The Reconstituited Soils: The Technology and Its Possible Implementation in the Remediation of Contaminated Soils

Article · November 2016

DOI: 10.6092/issn.2281-4485/6302

1 author:

Paolo Manfredi
m.c.m. Ecosistemi s.r.l.

EQA – Environmental quality / Qualité de l'Environnement / Qualità ambientale, **21 (2016) 19-32**

THE RECONSTITUITED SOILS: THE TECHNOLOGY AND ITS POSSIBLE IMPLEMENTATION IN THE REMEDIATION OF CONTAMINATED SOILS

Paolo Manfredi

Ecosistemi s.r.l. Loc. Faggiola snc – Gariga di Podenzano (PC)

*Corresponding author: manfredi@mcmecosistemi.com

Abstract

Reconstitution technology is a pedotechnique whose action supplements soil structure with organic and mineral components that are quality and origin certified. The treatment procedure performs a mechanical action which forms an organic matter lining within the mineral fraction by means of soil structure disintegration and subsequent reconstitution. Results produced by the technology in the field of agronomy suggest that such method may be employed to remediate contaminated soil by altering its properties according to need.

Key words: *reconstitution technology, land remediation, bioremediation, reconstituted soils, degraded soils, contaminated soils.*

Introduction

Soil is a non-renewable resource which is globally exposed to negative interference in relation to human activity: its vulnerability results in degradation processes which reveal an imbalance of its properties. Soil decline and loss are caused by a number of reasons such as constant landscape transformation, intensive farming, aimed at securing high production levels, and contamination.

Suitable land management policies are not the only special tools for countering such interference; it's necessary to take direct action, thanks to pedology and its implementation which are crucial in making a substantial technological contribution towards tackling degradation causes and effects. Reconstitution is a recently developed pedotecnique which performs a modification in the characteristics of infertile, degradation, or desertification affected soils by means of a mechanical treatment which takes place through separate stages. The conceptual model of the treatment is based on the incorporation of organic matter within the mineral fraction. Such organic matter is supplied by a number of matrices of fibrous and earthy type supplemented with additional suitable materials. The product thus generated, known as reconstituted soil, is a new kind of soil characterized by neo-aggregates which have specific properties different from the original soil materials. This technology, protected by two patents, is designed to act on two main soil conditions: on those soils which have undergone substantial modifications in relation to original conditions thus causing a partial or total soil loss, or on farmland areas which have suffered agronomic and environmental deterioration due to actions that previously impaired its functions.

DOI: 10.6092/issn.2281-4485/6302

A number of studies and field testing have been conducted over the last decade in order to define the agronomic and environmental characteristics of reconstituted soils mostly thanks to LIFE + 2010 (Life 10 ENV IT 400 “New Life”) funding which has supported both research and technological implementation. The work has disclosed some important evidence concerning the effectiveness of the method aimed at countering soil deterioration and improving agricultural production.
This paper summarizes the results achieved by implementing reconstitution in two sites whose edaphic conditions were seriously compromised compared to their presumed original conditions. The first case deals with the plot of a farm which was unsuccessfully rehabilitated after a mining activity (gravel pit). Such plot was scarcely productive due to insufficient quantity and poor agronomic quality of the soil used for the covering-up layer. The second site is a former landfill area for municipal solid waste which was covered up, upon exhaustion of disposal limits, with a thin layer of soil from different locations. No renaturalization has occurred on such soil over the years, just a colonization of weed species (Giupponi et al., 2013; 2014).
During the experiments it was possible to outline some peculiarities of reconstituted soils which may potentially be helpful in the implementation of the technology for the remediation of contaminated soils. Reconstitution treatment, by generating a modification in the nature of soils may offer the chance to improve the efficiency of bioremediation techniques (biopile, landfarming, phytoremediation), help reduce contamination and increase the protective power of soil.

Materials and methods

Research areas

The sites to be monitored for testing the technology were selected because of their common degradation which had distinct causes. The degraded farmland in “Località Matta”, municipality of Gossolengo (PC), is a flat plot of land of 6 ha. On-site soil is the result of backfilling operations and excavation-pit refilling which took place after a mining activity. Refilling was performed with silty clayey soil and subsoil mainly from nearby hills, and only partially with waste from the sugar industry (defecation calcium). On this plot crop yields were exceptionally compromised. The second area is located within the municipality of Piacenza in “Località Campo Santo Vecchio”. It’s a flat area of approximately 20 ha. which was used as landfill for municipal solid waste in the 70s. Upon exhaustion of disposal limits covering up was carried out using soil from various locations, mostly from excavation works. Later various renaturalization processes were carried out (shrubs and tree planting of various species) unsuccessfully.

