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## INNOVATIVE TREATMENT AND VALORISATION OF WASTE COMING FROM DIMENSIONAL STONES WORKING PLANTS: PIEDMONT SAMPLES

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### Abstract

Residual sludge management, for waste material coming from dimensional stones working plants, is a discussed problem, object of legislative changes and potential application developments. The main problems related to their management are: their size distribution (fine materials, potentially asphyxial), the presence of heavy metals (due to the treatment with gangsaw with abrasive shot and diamond framsaw) and the presence of TPH (mainly due to oil machines losses). The residual sludge management, considered according the Legislative Decree 152/06, can be used, as waste, for environmental restoration (R10) or for cement plants (R5). But It is also possible to think about their systematic treatment in consortium plats, for the production of secondary raw materials (filler, etc..) or "New Products" (eg. artificial loam).

The paper will report the results of a recent experimentation [AFIB working plant in Trino Vercellese – VC), to recovery such waste for the production of “artificial loam” (Bioremediation treatments (FORNARO & DINO, 2008; MEDINA ET AL., 2009)], basing on the first experimentations run out in Lodrino (CH) and in ACEA plant (Pinerolo – TO) [DINO ET AL. 2006]. During the experimentations a mix was produced, consisting of residual sludge, compost, natural loam, shredded green materials and nutrients. The components were designed to start up and accelerate the process of aerobic degradation, in order to transform the organic matter and obtain a structurally, chemically and biologically stable product. The final (new) product is an “artificial loam” with suitable characteristics to support a consortium vegetable, also once finished the organic fermentable components. The trials lasted from 8 (AFIB) to 12 (ACEA and Lodrino) weeks; during these periods the piles were periodically turned (to aerate and mix the material and stimulate the growth of microbial colonies able to degrade and mineralize organic matter) and monitored (by means of systematic sampling and physical-chemical analysis). In order to evaluate the quality of the artificial loam, phytotoxicity tests were set up on different test plants. It was also estimated the microbial load both on sludge as such and on produced artificial loam, to obtain an indication of the status of organic soils. The results confirm that the developed protocol offers the chance of handling such a waste material to produce a loam potentially useful for land reclamation of industrial and residential areas. They also show a good performance of the process (reduction of the concentration of heavy metals and increasing of organic matter). After all, it should be interesting to implement the experimentations of such applications, which are also interested by international patent (EU Patent No 1299265); several EU projects (past and present) concerned such topic.

## Purpose

The paper aims to demonstrate that, by mean of an appropriate bioremediation treatment of residual sludge (actually managed as waste, CER code 010413), it is possible to produce artificial loam for quarries or civil works rehabilitation. The treatment consists in a transformation and revitalization of an asphyxial material (very fine size distribution: more than 40% of them have a size distribution inferior than 25 $\mu$ m), thanks to the mixing and composting with organic materials and nutrients. At present time the residual sludge management and final disposal represent a big problem for the eco-sustainable development of quarry and mine activities.

## Methods

The bioremediation treatment of the residual sludge is one way to valorize such waste: it is an experimental method, not yet industrially applied, but quite promising.

The residual sludge employed for the three experimentation comes from siliceous (mainly gneisses and granites) dimensional stones quarries and working plants, and in particular, for what concerns working plants, It derives from the block working by means of gangue saw with abrasive shot and diamond frame saw. In the first case, the sludge contains, as pollutants, heavy metals coming from abrasive shot (Fe, Ni, Cr) and lime (used as antioxidant), in the second case, instead, they contains metals used as binder material for diamond cutting tools (Co, Cu). The solid fractions constitute, for their own chemical-physical characteristics, incoherent and asphyxiated masses, unusable, as such, for agricultural-rehabilitation. The sludge also contains a variable concentration on TPH (coming from working tools).

Heavy metals (Fe, Cr, Ni, etc...) can be separated and recovered using magnetic or gravimetric separation (DINO, 2004). Other substances immiscible with water, such as mineral oils, lubricants (C12-C40), etc..., require a specific degradation process not to pollute the material.

The paper outlines bioremediation process: the aim is to demonstrate that it is possible to decrement TPH pollutants, improve the physical structure of the sludge as such and contemporary obtain an “artificial loam” to use for environmental reclaim, etc... The proposed process is based on the mixing of: residual sludge (approx 60-75 % dry substance), natural loam (5-15 % d.s.), mature compost (5-15 % d.s.), shredded green material (10-20 % d.s.) and microbial specific activators<sup>1</sup>.

Each component is useful to start and accelerate a natural degradation process (under aerobic conditions), in order to convert the organic fermentable components and obtain a structurally, chemically and biologically stable product. It is not a simple fills with alternating layers of inorganic and organic materials (BURRAGATO ET AL., 1999) and nor a mere mixing of organic and mineral materials: it is an artificial loam able to support a vegetable consortium which can survive also when the initial organic fraction is completed run out.

