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PROCEEDINGS

The Capital Region of Denmark

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HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

ATV JORD OG GRUNDVAND

Deltares Enabling Delta Life

Topic	Last name	First name	Authors	Title	Form of presentation
1A.6	Toernqvist Font	Malene	Malene Toernqvist Front, Charlotte Riis, Anders G. Christensen, Nancy Hamburger, Peder Johansen, Lone Tolstrup Karlby	Delineation of contaminant plumes using Low-Level MIHPT (LL-MIHPT)	Lecture
1A.4	Deus	Nico	Nico Deus, Jörg Elbracht, Bernhard Siemon	3D-Modelling of the salt-/fresh water interface in coastal aquifers of Lower Saxony (Germany) based on airborne electromagnetic measurements (HEM)	Lecture
1A.5	Falkenberg	Jacqueline Anne	Jacqueline Anne Falkenberg, Mette Marie Mygind, Anne Mette Bräuner Lindof, Jette Kjøge Olsen, Jens Dengsø Jensen, Anders G. Christensen	Screening for Fluorinated Compounds (PFAS) around Potential Sources of Pollution at Danish Defence Establishments	Lecture
1A	Simone	Laura	Laura Simone, Thomas Held	"Multiple-lines-of-evidence" approach applied to Assessment of Residual Dense Non-Aqueous Phase Liquid (DNAPL)	Poster
1A	Ancilletta	Antonio	Ezio Crestaz, Antonio Ancilletta, Leonardo Patata, Michele Pellegrini, Felice Tatangelo, Stefano Isidori	Groundwater flow and transport modelling aimed at an exploratory spatial data analysis of Ust-Kamenogorsk aquifer system, East Kazakhstan	Poster
1A	Coetsiers	Marleen	Marleen Coetsiers, Pieterjan Callewaert, Michele Remonti	Groundwater flow and transport modelling as a tool for developing and evaluating remedial actions – case study of a complex groundwater contamination	Poster
1A	Oliva	Andresa	Andresa Oliva, Marcus Baessa, Elias Isler, Marco Pede, Hung Kiang Chang	Optimizing of The Characterization of NAPL Contaminated Site Using Ultra-Violet Optical Screening Tool and Geophysical Survey	Poster
1A	Larsen	Lars Christian	Lars Christian Larsen, Peder Johansen	Tracing an extensive MtBE plume in a sandy aquifer trying to escape monitoring wells using thorough hydrogeological site understanding	Poster
1A	Lobo	M.Carmen	M. Mar Gil-Diaz, Ana M. Guerrero, M.Carmen Lobo	Monitoring of the doramectin diffusion into soil amended with pig manure	Poster
1A	Teasdale	Christopher	Christopher Teasdale, Jean Hall, John Martin, David Manning	Ground Gas Monitoring: Examining Spatial Trends on Short and Long Temporal Scales	Poster
1A	Riis	Charlotte	Charlotte Riis, Gro Lilbaek, Anders G. Christensen, Mikael Joergensen, Martin Stærmose	Detailed Hydrogeological Characterization of a Soft Chalk Aquifer through HPT-Logging and Coring	Poster
1A	Shoari	Niloofar	Niloofar Shoari, Jean-Sebastien Dubé, Shoja'eddin Chenouri	Statistical distribution of left-censored concentration data – Example from a soil characterization study in Montreal	Poster
1A	Kaman	Harun	Harun Kaman, Mahmut Çetin, Cevat Kırda	Determination of salt budget for large irrigated areas	Poster
1A	Kaman	Harun	Harun Kaman, Abdullah Sayıcı, Assist. Selçuk Özmen	Determination of irrigation water salinity: a case study	Poster
1A	Kaman	Harun	Harun Kaman, Selçuk Özmen, Hasan Çetin, Abdullah Sayıcı	Investigation of irrigation waters qualities in Antalya-Kumluca region, Turkey	Poster
1A	Kozubek	Petr	Petr Kozubek	Variability in Groundwater: Natural Attenuation Rate vs. Short-Term Fluctuations	Poster
1A	Fiúza	António	Maria de Lurdes Dinis, Joaquim Góis, António Fiúza, José Soeiro Carvalho, Ana Cristina Meira Castro	Fate of Hazardous Elements in Soils Surrounding a Coal-Fired Power Plant Complex	Poster
1A	Volpe	Angela	Angela Volpe, Michele Pagano, Paola Grenni, Anna Barra Caracciolo, Giuseppe Mascolo, Simona Rossetti	Biological degradation of UV-filters in marine sediments: a laboratory microcosm study.	Poster
1A	Takala	Mikael	Mikael Takala, Jenni Takala	Best Available Technique for Surface Water Discharge Monitoring at Finnish Outdoor Shooting Ranges	Poster
1A	Zakariadze	Nino	Nino Zakariadze	Preparation of Medical Geology Atlas	Poster
1A	de Jonge	Hubert	Hubert de Jonge, Lone Tolstrup Karlby, Nanna Muchitsch, Mads Terkelsen	A novel passive sampling approach for in-situ measurement of groundwater- and organic pollutant fluxes: conceptual approach and cases from the Capital Region of Denmark	Poster
1B.5S	Møller	Mads Georg	Tage Vikjær Bote, Per Loll, Thomas Larsen, Bjarke Hoffmark, Arne Rokkjær, Mads Georg Møller	Vapor intrusion - state of the art	Free Session Proposal
1B.6	Wagelmans	Marlea	Marlea Wagelmans	Protocols for ecological risk assessment	Lecture
1B.7	Ramakers	Peter	Peter Ramakers, Joost Van Schijndel, Gerard Borggreve	Residential location contaminated with cumene: building team construction results in a successful (in-situ) remediation	Lecture
1B.9	Frogner-Kockum	Paul	Paul Frogner-Kockum, Märta Ländell, Gunnel Göransson, Yvonne Ohlsson	Quantification of contaminant transport from sediment	Lecture
1B.9	Otte	Piet	Piet Otte, Martin Schans, Martin Meerkerk, Frank Swartjes	Assessment of risks caused by the permeation of organic contaminants in groundwater through polyethylene drinking water pipes	Lecture