Treatment procedures

Both reconstitution procedures were preceded by preliminary assessment of soil quality in relation to: superficial stoniness; usable depth – thickness; limitations and hindrance to root development; profile of the layer of usable soil; coarse soil particles (skeleton) (Costantini, 2007); such observations were combined, when available, with data on the amount of surface waste all along the soil top layer. Such parameters supplied the elements for defining treatment procedures, targets and final morphological layout.

At both sites preliminary assessment followed a random line transect sampling (Suppl. Ord. G.U. n. 121 del 25/05/1992) carried out by collecting undisturbed (Suppl. Ord. G.U.n. 173 del 02/09/1997) and disturbed samples characterized by 4 samples per hectare.

Soil characterization was carried out according to the methods of chemical and physical analysis of the soil of "Gazzetta Ufficiale Italiana" by analyzing the following parameters: bulk density (Method ISO/DIS 11272); particle density (Method ISO/DIS 11508); skeleton (Metodo II.1 Suppl. Ord. G.U. n°248 del 21/10/99; texture (Metodo II.5, Suppl. Ord. G.U. n°248 del 21/10/19999 – ISO/DIS 11277); reaction (Metodo III.1, Sppl. Ord. G.U. n. 248 del 21/10/1999 ISO/DIS 10390); organic carbon (Metodo VII.3, Suppl. Ord. G.U. n. 248 del 21/10/1999, (Walkley-Black 1934)); total nitrogen (Metodo XIV.2 + XIV.3, Suppl. Ord. G.U. n. 248 del 21/10/1999 – ISO/DIS 11261); total limestone (Metodo V.1, Suppl. Ord. G.U. n. 248 del 21/10/1999 – ISO/DIS 10693); active calcium carbonate (Metodo V.2 Suppl. Ord. G.U. n.248 del 21/10/1999); assimilable phosphorus – Olsen (Metodo IV.3 Suppl. Ord. G.U. n. 248 del 21/10/1999).

As far as salinity (1:2,5), cation-exchange capacity and exchangeable bases determination are concerned, they were calculated according to the analytical procedures reported in "Methods of Soil Chemical Analysis" (Colombo and Miano, 2015). The choice of additional materials suitable for the production of reconstituted substratum was made by calculating the average values of soil characterization. Matrices incorporated to natural soil during the pre-blending procedure are waste materials such as: pulp and paper mill primary and secondary sludges; sludge from the washing process of natural aggregates; dredged sludge from waterway sediments, such as hydroelectric reservoirs and acqueducts; waste from pruning and landscape maintenance; some types of combustion ashes; desulfurization gypsum; organic sewage sludge from the food and agricultural industry.

The characteristics of additional materials were defined from an environmental and agronomic point of view prior to their use in order to assess their suitability. Environmental analyses were conducted to detect the presence of contaminants and on the eluate extracted over a 24 hour time span (UNI 10802:2004); phytotoxicity was assessed by carrying out two tests which employed *Lepidium sativum* (IRSA 1983); organic testing for agronomic sustainability was carried out employing *Lactuca sativa* (Astorri, 1998). Both methods were modified by applying matrix dosages (20 – 50%) higher than the ones stated by previously mentioned methods. The agronomic properties of additional materials were identified by applying different methods in relation to their nature. Basically fibrous components were identified with the same procedures used for substrata: reaction (UNI EN 13037); salinity (UNI EN 13038). The same analytical procedures already mentioned in