Pollution by TPH/mineral oil represents the main part of chemical contamination that can be removed by biological treatment. The easy-to-moderate “biodegradability” of TPH requires, however, that the degrading agents (i.e. naturally occurring autochthonous, aerobic micro-organisms) have access to the pollutants. To product a good value “loam” it is necessary to ensure the constancy of the “raw materials”: in particular it has to be guaranteed a sufficient content of organic material, potentially fertile. A correct mixing, to form the piles for the “composting” treatment, is fundamental to uniform all the elements required for microbial activity in the material. It has to be foreseen a periodic piles-turning, in order to ensure the oxygenation of the mix: the piles turning have to be more frequent during the first 4 weeks and shall be once a 10-15 days during the last 4-8 weeks. The piles have to be located under a covered shed (as in ACEA experimentation) or under semi-permeable sheets (as done during Lodrino and Trino Vercellese tests), so that it is possible to prevent leaching phenomena (due to weathering).

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<sup>1</sup> provided by Envirorem – CH. European Patent nr.0962492: “procedure for land reclamation when contaminated by organic matters not easily biodegradable”.

The paper presents the results concerning three different experimentations: Lodrino (CH), ACEA Pinerolese (Pinerolo – TO, IT) and Trino Vercellese (VC – IT).

## Results

The first field test took place in 2002 (it lasted 12 weeks from July to October). The sludge came from Lodrino quarry basins (Canton Ticino, Switzerland). Such sludge was practically free of heavy metal because it came from the extraction (perforation with widia tools).

To obtain an homogeneous product, the materials were mixed using an excavator. Two stock piles were set out and the obtained mix was sieved to about 20-25mm. Once the mixing process ended, each piles were covered by a semi-permeable sheet, and there were periodical piles-turning.

It is possible to underline that, after the composing treatment, there was a quite good increase in the phosphorous, potash, magnesium, calcium, nitrogenous and organic carbon concentrations. And most of all the really important thing was the huge decrease in the TPH (from 715 mg/kg to 220 mg/kg in 12 weeks - 750 mg/kg limits for industrial land accretion – D.M. 471/99) and the wide increase in the CFU (from  $10^0$ - $10^1$  to  $10^7$ - $10^8$ ) (DINO ET AL., 2003).

The “artificial loam, obtained from the treatment”, was employed for a rehabilitation of a civil work (landside) (fig. 1).

The second experimentation was set out at ACEA Pinerolese composting plant (Pinerolo – TO), It lasted 12 weeks from March to June 2005). In this case sludge from Luserna Stone treatment were employed: from gangue saw with abrasive shots (Sludge A) and from diamond frame saw (sludge B). Their humidity was approximately 30%. In this experimentation nearly 140m<sup>3</sup> (250t) of sludge (type A, B and a mix of both) and 60m<sup>3</sup> (40t) of shredded green material, compost, topsoil and nutrients were used to get 4 different mixes. The obtained mixes were placed in a covered shed, placed in depression by suction filtration and air regulation. During the treatment in ACEA plant periodic piles turning and watering were carried out.

In sludge A (gangue saw with abrasive shot) it was observed the presence of higher amounts of Mg and Ca due to an addition of lime, while the increase of Fe and Mn is due to metal grit. The composition of sludge type B (diamond frame saw) instead does not significantly vary from the one of the starting material. (DINO ET AL., 2006)

At the end of the experimentation, some contaminants, such as TPH, were reduced within the limits of legislation (ex. DM 471/99), reaching 10 ppm content. The results of the analysis shows a yet high content of some heavy metals (Co - only for mixtures containing sludge B; Cr, Cu - for sludge A) and a not right content of organic carbon, humic and fulvic acids and C / N ratio (for two mixes). Such results are not surprising: it was not possible to produce a soil rich in organic matter, because of the high content of inert materials. This was not the purpose of experimentation, in fact, it was intended to get an “artificial loam” (fig. 2) for environmental recovery and not a fertilizer. And furthermore the content of heavy metals can be decreased by opportune magnetic or gravimetric separation (DINO, 2004).

By enhancing the “bioavailability” and/or by exponentially increasing the colony-forming units of the matrix (i.e. “bio-augmentation” from  $10^4$ - $10^5$  to  $10^7$ - $10^8$  CFU/g) both the physical/chemical soil structure and the reduction of the TPH pollutants (from 65-100 ppm to <10 ppm ) can be achieved in a reasonable 3 to 4 months’ period of operations (DINO ET AL., 2006).

The five different materials (four from the bioremediation process and one from natural soil) were used to fill different pots in which we sowed 10 seeds/pot (lentils, corn and wheat). During the agricultural experimentation phase It was possible to monitor different parameters, as plants germination (ten days after the seed-time) and growth (thirty days after the seed-time) (DINO ET AL., 2006). The mixes obtained from the treatment, according to the results from corn, wheat and lentils seeding, are not toxic, even if it is possible to evidence that the too fine grain structure and the trend to “package” is not good for the germination.

