Theme B, ThS B2, New functions of the subsurface

AN INTEGRATED APPROACH FOR THE UTILIZATION OF WASTE ON SOIL – INNOVATIVE MANAGEMENT AND TECHNOLOGIES

Katalin Gruiz, Viktória Feigl, Emese Vaszita, Orsolya Klebercz, Éva Újaczky and Ágota Atkári
Budapest University of Technology and Economics, Dept. of Applied Biotechnology and Food Science
Budapest, Gellért tér 4, H-1111 HUNGARY, e-mail*: gruiz@mail.bme.hu

ABSTRACT

This paper introduces an environmental risk management approach based on the site specific risk associated with solid waste and its utilisation on soil. The presented waste utilisation applications include microcosm tests and field experiments on the remediation and improvement of degraded, contaminated soil and rock using wastes, the preparation of cultivation medium and geotechnical constructions from waste and the use of wastes as nutrient supply to reduce CO_2 emission into the atmosphere.

Keywords: waste reuse, degraded soil, contaminated soil, waste on soil, geotechnical construction

1. INTRODUCTION

Our soils are globally subjected to various soil degradation processes such as organic matter decline, acidification, erosion, compaction, pollution, etc. or they are *ab ovo* low quality soils, such as sand, waste rock, mooreland, podzol, low permeability soils, unable to fulfil land use requirement. Soil deterioration is a global environmental problem. If the soil starts to deteriorate, the rich, fertile areas will soon become barren! On the other hand management and disposal of various waste materials produced as a result of human activity is one of the actual problems to be solved worldwide.

Can we link the requirements of sustainable quality of soil with the goal of waste utilisation? There is an ancient invention: the 2500 years old *terra preta do indio*, namely the black indian soil. It is an artificially produced cultivation medium of the native Indians along the Amazonas which has even up to nowadays preserved its best soil qualities, humic substance content and fertility. It did not deteriorate and cannot be deteriorated.

The ancient native Indian knowledge combined with the modern engineering toolbox of environmental management may support an innovative approach: waste addition to the soil in a scientifically substantiated and conscious manner, normalization of the soil's carbon and other element cycles, protection of soils from deterioration, increasing soils' resistance to adverse effects, development from waste of cultivation media or suitable vehicle for geotechnical purposes.

The new approach and the scientific and engineering-knowledge based soil management could provide long term help for our soils suffering from globally occurring soil deterioration and may slow down the disadvantageous changes.

It sounds simple and obvious that the hidden values of wastes should be utilised, however the practical implementation is problematic and scarce. There is a large gap between the opportunities and real achievements. Due to the dispersion, to the lack of waste inventory, to the limits of the waste processing industry, waste exploitation is far behind the possibilities. Wastes are handled based on "default" characteristics, not the real values and risks.

2. MANAGEMENT FRAMEWORK OF WASTE UTILISATION ON SOIL

Risk Based approach combined with a Value Based evaluation of wastes makes possible the matching of certain wastes with degraded or low quality soils to find a technology for utilising the waste in soil remediation, amelioration and sustainable soil use, or utilising certain soils for waste elimination in a sustainable and eco-efficient manner (SOILUTIL, 2010).

Quantification of Environmental Risk and Life Cycle Assessment together are theoretically appropriate tools to evaluate the short and long term risks associated with the utilisation of waste in soil amelioration and to compare them with other waste treatment options. The short and long term risk resulted from non-appropriate handling and storing of wastes and from soil degradation can be quantified and compared with the utilisation of waste on soil. The values and advantages can also be quantitatively evaluated by technological and socio-economic evaluation tools. The two together could serve as a basis for a good decision making on the proper utilisation of wastes for soil-improvement (Gruiz, 2009).

Unfortunately risk based judgement and decision making is not fully applied in the waste management practice today. In spite of the successful individual applications neither Europe has got a comprehensive management methodology and toolbox on the utilization of wastes for soil improvement. The judgement of wastes based on a "default hazard", cannot take into consideration the chemical composition, the concrete contaminant content, the planned use-category and the site specific risk of the waste on soil. The same waste can pose no risk in one land use, but high risk in another one. The risk scenario should be created in every single case for proper risk calculation of the waste to be placed on soil. Considering the values in addition to risk, the use value of the waste may overweight its risk in the same use.