DOI: 10.6092/issn.2281-4485/6302

relation to salinity, total limestone, active limestone, ESP (Exchangeable Sodium Percentage), total nitrogen, organic carbon, ratio C/N, cation exchange ability, exchangeable bases, base saturation, and available nitrogen were used to identify the other characteristics and the typologies of materials to be mixed with the soil.
Analytical data resulting from the characterization of natural soils and additional materials were used to set up the blending criteria which regulate the amount of components in relation to properties such as: reaction, organic matter supply, carbon-nitrogen ratio, salinity, assimilable phosphorus, active limestone, and other aspects such as the ratios between exchangeable bases (Mg/K; Ca/Mg).
The treatment has taken place inside a processing plant located on the edge of the plot undergoing rehabilitation (in-situ), whereas on the landfill site it was located outside the borders of the site (ex-situ). Soil supply followed different procedures in relation to each of the two types of remedial action needed. At the agricultural site a suitable layer of soil was excavated and piled up near the plant; at the landfill site the thin layer of available soil removed could be reconstituted only partially because the amount of waste such as plastic, glass, demolition debris and molding sand didn't allow its complete exploitation. Therefore it was necessary to use silty clayey subsoils from quarries.
Additional matrices were provided thanks to a weekly planning; the choice of materials was organized in relation to their characteristics, and to the amounts necessary for the first production stage: pre-blending. Increase variations were ensured by automatic weighing systems.
Amounts of additional matrices incorporated to the pre-blend account for, depending on the typology, 30 - 50% of the total weight of reconstituted soil.
Pre-blending, carried out by construction equipment, or by a specific machine equipped with a crushing roller, was followed by a disintegration treatment where a special mechanic system performed the destructuring of aggregates and the defibering of organic components.
The disintegrated product was then submitted to the next stage of reconstitution where mechanical elements conveyed a sequence of pressure shocks of different intensity in relation to the nature of the material, thus generating the new aggregates of reconstituted soil. After production reconstituted soils were repositioned in each respective area according to the instructions of the project.
Data from preliminary investigation concerning the limitations on both sites helped determine the amount of reconstituted soil which was to be produced in order to increase the thickness of its layer and its root penetration, and to reduce, by means of sieve analysis and fragmentation, the content of skeleton and particle size. In addition the greater amount of soil produced contributed to the dilution of inerts as the input of additional matrices was on the whole below 2 mm.

Results

Agricultural plot site

The main limitations (Table 1) evidenced by on-site preliminary observations indicated a percentage frequency of occurrence of 28% for skeleton and 11% for surface stoniness (medium pebbles, coarse pebbles). Below the horizon involved in crop growth (40 cm.) there was a copious amount of demolition debris and construction site waste (plastic scraps, bricks and concrete) which reduced the depth available and represented a limitation to root penetration which was scarce (30-40 cm.). The lower boundary of the soil surface layer was level.

Table 1. *Characteristics of the agricultural area (Gossolengo PC) before and after reconstitution treatment.*

Parameter	UM	Values	
		Agricultural soil before reconstitution treatment	Agricultural soil after reconstitution treatment
Soil depth	cm	40	110
Root penetration	cm	35	100
Texture	%	Silty clay loam	Silty clay loam
Skeleton	%	28	5.5
Surface stoniness	%	11	2.5
Salinity (1:2,5)	dS/m	0.25	0.49
Slope class	%	< 0.2	<0.2
Particle density	g/cm^3	2.42	2.14
Bulk density	g/cm^3	1.64	1.08
pH Reaction in water	-	8.3	7.8
CEC	meq/100g	18.2	30.1
Total limestone	g/kg	265	180
Active limestone	g/kg	85.3	52.15
Organic Carbon	g/kg	9.3	43.9
Total Nitrogen	g/kg	1.69	3.9
C/N ratio	-	5.5	11.2
Phosphorus Olsen (P_2O_5)	mg/kg	37.5	129.2

The structure of aggregates was mostly medium polyhedral, and secondarily platy; there was a high frequency of occurrence of cemented limestone aggregates, and a widespread formation of crusts at the soil surface with resulting cracks; the soil appeared very compressed and with low porosity with an average value of 1,64g/cm^3 in bulk density and of 2,42 g/cm^3 in particle density.

Moderately fine-textured soils (silty clay loam) had an 8,3 pH (moderately alkaline) and an irrelevant salinity of 0,25 dS/m (EC 1:2,5); low organic matter values (9,3 g/kg) and a low C/N ratio (5,5) revealed an elevated mineralization. High levels of total limestone characterized the soil at the site as strongly calcareous. The concentration of active limestone at 85,3 g/Kg was considered as upper medium. High amounts of the last parameter influenced nitrogen availability (P Olsen 37,5 mg/kg P_2O_5) which was very low.

Results gathered from observations and analytical characterization evidenced a low agronomic yield of the plot. After reconstitution the site doesn't retain its original

DOI: 10.6092/issn.2281-4485/6302

features. Conditions have been altered (Table 1). The greater amount of soil produced by the treatment allowed to create a crop horizon of 110 cm.
Such condition assured an equivalent depth suitable for root penetration. Repositioning of the soil was carried out following the linear inclination of the previously positioned layer. The skeleton is lower (5-6%) and surface stoniness is limited (2,5%). Bulk density (1,1 g/cm^3) and particle weight (1,6 g/cm^3) are low.
Soil structure is medium granular, and secondarily polyhedral (fine-medium) with rarely occurring cemented aggregates, and surface crusts only occurring in the first 2-3 months after soil re-positioning.
The texture remains silty clay loam; from a chemical point of view reconstituted soil is characterized by a 7,8 pH medium reaction (mildly alkaline), salinity is negligible at 0,49 dS/m (1:2,5); the level of organic matter is high (43,9 g/kg) like the 11,2 C/N ratio. Total limestone has a value of 180 g/kg (very calcareous) and the concentration of active limestone is 52,1 g/kg (medium). The concentration of assimilable phosphorus, expressed in P_2O_5 is 129,2 (high).

