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Life Cycle Assessment of a Bitumen Anti-root Barrier on a Green Roof in the Mediterranean Area

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Abstract

The water resources management in urban areas requires the use of sustainable infrastructures. The new technologies, as the Best Management Practices (BMPs), are useful to reduce the impacts of Climate Change in urban areas (heat islands). The BMPs ensure the control of urban runoff, prediction-prevention, reduction of the urban heat islands and water quality control. Among the BMPs, green roofs also make a first treatment of the quality of rainwater. This feature increases the sustainability of this infrastructure. The sustainability concept requires the use of the absolute estimation techniques, to properly choose the infrastructure materials. Life Cycle Assessment (LCA) method has been considered a measure of the sustainability of a BMPs, because it provides a measure of sustainability before and after the operating phase. In this paper, LCA method is used to assess the environmental cost of a bitumen anti-root barrier on the green roof of a building at the University of Calabria (Southern Italy).

Keywords: Green roof, Life Cycle Assessment, Sustainability, Anti-root bitumen membrane

Introduction

To realize a sustainable structure, it is necessary to determine the impact of the project on the environment, the economy and the society. The environmental issues play a key role in social and urban development [1]. Sustainable development does not necessarily prejudice productive activity due to the economic balance linked to it; instead, it needs to protect natural resources and maximize the process effectiveness. There are many studies that promote the sustainable management of water resources through special methods that quantify the sustainability [2, 3, 4, 5, 6]. A valuable tool that estimates the sustainability is the Life Cycle Assessment (LCA) - a useful method to support decisions. LCA is an objective method that defines the ecological budget of a product or system, because it considers all product or system information linked to the life cycle. This analysis aims to identifying the most important characteristics of the product life phases from cradle to grave. Because the sustainability level of a product depends on the contribution of the extraction, processing, assembling, use and disposal phase. The LCA completes the evaluation of the sustainability of green roofs in water management in urban areas. Green roofs are vegetated systems that improve urban water system management [7], promote energy saving in buildings [8, 9], improve the city climatic conditions (heat island) [10] and protect urban ecosystem biodiversity [11, 12]. Comparing the quality of water discharged from the traditional roofs with the one from a green roof, it is possible to note a reduction of the concentration of pollutants [13] and heavy metals [14]. The purifying rain water treatment is conditioned by the choice of anti-root layer and the waterproofing of green roofs.

The application of the LCA method to green roofs also provides a long-term sustainability assessment and highlights the environmental potential of these low impact infrastructures by increasing their diffusion. Studying the sustainability of low impact infrastructures is useful to show that environmental impacts depend not only to the operational phase, but also on the complex life-cycle structure of the product and the materials that make up it. Material Sustainability Analysis allows choosing from alternative materials with better performance.

Main body / Methods

The University of Calabria is located in the southern Italy, near Cosenza (39°18¢ N, 16°15¢ E). The climate is Mediterranean, with a mean annual temperature of 15.5°C and an average annual precipitation of 881.2 mm. The green roof is part of the "Urban Hydraulic Park," which also includes a permeable pavement, a bioretention system and a sedimentation tank connected to a treatment unit. An extensive green roof was installed on the existing rooftop of the Department of Mechanical Engineering. The original impervious roof was divided into four sectors (Figure 1).

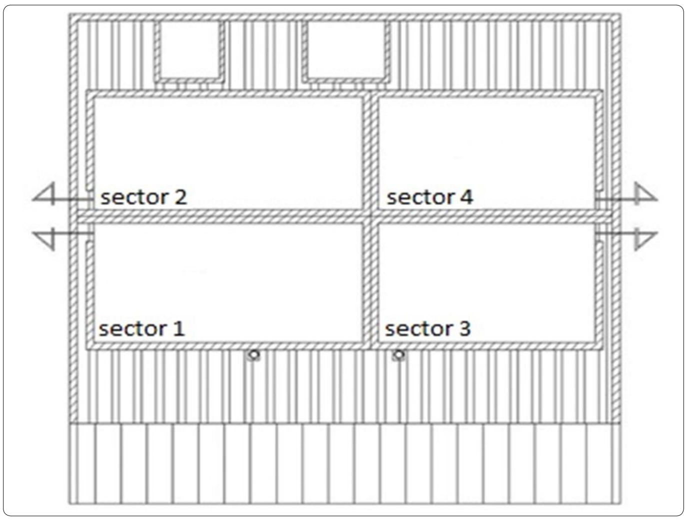

Figure 1. Green roof map - Rende (Italy)

