de concepción. Su aplicación al diseño y otros procesos proyectuales: Editorial Pontificia Universidad Javeriana, Bogota, Colombia.

UNESCO. (2016). Informe de las Naciones Unidas sobre el Desarrollo de los Recursos Hídricos en el Mundo 2016: Agua y Empleo. Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura, París. Retrieved from http://unesdoc.unesco.org/images/0024/002441/244103s.pdf.

WWF. (2007). World's top 10 rivers at risk. World Wildlife Fund, Switzerland.