Landfill site

The landfill area (Table 2) where the remedial action took place (UE – Life+2010-LIFE10/ENV/IT/0400/NEWLIFE) had a very shallow soil depth average (23 cm.) with reduced root penetration; the lower boundary of the surface horizon was ondulated and in direct contact with a massive amount of waste such as bricks, concrete, plastic bags, solid municipal waste and foundry waste. Skeleton (34%) and surface stoniness (8,5%) were frequent, namely pebbles, stones and demolition debris. Soil in the area was heavily compacted and badly drained, with water stagnation in spring and autumn (Cassinari et al., 2015). The soil surface had abundant and wide depressions created by waste settlement over decades. There was frequently emerging plastic material.
Superficial cracks, which depending on soil typology were linked to the formation of surface crusts, together with even bigger cracks, could be found all along the horizon of the landfill cover soil. The structure of aggregates was remarkably heterogenuous because of the wide typology of soils used as cover layer. The average bulk density of the soil was 1,28 g/cm^3 , while particle density was 2,23 g/cm^3.
Samples from different soils revealed a medium texture (silt loam) with an average alkaline reaction (pH 8,0) and a marginal salinity (1:2,5 dS/m 0,42).
The presence of organic carbon was high (2,6%) with an average C/N ratio (9,2) as the area was affected by a thirty-year long abandonment.
The soils, being strongly calcareous, (215,2 g/kg) had slightly high concentrations of active limestone (66,19 g/kg) and a low concentration (42,9 mg/kg P_2O_5) of available phosphorus (Olsen method).
Limitations to root development of small to medium size plants (shrubs and trees) generated by insufficient soil depth, together with other properties which were not liable to be modified by normal soil amendment practices evidenced that it was impossible to carry out a renaturalization process at the site, which could only be used sporadically as pasture land.

Table 2. *Landfill site (Borgotrebbia PC): characteristics of the soil before treatment, of the soil used to partially replace in-situ soil and of the soil after treatment.*

Parameter	UM	Values		
		Soil of former landfill before reconstitution	Subsoil from quarries	Soil of former landfill after reconstitution
Suitable rooting depth	cm	< 23	-	100
Texture	%	Silt loam	Silty clay loam	Silt loam
Skeleton	%	34	9	4,5
Surface stoniness	%	8,5	-	2,5
Rocciosità		Absent	-	Absent
Waste materials (surface)		Frequent	-	-
Salinity (1:2,5)	dS/m	0,42	0,38	0,57
Slope	%	< 0,2	-	< 0,2
Particle density	g/cm^3	2,2	2,5	1,9
Bulk density	g/cm^3	1,2	1,3	0,9
pH Reaction in water	-	8,0	8,1	7,8
CEC	meq/100g	28,6	26,9	32,5
Total limestone	g/kg	215,2	140,2	149
Active limestone	g/kg	66,1	49,6	48,4
Organic carbon	g/kg	26,0	10,7	53,2
Total nitrogen	g/kg	2,8	0,7	3,85
C/N Ratio	-	9,2	15,2	13,8
Phosphorus (P_2O_5) Olsen	mg/kg	42,9	25,2	68,8

Due to the significant presence of waste materials, the rehabilitation treatment could be performed only on a limited amount of soil. Hence, it was necessary to use quarry soil (Table 2) in order to allow production with standard proportions (40 – 50%). After remediation the soil layer available for root development is about 1 meter deep, the content of skeleton is limited (4,5%), and so is surface stoniness (about 2,5%). Bulk density at 0,95 g/cm^3 and particle density at 1,95g/cm^3 are low.
The structure of aggregates is granular (medium dimensions). There's also the presence of secondary structures which are generally polyhedral. A fibrous crust resulting from poorly degraded cellulose components, which developed after soil repositioning and settlement, rapidly disappeared after shallow working operations.
After reconstitution treatment the chemical fertility characteristics of repositioned soil reveal a silt loam texture with a slightly alkaline reaction (pH 7,8), and salinity levels of 0,57 dS/m. The soil is rich in organic carbon (5,3%) and has a high C/N ratio (13,8). Highly calcareous soils (149 g/kg) have an average to low concentration of active limestone of 48,4 g/kg, and a high assimilable phosphorus (Olsen P_2O_3) value (68,86 mg/kg).