1B.10	Leroi	Steve	Steve Leroi, Adrien Kahn	an approach to Risk assessment and management of contaminated land in Asia	Lecture
1B.8	Provoost	Jeroen	Jeroen Provoost, Jan Bronders, Ilse Van Keer	Probabilistic risk assessment for six vapour intrusion algorithms	Lecture
1B.8	Provoost	Jeroen	Jeroen Provoost, Karen Victor	New concepts in vapour intrusion	Lecture
1B	Ahn	Joo Sung	Joo Sung Ahn, Sang-Woo Ji, Yong-Chan Cho, Seung-Jun Youm, Gil-Jae Yim	Predicting the occurrence of acid rock drainage through a geochemical stream sediment survey	Poster
1B	Cornelis	Christa	Christa Cornelis, Mirja Van Holderbeke, Ann Colles, Griet Van Gestel	Contaminant intake from eggs of backyard chicken: what are safe soil concentrations?	Poster
1B	Steen	Jesper Alroe	Jesper Alroe Steen, Maren Hostrup, Mette Marie Mygind, Boerge Hansen, Henrik Soegaard Larsen, Jacqueline Anne Falkenberg	Occurence of antimony in soil and groundwater at former shooting ranges	Poster
1B	Pease	Camilla	Camilla Pease, Jennifer Gill, David Schofield, Matt Pannett, Andrew Goddard	Recent Advances in Human Health Toxicology of Trichloroethylene (TCE) and its Application in Soil Screening Criteria	Poster
1C.23S	Bardos	Paul	Paul Bardos, Juergen Braun, Miroslav Černík, Daniel Elliott, Elsa Limasset, Hans-Peter Koschitzky	Nanoremediation - all you wanted to know (a practical guide to nanoremediation)	Free Session Proposal
1C.24S	Bartke	Stephan	Paul Bardos, Stephan Bartke, Nicola Harries, Hans-Peter Koschitzky	Nanoremediation - your future business opportunities (strategic and market intelligence)	Free Session Proposal
1C.12	Verbeeck	Mattias	Mattias Verbeeck, Richard Lookman, Johan Gemoets, Beatrijs Lambié	In-situ Zinc Bioprecipitation through Organic Substrate Injection in a High-flow Aquifer: From Laboratory to Full-scale	Lecture
1C.2	Bewley	Richard	Richard Bewley, Rick Parkman, Paul Bardos, Marcus van Zutphen, Jonathan Smith	The Regulatory Basis for Sustainable Remediation Practice in the European Union and United Kingdom	Lecture
1C.3	Patek	Regine	Regine Patek	Public Funding scheme for Remediation Projects in Austria	Lecture
1C.15	Maalouf	George Y.	George Y. Maalouf	Accelerating Trichloroethylene Remediation in Saprolite and Fractured Crystalline Bedrock by In-situ Chemical Oxidation and In-situ Chemical Reduction - a Successful Case Study of Combined Remedies at a Challenging Site	Lecture
1C.19	Pensaert	Stany	Stany Pensaert	Environmental dredging of a chromium contaminated fjord in Valdemarsvik, Sweden.	Lecture
1C.7	Birnstingl	Jeremy	Jeremy Birnstingl	Combined Remedy Synergies – Examples and Conceptual Road Map	Lecture
1C.9	Schmidt	Kathrin Rachel	Kathrin Rachel Schmidt, Sarah Gaza, Andreas Tiehm	Aerobic biodegradation of trichloroethene without auxiliary substrates	Lecture
1C.20	Kowalski	Krzysztof	Krzysztof Kowalski, Sanne Skov Nielsen, Pernille Erland Jensen, Thomas Larsen, Mads Terkelsen, Lisbeth Ottosen	Challenges and hopes for scaling up an electrodialytic remediation method for treating CCA contaminated soil	Lecture
1C.12	Riis	Charlotte	Charlotte Riis, Martin Bymose, Dorte Pade, Evan Cox, James Wang, David Gent, Mads Terkelsen	Full-Scale Electrokinetics-Enhanced Bioremediation (EK-BIO) of PCE DNAPL Source Area in Clay Till	Lecture
1C.17	Baciocchi	Renato	Daniela Zingaretti, Iason Verginelli, Renato Baciocchi	Combined Fenton-like oxidation and CO2 sparging for the treatment of groundwater contaminated by organic compounds	Lecture
1C.10	Borggreve	Gerard	Gerard Borggreve, Albert Smits, Dennis Scheper, Adri Nipshagen, Rene Tjassens, Michiel Pluim	Fully Automated Enhanced Biodegradation of Chlorinated Ethenes with an On Site Anaerobic Bioreactor	Lecture
1C.17	Smits	Albert	Albert Smits, Gerard Borggreve, Dennis Scheper, Mart Jansen, Michael Mueller	The Advantage of Bench Scale Treatablity Studies as a Decision Making Tool for a Full Scale Isco Approach in an Innovative Tender Procedure	Lecture
1C.22	Gammeltoft Hindrichsen	Anne	Anne Gammeltoft Hindrichsen, John Ulrik Bastrup, Jan Slunský	Batchtests and field application of in situ remediation of groundwater contaminated with chlorinated solvents by direct injection of nanoscale Zero Valent Iron on three locations in Denmark.	Lecture
1C.10	Rodrigues	Romain	Romain Rodrigues, Stéphanie Betelu, Frédéric Garnier, Stéfan Colombano, Antoine Joubert, David Cazaux, Guillaume Masselot, Theodore Tzedakis, Ioannis Ignatiadis	SILPHES – Investigation of chemical treatments for the remediation of recalcitrant chlorinated solvents	Lecture
1C.7	Villarroya	Fermín	Fermín Villarroya, Esperanza Montero, Juan Pedro Martín	Pollution of soil and groundwater by industrial oils dumping in Jarama River Basin (Madrid, Spain)	Lecture
1C.16	Lookman	Richard	Edward van de Ven, Art Lobs, Tim De Bouw, Richard Lookman	Implementing In-situ Chemical Oxidation on an industrial EX-rated site	Lecture
1C.7	Beaulieu	Michel	Michel Beaulieu	Lac Megantic : The rehabilitation of a town following a petroleum loaded train explosion	Lecture
1C.9	Bewley	Richard	Richard Bewley, Paula Hick, Anthea Rawcliffe	Meeting the challenges for bioremediation of chlorinated solvents posed at operational sites: a comparison of case studies	Lecture

