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Tullia Bonomi
Marco Masetti

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Marco Faggioli
Stefania Stevenazzi

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Preface

FLOWPATH 2019, the 4th National Meeting on Hydrogeology, was held in Milan from 12th to 14th June 2019. According to the aim of the previous Editions of FLOWPATH, held in Bologna (2012), Viterbo (2014) and Cagliari (2017), the conference is an opportunity for Italian hydrogeologists to exchange ideas and knowledge on different groundwater issues.

The objectives of the conference are:

- To promote dialogue and exchange of scientific knowledge among young hydrogeologists;
- To deepen the theoretical and practical aspects of our understanding on groundwater;
- To update all the stakeholders, researchers and professionals on recent challenges in the hydrogeological sciences;
- To encourage researchers, professionals and administrators to contribute to the improvement of water resources management.

This Volume of Conference Proceedings contains the abstracts of oral and poster contributions accepted to FLOWPATH 2019. The abstract were evaluated by the Scientific and Organizing Committees. This volume contains 99 abstracts, submitted by Authors coming from Universities, Public Authorities and Private Companies of Italy and many other countries, such as Australia, Belgium, Croatia, Czech Republic, Greece, Hungary, Israel, Malta, Morocco, Nigeria, Spain, Switzerland, The Netherlands, U.K., and U.S.A.

The conference focuses on four themes of great importance:

1. Groundwater Resource Management
2. Fractured Rocks and Karst Aquifers
3. Contaminated Sites
4. Urban Hydrogeology

The content of the Conference Proceedings is organized according to the four topics of the conference. The keynote lectures open the sessions were they were presented, followed by the scientific contributions in alphabetical order by first author's family name.

Editors:
Luca Alberti
Tullia Bonomi
Marco Masetti

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Anaerobic and aerobic bioremediation of chlorinated solvents and hydrocarbons plumes from an old landfill in the Venice lagoon environment

Giovanni Pietro Beretta[1], Lucia Cavalca[2], Martina Bertolini[2], Sarah Zecchin[2], Giovanni Buscone[3], Laura Ledda[3], Laura Ferrari[3], Giacinto Carnevale[3], Gerardo Bozzetto[4], Jacopo Terrenghi[5]*

[1] *Università degli Studi di Milano, Dipartimento di Scienze della Terra "A. Desio", Milano, Italy.*
**Corresponding email: giovanni.beretta@unimi.it*

[2] *Università degli Studi di Milano, Dipartimento di Scienze per gli Alimenti, la Nutrizione e l'Ambiente, Milano, Italy*

[3] *Tauw Italia S.r.l., Milano, Italy*

[4] *Nuova Alba S.r.l., Milano, Italy*

[5] *Indipendent geologist, Italy*

ABSTRACT
An old industrial waste landfill with a surface of 16 ha in the surroundings of the Venice lagoon has produced heavy hydrocarbons and chlorinated compounds groundwater contamination. Microbiological and chemical results of a two field tests have confirmed the feasibility of bioremediation and have allowed the facilities design. An organic substrate, able to increase the reductive dehalogenation, was injected and recycled in anaerobic barrier near the landfill; air sparging was performed and nutrients injected in order to increase hydrocarbons degradation in aerobic barrier downgradient. Hydrogeological investigation and microbiological analysis were carried out to verify the effectiveness of the reclamation in anaerobic environment, having achieved chlorinated compounds degradation values of almost 24 kg/day. Further studies are underway to improve the aerobic barrier.