Discussion

Both remedial procedures enable to compare soil conditions before and after treatment estimating how much agronomic and environmental properties have

DOI: 10.6092/issn.2281-4485/6302

changed and how, on the basis of these changes, potential applications may be devised in order to use this technology for the remediation of reconstituted soils.
At both sites the amount per hectare of repositioned soil succeeded in increasing the thickness for crop growth and root penetration: soils shifted from a condition of shallow or medium depth (23 and 40 cm) to one of greater depth (100 and 110 cm). Skeleton and surface stoniness dropped considerably due to sieving which affected the coarser fractions, to fragmentation resulting from the treatment, and to dilution with aggregate-free materials above 2 mm. in size.
The increase in thickness of the first horizon allows to extend its protective power thanks to a number of factors such as: increase in cation-exchange capacity, high levels of organic matter, high water retention, and resulting low water percolation and surface runoff (Manfredi P. et al., 2014). It’s worth pointing out that the low concentration of heavy metals and other polluting agents, which characterize the matrices employed (Table 3), allows the method to be used in soil treatment for mitigating the concentration of polluting agents and their availability.

Table 3. *Average concentrations of heavy metals in some additional materials used in the pre-blending stage.*

Parameters	Dredging sludge	Sludge from food and agricultural industry	Water purification sludge	Lignocellulosic sludge and matrices
Cadmium mg/kg $_{ss}$	**< 0,1**	**0,31**	**0,1**	**<0,1**
Arsenic mg/kg $_{ss}$	**0,3**	**4,2**	**3,57**	**<0,1**
Lead mg/kg $_{ss}$	**13,6**	**11,5**	**< 0,1**	**23,8**
Nichel mg/kg $_{ss}$	**3,2**	**0,5**	**10,7**	**42,8**
Copper mg/kg $_{ss}$	**0,7**	**69,7**	**12,8**	**20.6**
Zinc mg/kg $_{ss}$	**8,6**	**7,1**	**20,4**	**26,3**
Chromium tot. mg/kg $_{ss}$	**15,4**	**70,6**	**3,9**	**115**
Mercury tot. mg/kg$_{ss}$	**<0,1**	**<0,1**	**<0,1**	**<0,1**

At both sites soil aggregation has been altered compared to original conditions revealing an overall granular-porous structure (fine and medium). Such change ensures a wider and deeper distribution of the root system in relation to the original degradation-affected soils, thus enhancing phytoremediation technologies.(Pilon-Smits, 2005; Wong, 2003).
After remedial actions there has also been a considerable decrease in the formation of superficial crusts and fractures. The formation of fractures, even broad ones, only occurs within a little time after soil repositioning, and is caused by the natural settlement of the soil. The decrease in particle and bulk density is the result of higher organic matter levels, and of a mechanical process which produces a porous structure. Reconstitution tends towards the aggregation of fine soil fractions generating new, lumpy-shaped aggregates. (Chenu, 1995)
The porosity increase of reconstituted soils results in: higher water retention capacity (Manfredi et al., 2014), higher water availability, lower percolation water and lower wilting point. These conditions influence thermal variations of treated

soils, and supply them with properties which increase heat capacity, hence with a temperature range more suitable to biological requirements (Manfredi et al. 2014; 2015). Such hydrological and thermal properties may enhance the efficiency of various technologies for the remediation of polluted soil such as landfarming (Mikkonen et al., 2012), phytoremediation (Nedunuri et al., 2000) and ex situ biopiling treatment (Ta-Chen Lin et al., 2010) because thermal conditions are more suitable to the activity of heterotrophic aerobic bacterial populations and to enzyme activities (Sulaiman et al., 2015).

In addition to porosity increase a higher workability was recorded in the soils examined, together with a sharp decrease in water for irrigation during ordinary agricultural practices (Tassi D., 2014). Such aspects facilitate management of bioremediation treatments such as biopiling, land farming and phytoremediation. (Wong, 2003).

Chemical characteristics of reconstituted soils may be controlled to meet the most suitable conditions for in-situ and ex-situ remediation. In order to achieve good results in biodegradation, phytoextraction and rhizodegradation of contaminants soils must have characteristics which may ensure a good efficiency in such processes (Atagana et al., 2003).