Topic	Last name	First name	Authors	Title	Form of presentation
1C.8	Lilbaek	Gro	Gro Lilbaek, Jacqueline Anne Falkenberg, Anders G. Christensen, Helle Overgaard	Estimation of Remediation Rates for Chlorinated Solvents in Confined Unsaturated Media	Lecture
1C.3	Nathanail	C. Paul	C. Paul Nathanail	Progress towards an ISO Document on Sustainable Remediation	Lecture
1C.2	Rizzo	Erika	Filip Alexandrescu, Erika Rizzo, Lisa Pizzol, Andrea Critto	Building a Network-based Expert-Stakeholder Framework for Sustainable Regeneration	Lecture
1C.14	Kozubek	Petr	Petr Kozubek, Jan Nemecek, Vladislav Knytl, Eliska Kosinova	DNAPL treated by application of surfactants followed by ISCO	Lecture
1C.21	Taylor-King	Christopher	Christopher Taylor-King	Surfactant Enhanced Aquifer Restoration at Former Chemical Works	Lecture
1C.7	Bastrup	John Ulrik	John Ulrik Bastrup, Jie Cheng, Daniel Chiang	Remediation in China	Lecture
1C.22	Tsakiroglou	Christos	Christos Tsakiroglou, MSc Katerina Terzi, Alexandra Sikinioti-Lock, Kata Hajdu, Christos Aggelopoulos	Optimizing the properties of nanofluids for the efficient NAPL remediation in porous media	Lecture
1C.27	Trötschler	Oliver	Oliver Trötschler, Hans-Peter Koschitzky, Bernd Lidola, Isabell Kleeberg, Stefan Schulze	Steam-Air Injection in Fractured Bedrock: Results and Lessons Learned of a CHC-Remediation At The Site Biswurm (Villingen-Schwenningen, Germany)	Lecture
1C.27	Hiester	Uwe	Uwe Hiester, Martina Müller	Complex boundary conditions for in-situ thermal treatments (ISTT) conducted during land recycling and remediation beneath buildings	Lecture
1C	Wagelmans	Marlea	Marlea Wagelmans, Niels van Ras	Use sediments for economically viable groundwater pollution management	Poster
1C	de Folly d'Auris	Alessandra	Alessandra de Folly d'Auris, Marco Tagliabue, Roberto Bagatin	Thermal desorption technology: two case studies	Poster
1C	Henssen	Maurice	Marlea Wagelmans, Anneke Roosma, Maurice Henssen	Successfully stimulated biological in situ remediation VOC contaminated source zones	Poster
1C	Furukawa	Yasuhide	Yasuhide Furukawa, Tetsuo Yasutaka, Takashi Kobayashi, Takaaki Shimizu	A case study of five options for sustainable in situ remediation of contaminated soil	Poster
1C	Kurashvili	Maritsa	Maritsa Kurashvili, Tamar Varazi, Marina Pruidze, Gia Khatisashvili	Model testing of new approach for cleaning soils polluted with organochlorine pesticides	Poster
1C	Stavelova	Monika	Monika Stavelova, Iva Dolinova, Maria Brennerova	Enhanced Reductive Dehalogenation of Chloroetenes by Application of Cheese Whey in Situ: a Case Study with Field, Chemical and Molecular Biology Analysis	Poster
1C	Escolano	Olga	Susana Del Reino Querencia, Olga Escolano, Manuel Rodriguez Rastrero, Jorge Bueno, Roció Millán	ISCO application in a saltmarsh area contaminated by fuel in southern Spain (BIOXISOIL project)	Poster
1C	Varazi	Tamar	Tamar Varazi, Maritsa Kurashvili, Marina Pruidze, Gia Khatisashvili, George Adamia, Nino Gagelidze, Marlen Gordeziani, George Zaalishvili, Mark Sutton	Different Tools to Avoid Deep Contamination and to Improve Phytoremediation Technology	Poster
1C	Martí	Vicenç	Vicenç Martí, Nuria Royo, Oriol Gibert, Cesar Alberto Valderrama, Maria Rosario Martínez, David Ribas, Irene Jubany	Denitrification capacity of leachates from wetland soils and vegetal biomass in the Llobregat river basin	Poster
1C	Lobo	M.Carmen	Dr M. Mar Gil-Diaz, Dr Agueda González , Juan Alonso, Paloma Pinilla, M.Carmen Lobo	Immobilization of Cr in soil using stabilized nanoscale zero-valent iron. Impact on barley plants.	Poster
1C	Canova	Fabio	Andrea Amantia, MSc Giacomo Donini, Msc Environmental Carlos Herrarte , Fabio Canova	Phyto Groundwater Containment in a Large Polluted Site in Southern Italy	Poster
1C	Jez	Erika	Domen Lestan, Erika Jez, Neza Finzgar	Remediation of toxic metals contaminated soil using EDTA soil washing	Poster
1C	Otaegi	Nerea	Nerea Otaegi, Ekain Cagigal, Miroslav Černík, Jan Slunský, Julian Bosch	Testing on emerging Nanoparticles for Arsenic removal under real conditions on a pilot field site, in Asturias, Spain	Poster
1C	Chang	YiKuo	YiKuo Chang, Cheng-Di Dong, Chiu-Wen Chen, Chih-Feng Chen, Zhen-Wei Hong, Yi-Liang Shu, Chia-Ying Li	Application of hydrocyclone separation system for contaminated soil treatment and flow simulation	Poster
1C	LION	Fabien	Fabien LION, Nicolas Aubert, Geoffrey Boissard, Stéfan Colombano	French national approach for delineation of contaminant source zones: combining mass-balance, mass-flux and mass-discharge methods	Poster
1C	Aranda	Elisabet	Patricia Godoy, MSc Andrea Calderón, Student Angela López-Eugenio, Student Rocío Reina, Research Scientist Inmaculada García-Romera, Elisabet Aranda	Isolation and Identification of Cultivable Anthracene Degrading Fungi from PAH Contaminated Soils for their Application in Phytoremediation	Poster