Two sectors are vegetated with native plants and differ from each other by the drainage layer. Another sector is characterized by bare soil with only a few spontaneous plants. The last sector is the original impervious roof. The maximum depth of the soil substrate is 8 cm. This depth was selected to investigate both the energetic (heat fluxes) and the hydrologic (water fluxes) behavior of a very thin extensive green roof under the Mediterranean climate. The soil substrate is formed by mineral soil with 74% gravel, 22% sand, and 4% silt and clay. The soil has a measured bulk density of 0.86 g/cm^3 and 8% organic matter, which was determined in the laboratory using the Walkley–Black method. Three different plant species were selected and planted [15]. The green roof is divided into square elements of 50 by 50 cm with alternating vegetated and non-vegetated areas. In this study, only one vegetated sector – sector 1 - of the green roof was considered (Figure 2). To design a green roof, it is necessary to have chemical-mechanical conditions which prevent the water infiltration in the underlying layers and prevent the infiltration of roots. As a protective layer of anti-root waterproof sheath, a type of waterproof sheath made of bituminous material, supplied in rolls [16] was used. The bitumen was chosen as a test material for an initial LCA for structural and functional importance in the green roof and for the environmental cost of disposal which suggests having to counteract the aging processes. These processes cause an increase in management costs.

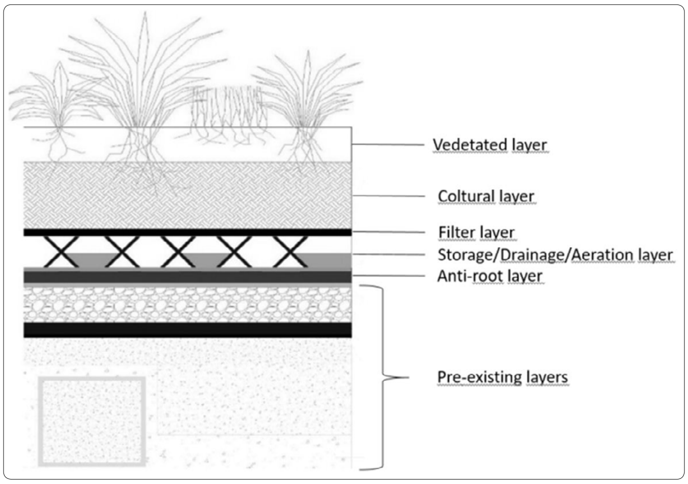

Figure 2. Sector 1 stratigraphy

To evaluate the product stability with the LCA method, it is necessary to evaluate the requests of water and energy linked to extraction techniques, production operations, transport and disposal. This analysis provides information on how each phase of the process affects the sustainability. The application of the LCA methodology consists of four steps, as specified in ISO 14040: objective and aim, inventory analysis, impacts assessment and improvement assessment.

The method structure related to the study case can be summarized as follows:

- goal - assessment of the impacts on the environment associated with the use of anti-root bituminous membranes on the green roof of the University of Calabria,
- system function - influence on the environmental factors of production, operation and disposal phases of bitumen membranes,
- functional unit – 1 kg of bitumen membrane,
- system boundaries - cradle to grave setting (excluding the extraction phase of raw materials, the analysis deepens of production, transportation, disposal stages),
- data quality - guaranteed by the experimental sites of the urban hydraulic park of University of Calabria with support Ecoinvent 3 database
- impact assessment - Impact 2002+ and ReCiPe Endpoints.

SimaPro 8.2.0 is a tool for the LCA application to bitumen in green roofs and is one of the most widely used software in Europe. SimaPro collects, analyzes and monitors the environmental performance of products according to ISO 14040-14044. SimaPro has been chosen for the ability to use Ecoinvent 3, which is one of the most used European databases containing extensive information about different types of bitumen in different life stages (production, operation and disposal). Estimating the sustainability of the anti-roof bitumen membrane is useful for quantifying lifecycle impacts and to delay its iteration caused by the aging process. Determining factors in the aging process of bitumen depend on the content of the mixture, the nature of aggregates, the particle size distribution, the temperature and time. All these factors operate together and accelerate the aging process [17]. Temperature is one of the most important parameters for oxidation processes: rheology studies showed an increase of the material to high temperature stiffness [18]. Mechanical and energy dissipation(stress) suffered by bitumen samples are temperature dependent [19]. Through nuclear magnetic resonance (NMR) experiments, it resulted that changes in the mechanical behaviour of pure and additive bitumen samples are temperature dependent.An additive presence allows quickly dissipating the energy transferred to sample. From the results of this study, it appears interesting to analyze bitumen with LCA. If the bitumen ages less rapidly, it protects the environment because it reduces the bad management of raw materials and emissions related to the production cycle. Bitumen contains compounds based on sulfur which may develop small amounts of toxic gaseous sulfur compounds such as hydrogen sulphide (H_2S). It is necessary to lengthen the useful life of the membrane by carefully managing phases before using. That requirement is backed by complex disposal techniques at the operating phase. It is therefore necessary to apply an LCA analysis of bituminous anti-root membrane.