In both soils after the treatment the reaction decreases shifting conditions from medium to slightly alkaline. This result is partly due to the choice of additional materials (with neutral to slightly acid reaction) and to their high organic matter concentrations. Reconstitution allows to control variations in soil reaction, also by using other correctives besides additional matrices, making it possible to return to the pH range which corresponds to the typology of remediation treatment desired (Boopathy, 2000).

In reconstituted soils salinity, whilst remaining within suitable range values, is higher than in original soils which have very low levels of the same, typical of leaching-affected soils.

A decrease in soil reaction has resulted in lower total and active limestone shifting soil conditions at the agricultural plot site from extremely calcareous (265 g/kg) to strongly calcareous (180 g/kg), and at the landfill site from 199 g/kg to 149 g/kg; active limestone shifts from medium high (85,3 g/kg) to medium (52,15g/kg) at the agricultural plot site while at the landfill site the reduction varies from 66,2 g/kg to 48,4 g/kg. The matrices employed have medium to high concentrations of calcium carbonate and active limestone, therefore it must be ruled out that the decrease of these two parameters is due to dilution.

Reconstituted soils have elevated concentrations of organic matter because the intended goal was to reach the values mentioned by the Reports of the Technical Working Groups (Van-Camp L. et al. 2004) which define the 2,1 – 6,0% organic carbon range as average. Such goal was achieved by using specific waste matrices with high organic matter concentrations (Corg. 150 g/kg), the organic matter being namely: cellulose, lignin and hemicellulose. After the cleavage and defibering processes, which take place within the mineral component, the conditions of these

DOI: 10.6092/issn.2281-4485/6302

organic matrices that are basically fibrous and have a high C/N ratio are favourable to carbon stabilization (Oades 1995; Skene et Al, 1996), and to the humification process, as demonstrated by the increase of humic acids in reconstituted soils.
The increase in organic matter of reconstituted soils, together with its even distribution mitigates inhibiting processes generated by contaminants (Labud et al., 2007).
The increase of available phosphorus (Olsen Method) recorded at both sites depends on the matrices selected for incorporation, and on the reduction in the amount of active limestone of original soils. The analytical validation carried out on the soil at the agricultural plot site after reconstitution records a shift from low and insufficient phosphorus availability (37,5 mg/kg) to medium high (129,2 mg/kg), and at the landfill site from low (42,9 mg/kg) to medium (68,8 mg/kg). The increased phosphorus availability improves growth conditions of microbial populations with positive implications on biodegradation of organic contaminants (Bossert and Bartha, 1984; Baker and Herson, 1994).
The characteristics of reconstituted soils and the objectives achieved depend on the type of matrices used, and on the treatment they were submitted to with natural soils. Materials added have properties of great interest (Calace et al., 2003; 2005) but, if used individually, they are ineffective whereas, if measured out prior to treatment, they produce reconstituted soils with the aforementioned properties.
The use of organic waste to enhance soil remediation has been adopted for quite some time (Bradshaw et Al., 1980), but it has never been contemplated to use the technology of reconstitution which offers a treatment focused on the nature of soils. This is achieved by improving various properties which help those physical, chemical and microbiological processes that are potentially most effective in soil remediation. Another positive aspect of the treatment of reconstitution is that, thanks to the pre-blending and disaggregation procedure, contaminants are evenly distributed in the soil. Such procedure helps to avoid the formation of higher concentration spots occurring in contaminated soil (hot spots) (Karen et al., 2009).
The implementation of this technology in view of achieving a better efficiency in treating soil degradation processes opens a wide field of study justified by some of the important potentialities discussed in this paper.

References

ASTORI C.(1998) Metodi per la determinazione della fitotossicità di biomasse di scarto: stima della possibilità di impiego. DIFCA- Università degli studi di Milano.

ATAGANA H.I., HAYNES R.J., WALLIS F.M (2003) Optimization of soil physical and chemical conditions for the bioremediation of creosote-contaminated soil *Biodegradation* 14:297–307.

BOOPATHY R. (2000) Factors limiting bioremediation technologies.Bioresource Technology, 74:63-67.

BOSSERT I., BARTHA R. (1984) The fate of petroleum hydrocarbons in soil ecosystems. In: Atlas RM(Ed). Petroleum Microbiology (pp 399–434). MacMillan Publishing Company, London Baker KH & Herson DS (1994) Bioremediation. McGraw-Hill, Toronto.COM CALACE N, NARDI E., PETRONIO B.M., PETROLETTI M., TOSTI G.