1C	Najmanová	Petra	Petra Najmanová, Ondřej Lhotský, Vladislav Knytl, Jan Slunský, Jan Filip	Removal of hexavalent chromium by application of nZVI NANOFER STAR	Poster
1C	Dastoli	Sara	Sara Dastoli, Elena Romano, Alessandra Polettini, Raffaella Pomi, Giorgia de Gioannis, Maurizio Morelli, Aldo Muntoni, Roberto Peretti, Antonello Serci, Barbara Villani, Antonello Zucca	Coordinated approach for treatment of dredged sediment from small harbours	Poster
1C	Georgi	Anett	Anett Georgi, Glenn Gillies, Katrin Mackenzie, Frank-Dieter Kopinke	Colloidal Fe-zeolites - a novel material for sorption-supported in-situ chemical oxidation (ISCO)	Poster
1C	Lobo	M.C.	A.E. Pradas del Real, M.C. Lobo, A. Pérez-Sanz	Plant response of chromium tolerant and sensitive clones of Silene vulgaris affects rhizosphere bacterial communities	Poster
1C	Machado	Susana	Susana Machado, João Pacheco, José Tomás Albergaria, Cristina Delerue-Matos	Remediation of water and soil contaminated with Amoxicillin using green zero valent iron nanoparticles	Poster
1C	Gungor	Burcu Ozkaraova	Burcu Ozkaraova Gungor, Ayse Kuleyin, Feryal Akbal, M. Oya Orkun, Dilek Gümüş	Fenton Process for The Purification of Polluted Waters	Poster
1C	Agut	Adeline	Adeline Agut	Adsorption-based technologies for innovative, sustainable & onsite hydrocarbon remediation	Poster
1D.2	Mars	Jan Frank	Jan Frank Mars, Peter Ramakers, Reinder Slager	Flowers 4 Brabant	Lecture
1D.3	Wagelmans	Marlea	Janneke Wittebol, Marlea Wagelmans	Biological treatment of micropollutants in drinking water resources	Lecture
1D.2	Koot	Corinne	Corinne Koot, Annemiek Wiegman, Reinder Slager, BSc Martijn van Houten	Regionally approached groundwater management in Zwolle: preventing risks and utilizing opportunities	Lecture
1D.2	Vasin	Sandra	Sandra Vasin, Hermann Josef Kirchholtes	A Groundwater Management Plan for Stuttgart	Lecture
1D.3	Weingran	Christian	Christian Weingran, H. Georg Meiners	How to get a camel to go through the eye of a needle: Successful site remediation of a former explosives production site: safe housing, working and drinking water production on a long-term basis	Lecture
1D.2	Alphenaar	Arne	Arne Alphenaar, Frank Swartjes, Piet Otte, Reinder Slager	Success and failure factors area-wide groundwater management	Lecture
2.3S	Gadella	Michiel	Michiel Gadella, Co Molenaar	The Final Countdown - "Successful remediation policies leads to the end of the Dutch Soil Protection Act"	Lecture
2.5	Wortelboer	Rob	Rob Wortelboer	Contaminated Sludge Beneficially Used in Foundations	Lecture
2.4	Scheper	Dennis	Dennis Scheper, Gerard Borggreve, Albert Smits, Adri Nipshagen, Dick Specht, Luuk Wallinga	What Can You Do for One and a Half Million - Urban Redevelopment Through Implementation of New Technology	Lecture
2.6	Lauwerijssen	Chiel	Chiel Lauwerijssen	Using innovative geotextile constructions as an in-situ bioremediation technique to remediate contaminated sediments and to improve water quality of shallow lakes	Lecture
2.5	Dedecker	Dirk	Dirk Dedecker, Ir Filip De Naeyer, Lic. Eddy Van Dyck	Flemish policy on the use of excavated soil	Lecture
2.6	Dickinson	Claire	Claire Dickinson, Hilary Allen	The Circular Economy – Maximising the Reuse of Soils – Making it happen	Lecture
2	Günes	Adem	Adem Günes, Nurgul Kıtır, Metin Turan, Fikrettin Sahin, Medine Gulluce, Prof.Güleray Ağar, Hatice Öğütçü	Effects of Plant Growth Promoting Microorganisms on Wheat Plant Growth and Amino Acid Content	Poster
2	Feigl	Viktoria	Viktoria Feigl, Mónika Molnár, Eva Ujaczki, Orsolya Klebercz, Ildikó Fekete-Kertész, Mária Tolner, Emese Vaszita, Katalin Gruiz	Ecotoxicity of biochars from organic wastes focusing on their use as soil ameliorant	Poster
3.4	Romijn	Reinier	Reinier Romijn, Almer Bolman	Let's make groundwater STRONGer – a watersystem-based approach towards 3D spatial development.	Lecture
3.4	Knudsen	Theis	Theis Knudsen, Christian Helweg, Lars Jacobsen	Aquifer Thermal Energy Systems in areas of drinking water and groundwater pollutions	Lecture
3.5	Lijzen	Johannes P.A.	Johannes P.A. Lijzen, drs. Sophie Vermooten, Hans Peter Broers, Suzanne van der Meulen, Michiel Rutgers	Ecosystem services of the groundwater and the subsurface; filling the knowledge gap	Lecture
3	Mars	Jan Frank	Jan Frank Mars, Linda Maring, Albert de Vries	Towards a sustainable and resilient city	Poster
3	Nathanail	C. Paul	C. Paul Nathanail, Matthew Ashmore	The HOMBRE BR2: Brownfield REMIT/RESPONSE for modelling the urban subsurface system	Poster
4	Berto	Raul	Edino Valcovich, Carlo Antonio Stival, Raul Berto, Giovanni Cechet	Green roofs technological analysis according to a performance-based approach	Poster
Open Topic	Wilson	James	James Wilson, Claus Ølund	Application of Trap & Treat™ Technology for Achieving Sustainable Remediation of Contrasting Contaminant Plumes	