The total (ca 150 m<sup>3</sup>) of the 4 mixes was used for quarry rehabilitation in Luserna Stone Basin: it was scattered, with an 8-10 cm thickness) in a hill side in “Cava del Tiglio” Loc. Pra del Torno, in Rorà Village (TO), see figure 3.a (DINO ET AL., 2006). It is evident that in the area on which was placed the obtained “loam”, the vegetation appears to be very abundant and, thanks to the particle size, it guarantees the retention of considerable quantity of water, available during drought periods. At present time (April 2012, see fig. 3.b) it is possible to underline that, without any kind of maintenance, the quarry rehabilitation is still active and integrated with the surrounding scenery.



Figure 1: Loc. Lodrino (Canton Ticino), in this area it was used a “artificial loam” obtained from a bioremediation treatment, after some months from the seeding



Figure 2: product– mix A – from bioremediation treatment (ACEA di Pinerolo plant)



Figura 3.a: “Cava del Tiglio” Loc. Pra del Torno, in Rorà Village (TO), in this area it was used a “artificial loam” (mix A, C and D) compared to natural soil. The rehabilitation at the bottom is realized using only compost from ACEA (June 2008)



Figura 3.b: “Cava del Tiglio” Loc. Pra del Torno, in Rorà Village (TO), in this area it was used a “artificial loam” compared to natural soil and compost (at the bottom). (April 2012)

The latest experimentation was conducted in AFIB stone manufacturing company (Trino Vercellese); the sludge produced in the working plant came from granitic rocks (diamond frame saw sludge).

Also in this case all materials have been initially stored in piles, and, after a sampling of the single fractions, they were mixed, homogenized by means of a excavator and watering; the obtained mix was disposed in two piles - Trino I and Trino II. The piles were left on open air, on a cemented area, covered by semi-permeable sheets (similar to the ones used during Lodrino experimentation).

The trial lasted 8 weeks, during those period there was a periodically piles turning. The monitoring was realized in the same days of the piles turning. The problem connected to the experimentation

was the progressively colder temperature (treatment during the autumn and winter periods), which badly influenced the result of the test.

Observing the obtained results it is possible to underline that the final product complies with the limits of D.Lgs. 152/2006 and in most cases also those of D.M. 471/99 and D.Lgs. 748/84. In fact, only Cr and Ni exceed the specified concentrations; this is due to the high content of these metals in the sludge as such. A simple pre-treatment [magnetic or gravimetric separation (DINO, 2004)] of the sludge should guarantee significant reduction of such contaminants.

Nevertheless, strong evidence shows that plant growth was optimal: at least 75% compared to the witness (sand and peat), and with an active microbial load increased of about 3-4 orders of magnitude. The artificial loam could potentially guarantee, during several seasons, a suitable vegetable consortium. The organic and N content shows a good implementation, in fact C/N value is comparable to the one of agricultural loam. Humic and Fulvic acids content demonstrate the right evolution of the material and the good mineralisation of organic substances.

There is an increment of 4 order of magnitude in CFU: from  $10^4$  in sludge as such to  $10^8$  in products obtained at the end of the experimentation. The lab. tests on *Lepidum sativum* shows a germination and growth index superior than 75%.

The test on lentils, corn and wheat are good for the first 10 days. At 40 days the essences show traces of phytopathy, due, however, mainly to the cropping system and not to the employed substrate (Fig. 4)



Figure 4.a: wheat growth at 10 days



Figure 4.b: corn growth at 10 days

## Main conclusions

The open field scale-up project, coordinated by DST-University of Turin, extends the objectives of the emerging bioremediation technologies to the quarry fines and sludge remediation, recovery and re-use.

The described tests showed how it is possible, on the basis of a specific operating protocol, to employ different kind of "waste" to obtain a product to use for environmental recovery, both in residential and industrial areas. This technology guarantees the re-use not only of "quarry" and working plants waste, but also of urban shredded green material and compost.

The protocol requires not only to increase the amount of organic matter in general but also to modify the structure, giving a good stability to the final product.

Thanks to the contribution of specific micro-organisms, the microbial activity and variability are intensified, ensuring the improvement of chemical fertility of the soil and the heavy metals content decrement.

The availability of specific machinery, such as wood chippers, turning-pile machine, excavators, etc.. and the planning of continuous monitoring systems for chemical and physical parameters, influences the final result in a positive or negative way.

The analytical determinations of the pollutants demonstrated the real capacity of this technology to significantly reduce the presence of organic and inorganic pollutants. The addition of the *inoculum* was certainly crucial for the success of the conversion of starting materials.

After all, it should be interesting to implement the experimentations of such applications, which are also interested by international patent (EU Patent No 1299265); several EU projects (past and present) concerned such topic.

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