(2003) "Metal ion removal from water by sorption on paper mill sludge" Chemosphere, 51: 797– 803.
CALACE N., CAMPISI T., IACONDINI A., LEONI M., PETRONIO B.M., PETROLETTI M. (2005) "Metal-contaminated soil remediation by means of paper mill sludges addition: chemical and ecotoxicological evaluation" Environmental Pollution, 136:485-492.
CASSINARI C., MANFREDI P., GIUPPONI L., TREVISAN M., PICCINI C. (2015) Relationship between hydraulic properties and plant coverage of the closed-landfill soils in Piacenza (Po Valley, Italy) Solid Earth, 6:929–943.
CHENU C. (1995) Extracellular polysaccharides: an interface between microorganisms and soil constituents. In: Huang, P.M., Berthelin, J., Bollag, J.M., McGill, W.B., Page, A.L. (Eds.), Environmental Impact of Soil Component Interactions, Vol. I. Natural and Anthropogenic Organics, Lewis, Boca Raton, FL, pp. 217-233.
COLOMBO C., MIANO T. (2015) Metodi di analisi chimica del suolo. Società Italiana della Scienza del Suolo – Associazione Italiana dei Laboratori Pubblici in Agrochimica.
COSTANTINI E.A.C. (2007) Linee guida dei metodi di rilevamento e informatizzazione dei dati pedologici – Ministero delle Politiche Agricole Alimentari e Forestali.
GERHARDT K. E., HUANG X.D., GLICK B.R., GREENBERG B. M. (2009) Phytoremediation and rhizoremediation of organic soil contaminants: potential and challenges. Plant Science, 176:20-30.
GIUPPONI L., CORTI C., MANFREDI P., CASSINARI C. (2013) Application of the floristic-vegetational indexes system for the evaluation of the environmental quality of a semi-natural area of the Po Valley (Piacenza, Italy). Plant Sociology, 50(2):47-56.
GIUPPONI L., CORTI C., MANFREDI P. (2014) The vegetation of the Borgotrebbia landfill (Piacenza,Italy): Phytosociological and ecological characteristics Plant Biosystems. 149(5):865-874.
IRSA (1983) Analisi della fitotossicità della sostanza organica in decomposizione mediante bioassaggio *Lepidium sativum*.- Metodi Analitici per i Fanghi: Parametri biochimici e biologici - Quaderno IRSA, 64:8.1-8.3.
LIFE 10 ENV IT 400 "New Life" www.lifepluscosistemi.eu
JONES R. J.A., YLI-HALLA M.. ALECONS D., LEIFELD J. (2004) Organic Matter an Biodiversity Status and distribution of soil organic matter in Europe in Reports of the Technical Working Groups (Vol. III) Organic Matter EUR 21219 EN/3.
MANFREDI P. CASSINARI C., TASSI D., TREVISAN M. (2013) Comparison between production data of corn growt in natural and reconstituted soils. Biochars, Composts and Digestates. Production, Characterization, Regulation, Marketing, Uses and Environmental Impact" (BCD 2013),17---20 October 2013 in Bari, Italy.
MANFREDI P., CASSINARI C., GIUPPONI L., TREVISAN M. (2014) Hydrological properties of natural and reconstituted soils: compared methods. European Geosciences Union, General Assembly 2014 Vienna, Austria 27 April - 02 May 20.
MANFREDI P., CASSINARI C., TREVISAN M (2014) Studio delle temperature in suoli naturali degradati a confronto con suoli derivanti dal loro trattamento (suoli ricostituiti) XII Convegno AISSA 6-7 novembre 2014 Atti.
MANFREDI P., CASSINARI C., TREVISAN M. (2015) Soil temperature fluctuations in a degraded and in a reconstituted soil Italian Journal of Agrometeorology, 3.