Keywords: bioremediation, contaminated groundwater, chlorinated solvents, hydrocarbons

METHODS
A 16 ha industrial wastes landfill located near the Venice lagoon (Dogaletto, VE) is elevated above ground level to a maximum height of about 11 m a.s.l.. From a geological point of view, the landfill area is characterized by the Mestre Unit and Dolo Unit, i.e. alluvial deposits consisting of sand, silt and clay (Beretta and Terrenghi, 2016; Provincia di Venezia, 2008). Based on many geological and hydrogeological investigations, the conceptual model of subsoil is characterized by an alternation between sandy and silty clay horizons; sandy aquifer horizons have a hydraulic conductivity in the order of 10^{-4} m/s and the aquitards/aquicludes having hydraulic conductivity less than 10^{-8} m/s. The groundwater contamination plume coming from the landfill, covers a surface of 17 ha and is contaminated by high concentration (up to 500-600 mg/l) of chlorinated ethenes and ethanes (CE, CA), BTEX, Chlorobenzenes and total petroleum hydrocarbons (TPH). In anaerobic conditions, highly chlorinated ethenes are easily dechlorinated by bacterial organohalide respiration with the

concomitant accumulation of the more toxic vinyl chloride (VC), which can be metabolically and co-metabolically oxidized in aerobic conditions (Weatherill et al., 2018). The use of sequential anaerobic/aerobic systems has been shown to perform complete degradation of chlorinated ethenes to ethanes. TPH can be efficiently degraded by aerobic bacteria, via sequential oxidative reactions and a final cleavage of catechols that enter TCA cycle. The enhanced bioremediation was tested in series anaerobic/aerobic barriers, respectively for CE,CA and for BTEX, Chlorobenzenes and TPH degradation, directly downstream of the landfill and at end of the plume. The positive outcome of the experimentation in test sites has allowed us to design and implement the plume bioremediation, after the approval of the Public Authorities (PA). Test site was expanded with 390 m long anaerobic barrier to degrade CE and CA by injection (20 wells) and recycle (19 wells) of a redox substrate, and 500 m long aerobic barrier to degrade BTEX, Chlorobenzenes and TPH by air sparging (43 wells), water extraction (18 wells) and water and nutrients recycling (35 wells). The effect of bioremediation on hydrochemistry was monitored by means of piezometers placed upgradient and downgradient the barriers (transects). Microbial populations were analyzed in order to determine the effect of the treatments. Phylogenetic and metabolic biomarkers were monitored on site by quantitative PCR analysis (qPCR) on DNA extracted from groundwater samples and cultivation of TPH degrading bacteria, during two years. The structure of microbial community was analyzed by Illumina NGS technique.

RESULTS

In the anaerobic active barrier, the addition of substrate improved the degradation rate of CE and CA between upstream and downstream until 98%. Chemical data were mirrored by an increment of metabolic genes for reductases: tceA from 10^4 to 10^6 and vcrA from 10^4 to 10^7 gene copy number/L of groundwater, and of organohalide respiring bacteria Dehalococcoides from 10^5 to 10^6 gene copy number/L. After two-year treatment, glucose-fermenting bacteria Bacteroidetes increased with respect to Dehalococcoides genus, indicating that Bacteroidetes were involved in the creation of the reducing power used for reductive dehalogenation. In the aerobic active barrier, where optimal concentration of oxygen have been reached, VC and TPH decreased (from 11'2000 to 310 µg/L and from 500 to 219 µg/L, respectively) although TPH-degrading bacteria were present in the order of 10^1 MPN/L.

CONCLUSIONS

The overall data demonstrate that active CE-degrading bacterial populations were present at the site. The addition of organic substrate improved CE reductive dechlorination as evidenced by chemical and microbiological data, whereas increasing of VC was observed only in certain circumstances due to lacking of injection of substrate, confirming the effectiveness of the system when optimally operated. Efficacy of the anaerobic barrier in the degradation of CE was about 82.5%, ranging between 69% and 98% in the various transects. Low efficacy in the aerobic barrier was likely due to high incoming load and difficulty to revert the environmental from reductive to oxidant. This will be improved with further interventions. The monitoring system led to a significant reduction in the plume

in two years of operation of the barriers. Based on results of Phase 1, a Phase 2 design was submitted to the PA and approved to improve effectiveness of both barriers.

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