Theme 4 - The role of the subsurface in climate change adaptation

GREEN ROOFS TECHNOLOGICAL ANALYSIS ACCORDING TO A PERFORMANCE-BASED APPROACH

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KEYWORDS

green roof, energy performance, upper horizontal closures, roofing

INTRODUCTION

This paper is the result of a research carried out by a workgroup coordinated by prof. Paolo Rosato and prof. Edino Valcovich and composed by PhD eng. Raul Berto, eng. Giovanni Cechet and PhD eng. Carlo Antonio Stival. The Research Fund of the Trieste University (FRA 2012) grants this research project.
The decision to develop the topic of green roofs is born from the recognition these solutions as an expression of the sustainability concept. A complete development of this topic is complex, in fact is

more frequently to treat separately the different aspects of sustainability, studying individually a solution, an idea, a system as an expression of it. The green roofs produce effects in the environmental, technological, social and economic spheres, so it is possible to analyse each of these effects in accordance with a comprehensive vision.
The scientific production, that is about the green roofs topic, reveals the excellence of these solutions according to the various aspects debated. However, based on the idea that in this historical moment is very important to increase the value of the existing buildings, we realized the need to evaluate the potential implementation of these kinds of top closures on existing buildings. For this reason, insights on the technological aspects developed with this main goal.

1. STATE OF ART

The overall performance offered by green roof solutions are still under discussion: the variety of effects brought from greening the top covers of buildings in different areas of performance, and the difficult in scientific proof of such effects, make complex the measurement of these effects in order to demonstrate the environmental, social and economical advantage.
However, in scientific research, is a widespread belief that the green roof technologies really increase the users' well-being, in particular because the compensation between the green surface positioned over the roofing and the natural ground replaced by buildings is consider how a positive effects.
In recent decades, the need to reduce negative effects generated by ground anthropization and increasing of energy consumption related to the technical services of the buildings, has led to the implementation in building envelopes of technical and architectural forms tipically of natural environments. We can speak, in different scene, of *Green Architecture* and *Green Technology*.
With Green Architecture meaning the inclusion of specific planning strategies – from urban scale to building shell – of technical elements able to reduce energy consumption from non-renewable energy sources, emissions of carbon dioxide in atmosphere and environmental impacts in general, the last ones descend from using of determinates construction materials.
With *Green Technology*, instead, we consider the mitigation of architectural and aesthetic impact. In particular, we consider the beneficial effects of some design solutions on technological scale, using, for example, an actual version of vernacular architecture, turning this one into an integration of build volume in a context of high natural connotation.
Greenery establishes the path to restore – at least in part – the natural value of original environmental system in particular location, allowing camouflage of constructions, as a valid alternative to hypogeum buildings. The continuity of green surface, compared with natural ground, can create specific habitat for plants and small animals.