Results and Discussion

We analyzed 1 kg of hot-worked adhesive bitumen membrane, by means of SimaPro 8.2.0. The impact assessment histograms obtained by applying the ReCiPe Endpoint method and Impact 2002+ method (are shown in Figure 3 and Figure 4 respectively). In both cases it is evident that the damage category that has a greater weight in the process is Resources, linked to the extraction processes of the raw materials and to the use of energy sources that are not clean. This analysis made it clear that CO_2 is the most important emission. The results are confirmed by comparisons between the ReCiPe Endpoint method and the Impact 2002+ method. It is clear that the largest impact related to the management of natural resources does not match the objectives of BMPs as a green roof.

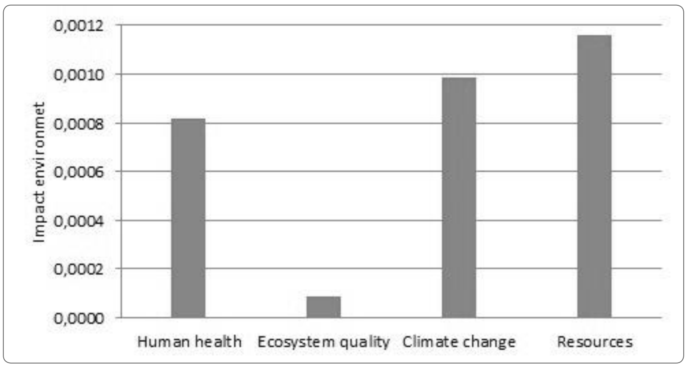

Figure 3. Impact assessment with Impact 2002+ method

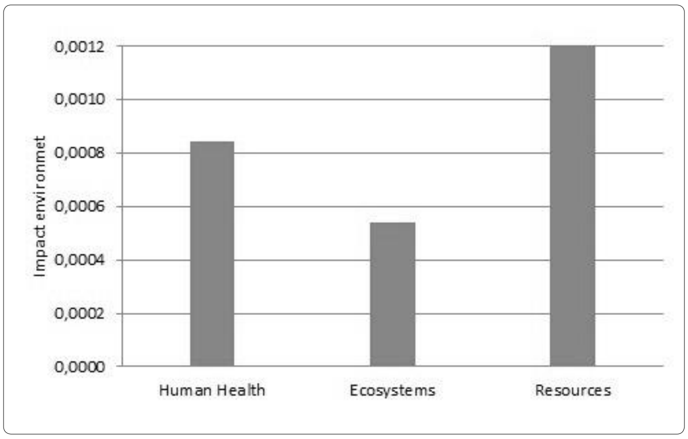

Figure 4. Impact assessment with ReCiPe Endpoint method

This result represents the ecological cost of this process. In the scientific literature there are different methods to calculate the ecological cost [20, 21, 22], which, in general, obey to the traditional laws of physical system conservation [23].

Conclusion

The use of sustainable BMPs infrastructures contributes to the water resources management in urban areas. Among the BMP, green roofs also provides a first treatment on the quality of rainwater. This feature increases the sustainability of this infrastructure. To carry out a measure of the sustainability of a BMP before and after the operating phase, the Life Cycle Assessment (LCA) method was used. This LCA method was used to assess the environmental cost of a bituminous anti-root barrier on the green roof of a building in the University of Calabria (Southern Italy). This analysis shows that, related to the specific use of bituminous membrane as anti-root membrane on the case study, the impact associated to the Resources category is not negligible. The CO_2 emission, furthermore, contrast one of the primary functions required for this type of low impact infrastructure (reduce the impacts of Climate Change in urban areas).To limit environmental costs, related mainly to CO_2 emissions, it is necessary to use bitumen with additives to counteract the aging process in order to avoid the premature replacement of the anti-root membrane and the iteration of its production cycle.