DOI: 10.6092/issn.2281-4485/6302

MICHEL R. (2004) Organic Matter an Biodiversity Status and distribution of soil organic matter in Europe in Reports of the Technical Working Groups (Volume III) Organic matter EUR 21319 EN/3.
MIKKONEN A., HAKALA K. P., KAISA L., KONDO E., VAALAMA A., SUOMINEN L. (2012) Changes in hydrocarbon groups, soil ecotoxicity and microbiology along horizontal and vertical contamination gradients in an old landfarming field for oil refinery waste Environmental Pollution, 162:374–380.
SALVI R., GIUPPONI L, CASSINARI C., BATTAGLIA R., MAROCCO A., TREVISAN M., MANFREDI P. (2014) Fluttuazioni stagionali della vegetazione di una discarica dismessa del piacentino Società Italiana di Scienze della Vegetazione—48° Congresso. 17-18-19 Settembre 2014, Roma
NEDUNURI, K., GOVINDARAJU, R., BANKS, M., SCHWAB, A., CHEN, Z. (2000) Evaluation of Phytoremediation for Field-Scale Degradation of Total Petroleum Hydrocarbons Journal of Environmental Engineering, 126(6):483-490.
OADES, J.M. (1995). An overview of processes affecting the cycling of organic carbon in soils. In: Zepp, R.G., Sonntag, C. (Eds.), The Role of Non-Living Organic Matter in the Earth's Carbon Cycle. Dahlem Workshop Reports. Wiley, New York, pp. 293-303.
PILON-SMITS E. (2005), Phytoremediation, Annu. Rev. Plant Biol., 56:15–39.
SKENE T.M., SKJEMSTAD J.O. OADES J.M. CLARKE P.J. (1996) The influence of inorganic matrices on the decomposition of straw Australian Journal of Soil Research, 34(3).
SULAIMAN A. ALRUMMAN A, DOMINIC B. STANDING B., GRAEME I. PATON (2015) Effects of hydrocarbon contamination on soil microbial community and enzyme activity. Journal of King Saud University – Science, 27: 31-41.
Suppl. Ord. G.U. n. 121 del 25.05.1992
Suppl. Ord. G.U. n.173 del 02.09.1997
TA-CHEN L., PO-TSEN P., SHENG-SHUNG C. (2010) Ex situ bioremediation of oil-contaminated soil Journal of Hazardous Materials, 176(1-3):27–34.
TASSI D. (2014) Terre Ricostituite e Terre Naturali confronto tra i due terreni in funzione della possibilità di ridurre la concimazione azotata in una coltivazione di Mais. Azienda Sperimentale Vittorio Tadini (www.mcmecosistemi.com/news _allegati/87- relazione-terre-ricostituite-2014.pdf).
UNI EN 13037 (2012) Ammendanti e substrati di coltivazione - Determinazione del pH.
UNI EN 13038 (2012) Ammendanti e substrati di coltivazione - Determinazione della conducibilità elettrica.
UNI 10802 (2004) Rifiuti - Campionamento manuale, preparazione del campione ed analisi degli eluati.
WALKLEY A., BLACK I. A. (1934) An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-37.
WONG M.H. (2003) Ecological restoration of mine degraded soils, with emphasis on metal contaminated soil. Chemosphere, 50:775–780.

LES SOLS RECONSTITUES: LA TECNOLOGIE E SON POSSIBLE EMPLOYEMENT DANS LA REHABILITATION DES SOLS CONTAMINES

Résumé

La technologie de reconstitution est une pedotecnique qui agit sur la structure du sol en y incorporant des composants de nature organique et de la qualité des minéraux et d'origine certifiée. Le système de traitement fonctionne par un procédé mécanique qui permet l'enduction de la matière organique dans la fraction minérale par la désintégration de la structure du sol et de sa reconstitution ultérieure. Les résultats obtenus par la technique dans le champ agronomique suggèrent que le méthode peut être utilisée pour faciliter la réhabilitation des sols contaminés par modification de leurs propriétés de façon ciblée.

Mots clés: *technologie de reconstitution, restaurer les sols, biorestauration, sols reconstitués, sols dégradés, sols contaminés*.

I SUOLI RICOSTITUITI: LA TECNOLOGIA E IL SUO POSSIBILE IMPEGO NELLA BONIFICA DEI SUOLI CONTAMINATI

Riassunto

La tecnologia della ricostituzione è una pedotecnica che agisce sulla struttura del suolo integrando in esso componenti di natura organica e minerale di qualità e provenienza certificata. Il sistema di trattamento opera attraverso un processo meccanico che consente il rivestimento della sostanza organica nella frazione minerale mediante la disgregazione della struttura dei suoli ed una sua successiva ricostituzione. I risultati ottenuti dalla tecnologia in campo agronomico suggeriscono che il metodo possa essere utilizzato per favorire la rimediazione dei suoli contaminati modificandone le proprietà in modo mirato.

Parole chiave: *tecnologia della ricostituzione, ripristino suoli, biorimediazione, suoli ricostituiti, suoli degradati, suoli contaminati.*

DOI: 10.6092/issn.2281-4485/6302