2. METODOLOGY

Evaluating of the potential in relation to place a green roof in a new building or to implement it in an existing construction, as replacement or as an integration of the previous coverage, this is the matter of this research work and it is handled in this scientific paper.

In particular, the performances have been analized in terms of contribution to contain energy consumption, to control local microclimate and regimentation of rainwater. Also evaluating the possibility to install green roof over existing building from a structural point of view: outlining critical issues, describing relationship with the Italian legislation concerning construction and, finally, proposing a critical analysis in relations to the most common building typologies on the Italian territory.

3. RESULTS

As part of an assessment of the energy performance, a solution of green roof is a highly complex system. It consists, in fact, of heterogeneous functional layers, in which it changes the moisture content, coherently with the functions carried out by a natural soil, which is the subsistence from the nutrients, the water storage, the breathability of the vegetable and cultivation layers.

Consequently, the performance of thermal insulation and thermal inertia are highly dependent, over a specific period, from climatic factors such as intensity of precipitation, solar radiation and outside air temperature.

To define the energy behaviour of a green roof, basing on the performances of the individual functional layers in the worst conditions of humidity, leads to assign performances significantly lower than those inferred from the experiments do.

Referring only to the thermal conductivity values of the materials forming the solutions of green roof, ir can be disclosed how the performance levels established by the regulations for top closures, in terms of thermal resistance, are reachable with a culture layer thickness above 100 cm. These conditions considerably reduce the chances to implement a green roof, especially in existing buildings, because we are in presence of high static load.

MATERIALS	*thermal conductivity* *[W / m·k]*	*Reference thermal resistance* *[m² · k / w]*	*Minimum thickness* *[cm]*
Expanded cork panels	0,040 ÷ 0,045	3,00	12 ÷ 14
Expanded polystyrene panels	0,036÷ 0,040		10 ÷ 12
Rock wool panels	0,034÷ 0,038		10 ÷ 12
Fir wood (1)	0,100 ÷ 0,120		30 ÷ 35
Cultivation layer of green roofs (2)	0,400 ÷ 0,900		120 ÷ 300

(1) It assumes an average moisture content in the wood equal to 15%; each percentage point more of moisture increases the thermal conductivity of a value equal to 1.2% from the base value.

(2) It assumes a degree of saturation of the soil equal to 50

Table 1 - Thermal insulation properties comparison of some materials related to a generic cultivation layer of a green roof.

From above, it results wrong to refer only to the parameter of thermal conductivity of the cultivation layer to define the properties of heat transmission of a green roof in the winter season. It is also necessary to underline that, unlike roof "traditional" technological solutions, the calculation of energy performance indicators in stationary regime is approximate, as the functional layers of a green roof varying considerably its physical – technical characteristics during the year, especially in terms of moisture content.

A green roof, in substance, is a complex system not describable through schematization or simplified models, in particular because it is a system capable of self-regulation as a function of external climate conditions. We can assume the combination of plant essences, cultivation layer, insulation and structural support as a layer of non-homogeneous and non-isotropic material, which operate as a thermal mass for evaporative cooling according physic - technical variables (Moody *et al.*, 2013).

In a formulation of technological performances, a green roof consists in a complex system of functional layers, in which the significant effects from the point of view of energy performances are explained, essentially, by the following:

- vegetal layer;
- cultivation layer;
- thermal isolation layer, "warm roof" solutions;
- structural layer.

The mutual interaction of these layers defines the complex mechanisms of heat exchange into the different levels of a green roof: conductive, convective, radiative and latent. The methods of heat exchange are otherwise attributable to functional layers mentioned above, influencing the design parameters needed to describe the energy performances of a green roof.

LAYER	*PARAMETRI SIGNIFICATIVI*			
	Shading	*Moisture content*	*Thermal conductivity*	*Weight*
Vegetal	● ■ ◆	▲ ● ◆		
Cultivation		▲ ● ◆	▲	▲
Thermal isolation			▲	
Bearing or structural layer			▲	▲

EXANCHANGE TIPOLOGY:

▲ CONDUCTIVE; CONVECTIVE; ■ RADIATION; ◆ LATENT.

Table 2 – Relationships between functional layers responsible of heat transfer in a green roof, different type of heat transfer and relative significant parameters.

The design of the vegetal layer, as the principal final value from the viewpoint of architectural and aesthetic of a green roof, also considers the different types of heat exchange in relations with these:

- radiative heat exchanges, related to the control of solar radiation coming from the outside (depending on the vegetal essence planted) and the absorption within the layer itself;
- convective exchanges between the vegetal layer, the soil and the external environment through air interposed;
- heat transfer for evapotranspiration of the leaves and the vegetation at ground level, depending on the parameter of stomatal resistance.

The main parameter that influences the performances offered by a vegetal layer is the Leaf Area Index (LAI), the ratio of the leaf area projected onto the surface and the surface itself expressed in [m2 / m2]. This parameter is an excellent synthesis to measure the effect of the vegetal layer on the overall performance of the green roof (Arlunno, 2011), specifically on evapotranspiration exchange and solar radiation control. The values of the LAI for green roofs are usually in the range 0.5 to 5.0. The percentage of coverage area protected by the leaves is a parameter directly related to, but not identical with the LAI (Sailor, 2008), and it affects the radiative heat flows on the surface of vegetal layer.