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References

1. Pirani E, Secondi L. Eco-friendly attitudes: What European citizens say and what they do. *Int J Env Res*. 2010; 5(1): 67-84. doi: 10.22059/IJER.2010.292
2. Maiolo M, Martirano G, Morrone P, Pantusa D. A Sustainability Synthetic Territorial Index (ISST) to assess the sustainable management of water resources. 3rd Dubrovnik Conference of Sustainable Development of Energy, Water and Environment Systems, Dubrovnik, Croatia 5-10 June. 2005.
3. Maiolo M, Martirano G, Morrone P, Pantusa D. Assessment criteria for a sustainable management of water resources. *Water Practice & Technology*. 2006; 1(1): wpt2006012. doi: 10.2166/wpt.2006.012
4. Maiolo M, Pantusa D. A methodological proposal for the evaluation of potable water use risk. *Water Practice & Technology*. 2015; 10: 152-163 doi: 10.2166/wpt.2015.017
5. Maiolo M, Pantusa D. An optimization procedure for the sustainable management of water resource. *Water Science & Technology: Water Supply*. 2016.
6. Maiolo M, Pantusa D. A proposal for multiple reuse of urban wastewater. *Journal of Water Reuse and Desalination*. 2017; 7(4): jwrd2017144. doi: 10.2166/wrd.2017.144
7. Mentens J, Raes D, Hermy M. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century. *Landsc. Urban Plan*. 2006; 77: 217–226. doi: 10.1016/j.landurbplan.2005.02.010
8. Bevilacqua P, Mazzeo D, Bruno R, Arcuri N. Experimental investigation of the thermal performances of an extensive green roof in the Mediterranean area. *Energy and Buildings*. 2016; 122: 63-79. doi: 10.1016/j.enbuild.2016.03.062
9. Nyuk Hien W, Puay Yok T, Yu C. Study of thermal performance of extensive rooftop greenery systems in the tropical climate. *Building Environment*. 2007; 42(1): 25-54. doi: 10.1016/j.buildenv.2005.07.030
10. Schmidt M. The interaction between water and energy of greened roofs, World Green Roof Congress, Basilea. 2005.
11. Celli G, Maini S, Corazza, Campanini L. Siepi e spazi naturali: colonizzazione, dinamica delle popolazioni di fitofagi e insetti utili e interazioni con le aree coltivate. C.E.R.A.S. Annali 1995. Supplemento a Innovazione e sperimentazione, Iniziative editoriale s.a.s. Castel S. Pietro Terme, (BO). 1996; 5(6): 327-337.
12. Piro P, Carbone M, Nigro G, Garofalo G. Il Parco di Idraulica Urbana: Installazioni sperimentali e infrastrutture tradizionali per studiare tecniche innovative, Servizi a Rete. 2014; 5: 39-42.
13. Berndtsson JC, Emilsson T, Bengtsson L. The influence of extensive vegetated roofs on runoff water quality. *Sci. Total Environ*. 2006; 355 (1-3): 48-63. doi: 10.1016/j.scitotenv.2005.02.035
14. Steusloff S. Input and output of airborn aggressive substances on green roofs. *Urban Ecology*. 1998; 144-48. doi: 10.1007/978-3-642-88583-9_24
15. Brunetti G, Šimůnek J, P Piro. A Comprehensive Analysis of the Variably Saturated Hydraulic Behavior of a Green Roof in a Mediterranean Climate. *Vadose Zone Journal*. 2016; 15(9). doi: 10.2136/vzj2016.04.0032
16. Piro P, Carbone M, Nigro G, Garofalo G, Ferrante A. Installazione di un modello sperimentale a verde pensile per la valutazione dell'influenza del sistema sulla gestione delle acque meteoriche in area mediterranea - 34° Corso di aggiornamento in "tecniche per la difesa dall'inquinamento". Edibios. 2013.
17. Lu X, Isacsson U. Effect of ageing on bitumen chemistry and rheology. *Construction and Building Materials*. 2002; 16(1): 15-22. doi: 10.1016/S0950-0618(01)00033-2
18. Saoula S, Soudani K, Haddadi S, Munoz ME, Stantamaria A. Analysis of the Rheological Behavior of Aging Bitumen and Preticting the Risk of Permanent Defonation of Asphalt. Materials Sciences and Application. 2013.
19. Filippelli L, Oliviero Rossi C, Carini M, Chiaravalloti F, Gentile L. Structural Characterization of Bitumen System by Prony-Like Method Applied to NMR and Rheological Relaxation Data. *Mol. Cryst. Liq. Cryst*. 2013; 572(1): 50-58. doi: 10.1080/15421406.2012.763210
20. Finnveden G, Östlund P. Exergies of natural resources in life-cycle assessment and other applications. Energy. 1997; 22(9): 923-931. doi: 10.1016/S0360-5442(97)00022-4
21. Szargut J, Ziębik A, Stanek W. Depletion of the non-renewable natural energy resources as a measure of the ecological cost. *Energy Conversion and Management*. 2002; 43(9): 1149-1163.
22. Shafiepour Motlagh M, Ashrafi K, Dalir F. LCA Frameworks integration in Carbon Footprint Modeling of Simple Cycle and Combined Cycle Power Plant for Sustainable Planning in Iran. *Int J Env Res*. 2016; 10(4): 645-654. doi: 10.22059/IJER.2016.59969
23. Carini M, Fatibene L, Francaviglia M. Covariantenergy in mechanics. *International Journal of Geometric Methods in Modern Physics*. 2007; 4(6): 907-918. doi: 10.1142/S0219887807002375