Even the vertical dimension of the vegetal layer influences the heat flow crossing the green roof throughout the year; in particular, in the winter season, the presence of the vegetal layer reduces the dispersion of heat for extra radiative flow towards the celestial vault (Palomo del Barrio, 1998).

The main energy effects related to the vegetal layer are inherent to the performance of roofing in summer, as they relate to the thermal inertia guaranteed by the technical element. It has been measured that the proportion of solar radiation reflected by the vegetal layer deviates significantly from that offered by a traditional roofing: the values of albedo are respectively equal to 0.23 and 0.10, with a consequent reduction of the quota transmitted to the massive layers of roof (Lazzarini *et al*., 2005).

The climatic conditions, in this case, play a decisive role in the entity of the inertial performances: the average porosity of cultivation and the variation of the voids saturation degree increase the thermal conductivity of the layer, because the water is a better thermal conductor than air, and reduce its thermal diffusivity. For the last reason it is possible to verify a reduction into the heat flow through the roofing in order to increase the volumetric moisture content (Palomo del Barrio, 1998).

For these reasons, to assume constant physical - techniques characteristics of the cultivation layer is incorrect: in calculations of stationary regime (peculiar of the winter season), for small thickness layers (less than 6 ÷ 8 cm) it is acceptable even neglecting the thermal resistance (Arlunno, 2011).

It is possible to derive empirical formulas to express the thermal conductivity λ [$W \cdot m^{-2} \cdot K^{-1}$] and specific heating c_p of a cultivation layer [$kJ \cdot kg^{-1} \cdot K^{-1}$] in function of the volumetric content of moisture θ in the same, expressed in [$m^3 \cdot m^{-3}$], according to a linear dependence (Moody *et al*., 2013):

$$\lambda = 1{,}13 \cdot \theta + 0{,}10 \left[\frac{W}{m \cdot K}\right] \qquad c_p = 4{,}75 \cdot \theta + 0{,}76 \left[\frac{kJ}{kg \cdot K}\right]$$

These empirical formulas are obtained from seasonal average values derived from measurements of a specimen of ground, initially dried in a furnace, to which subsequently controlled amounts of water have been added.

Finally, the greater incidence parameters to establish the summer performances of a green roof are the LAI and the average thickness of cultivation layer. Also specific parameters of the dry soil, such as density, thermal conductivity, the moisture content and the specific heat affect significantly.

FUNCTIONAL LAYER	*IMPACT ON THE ENERGY PERFORMANCES IN THE SEASON*	
	WINTER	*SUMMER*
vegetal	reducing convective heat transfer increase of transpiration phenomena with consequent increase of heat flows	reduction of the solar radiation incident on the roofing produced by shading (LAI with ≥ 3) heat dispersion for evapotranspiration phenomena
cultivation	increase of thermal resistance compared to non-insulated roofing thermal insulation does not exceed the isolated shells thermal conductivity variable as a function of moisture content negligible contribution for thicknesses and significant only for intensive green roofs	heat flow reduction during the input than non-insulated roofing reduction of the temperature at the base of the layer respect to a traditional roofing need of higher water content to dissipate latent energy
thermo insulated	necessary to obtain adequate thermal resistance values	significant performance depending on the material that constitutes it
structural	variable performance as a function of the material constituent	effects of thermal inertia as a function of surface mass

Table 3 – Summary statement about the effects of green roofs typical functional layers in the energy performance determination, for summer as for winter, in mediterranean climate.

About the microclimate mitigation effects in the urbanized contexts, the roof greening are configured as technological systems able to ensure the continuity of complex ecological system. This is constituted by flows of energy, materials and information related to the man-made and natural component, even with significant changes to the scale of individual buildings as to the larger urban settlement.

In particular, cities are an energy-intensive system that leads to some negative effects on the natural component, such as the increase of the temperature of the “urban foliage”, waterproofing of surfaces and reducing the ecosystem biodiversity.

The different morphological characteristics of urban soils (slope class, roughness, surface color), the mutated heat capacity of an anthropogenic object related to pre-existing conditions of natural soil, pollution agents emitted into the atmosphere by human activities (primarily traffic, conditioning and ventilation systems, industrial installations, etc.) result as alterations of radiative and mass fluxes that characterise an intact atmosphere.

In the proximity of a large urban settlement, you may experience a discontinuity in the atmospheric layer in direct contact with the Earth surface defined Urban Boundary Layer: in its interior, the layer enveloping the built volumes is defined Urban Canopy layer. This phenomenon also identified by the Planetary Boundary Layer, that is the vertical portion of the atmosphere in which activities are concentrated and the resulting changes induced by them. These features of this air layer depend on the energy shares of solar radiation reflected and absorbed by surfaces in it included, from the shape of urban spaces in relation to accessibility solar and widespread human activities.

The anthropogenic surfaces tend to reduce the component of solar radiation reflected, the albedo, condition that involves a greater share of energy absorption. The albedo of a vegetal surface, usually equal to 0,20 ÷ 0,30, is lower than the albedo of some surface materials amply diffused in contexts of high-density population and employed for the realization of roofing finishes. Among these materials we can identify, for example, the asphalt (albedo: 0.04 ÷ 0.10), pebbles and crushed stones (albedo: 0.10 ÷ 0.15), tiles and brick tiles (albedo: 0.10 ÷ 0.30), metal sheet (albedo: 0.10 ÷ 0, 15).

Comparing the heat balance of an urban location with heat balance of a rural location, both similar in size and geographic position, there is a drastic reduction of the heat exchanges of latent heat through evapotranspiration and an increase of the energy stored in the building (Cleugh *et al*., 1986).

Considering the plant in its entirety, the interaction among leaves in terms of geometry and orientation, makes the definition of the energy balance a great complexity operation. It is however possible to affirm that the global albedo of vegetation decreases with increasing height of its development and with the apparent height of the sun in the sky.

If the presence of green areas in urban context, also placed on the roof of a building, allows improving the energy balance, the contribution is not exhaustive, in fact it should be integrated with the larger scales, also with an optimized landscape design.

The performance more efficacious due to the green roofs is the control of rainwater downflow, in particular:

- superficial flow control;
- flow rate reduction of rainwater conduct toward disposal system;
- hydrograph peak wave reduction, that is maximum instant water flow over roofing;
- delay on the confluence of peak wave to the disposal system (Ciaponi *et al*., 2014).

The water systems management of a green roof is allowed by processes of water storage that regulate the dispersion in the atmosphere, by the evapotranspiration phenomena for a quota that can exceed 60% of the volume precipitate (Bengtsson, 2005). The drainage system captures a portion of the remaining meteoric water volume, this quota depends on the inclination of the roofing itself:

- the effects of detention are measured by determining the ratio between the hydrograph peak output from a waterproof roofing and the output from the green roof in exam;

- the effects of retention are related to the volume of water held.

Essential parameter for the quantification of these effects is the outflow coefficient ψ, defined as the ratio between the volume of water going out from the roofing and the volume of water gravitating on it, in the same time interval. Green cover, in comparison to a traditional waterproofed roofing, presents an outflow coefficient significantly lower: related to an impermeable surface, for which $\Psi = 0{,}95 \div 1{,}00$, an extensive green, characterized by a layer of a thickness of culture to 10 cm, it reduces the outflow coefficient to the value $\Psi = 0.40 \div 0.45$. Cultural layers of 40 to 50 cm, adapted to an intensive greening, show a value $\Psi = 0.10 \div 0.15$ that is closed to the one of the fallow soil.

This performance is of great interest when is compared to the analogue features in a traditional high-energy performance roofing. Therefore, the flow coefficient is then the most effective parameter to highlight the contribution of green roofs with the appropriate demands to the environmental protection class of requirements, even if for arrangement of any public incentive mechanisms.

The green roofs, if they are used on a larger scale of the single building, or rather to neighborhood scale or more properly of scale to drainage basin, represent an effective strategy for the control of atmospheric precipitation, even if of considerable intensity. Green roofs prevent possible phenomena of flooding and restoring the hydrological cycle in contexts with high-density building: this fact underlines the potential of a diffused conversion to green roofs in an urban area, in particular if this process is disciplinated by town planning.

The partial transformation of a cover by greening, subordinated to the structural layer residual bearing capacity, consists in the replacement of the original functional layers with new layers that lead to a greater reduction in energy consumption and increase in the environmental performance of the building shell.

The structural performances resulting from the behavior of the technical element of coverage in existing buildings are referred to two different scales:

- Local: it requires that the coverage bearing structure is capable to withstand the stresses arising from the overload, induced by the functional layers;
- Global: it requires new performances verification of the overall structural subsystem.

Operating on existing buildings, to determine the extent of overloading results an applicable action essential in the redaction of design specifications, which can lead to reduce the ranks of technological solutions applicable or to exclude its implementation, unless significant interventions of structural reinforcement and structural stiffening. In existent structural system, extensive green roofs typology is previleged, because it has a smaller thickness and, consequentially, induces a minor overload. In new building, the cost of realization of green roof is the binding condition.

From the analyzes carried out, we can say that the need to proceed with the evaluation of structure safety of an existing building, as intervention object for the realization of green roofs, and its possible structural adjustment, strongly depend on the construction typology of building itself.

For buildings with a large number of stories and a reduced floor area, in fact, the need to evaluate the safety and the adaption of buildings is less likely than for the ones having a limited number of plans and a big floor area. Also the type of structure affects in this sense: in case of heavy structures, the increase of loads on roofings will be less incident than the whole of the loads acting on the foundation; it is the opposite for buildings with lightweight structures.

building typology	Likelihood of having to conduct security assessment
Type "in line"	High
Type "block"	Medium
Type "terraced"	High
Type "tower"	Low
Type "walkway"	High
Type "isolated"	High

Table 4: Probability of needing to perform an assessment of the sutructural safety for the realization of a green roof in function of the building typology.

4. FUTURE PROSPECTS

The research work summarized in this paper tries to address some of the main issues that may concern the green roofs also in order to lay the foundations for future works, which will examine more in depth the matters discussed.

The need to debate what results in this work by the assessments over one or plus existings buildings choosed as case of study, rapresents an aim that we want to pursue. Moreover, it results really to treath also the topic of vertical green, intended as element of vertical opaque enclousure, that can be integrated into building shell in order to complete green roofing solutions.

The research of a greater continuity between natural environment and antropized environment is a fascinating challenge for all stakeholders of architecture ad technical discipline, from a point of view of archievment of environmental preservation objectives.

Definitively, we consider that there a lot of possibilities in the research about this topic and that the diffusion of this technical solutions of roofing represents the key into the necessary process of building and urban requalification, one of the greatest challenge of our times.

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