Figure 1 shows the scheme of the risk management concept of waste utilisation for soil improvement. The first step of the process is information collection on the waste, its origin, and composition, on the land and soil use at the place of application. The waste treatment and utilisation technology as well as the possible alternative options should be also listed in this initial phase. The next step is the creation of the risk scenario for risk calculation. The hazard of the chemical substances or of other hazardous components (e.g. hygienic) of the waste should be assessed based on the known adverse effects of the substance, of the mixture of substances or components of a product. The result of the hazard assessment is the "no effect" value, which is the predicted concentration or level, which does not pose risk on the environment (PNEC=Predicted No Effect Concentration for the ecosystem) and on humans (DNEL=Derived No Effect Level). The calculated "no effect" value should be compared to the predicted concentration in the soil and the connected environmental compartments after waste utilisation (PEC=Predicted Environmental Concentration). To calculate this value we have to take into consideration the fate, the behaviour and the transport, such as partition between soil phases, biodegradation and bioaccumulation of the waste components in soil. Calculation is done on a yearly-basis and sustainability is controlled based on the mean value of seasonal oscillation. The ratio of PEC and PNEC/DNEL is the Risk Quotient (RQ). This is an iterative process within which, data precision and calculation can be increased if the conservative estimates do not fulfil the $RQ<1$ criteria. When managing the risk of waste utilisation on soil we have to understand that the hazard associated with the waste differs from the land-use specific risk of waste utilisation on soil. Even if there is some risk it can be fully controlled and, the value-based benefits may overcompensate the risks. Smart, risk-based compromise may lead to the acceptance of a low-risk utilisation of waste on soil compared to a high risk or very highcost waste disposal or other physico-chemical waste treatments. The last and most important task of efficient waste management is the publication of the results and making the information accessible for interested parties. The IT-tools available today may completely fulfil these requirements.

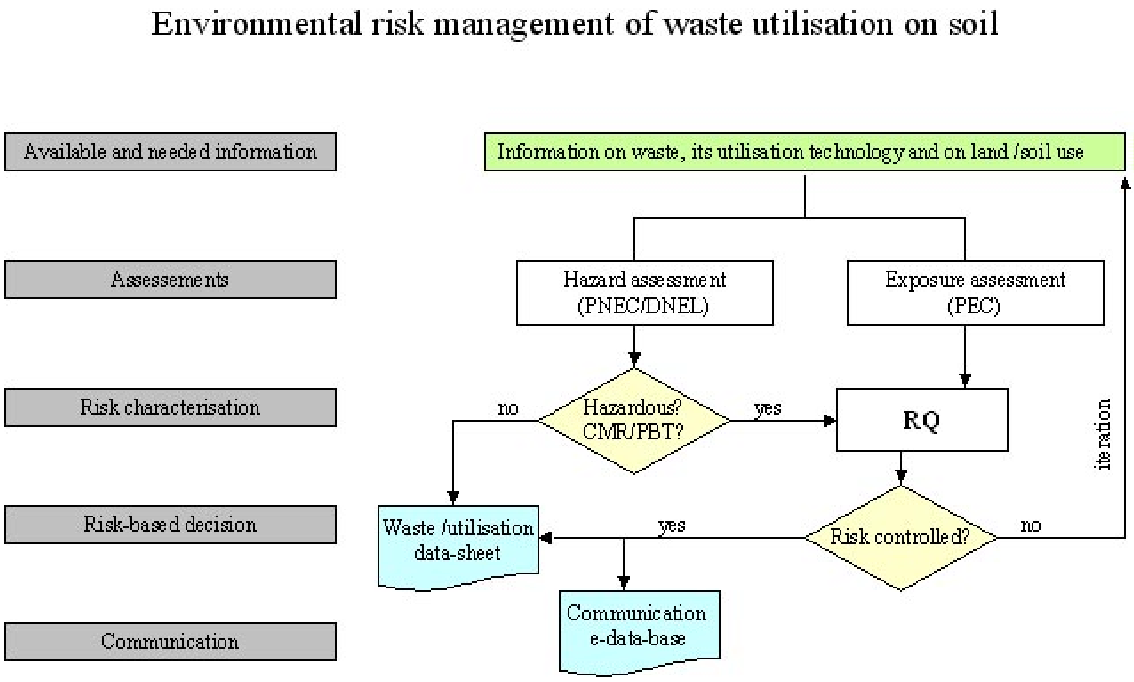
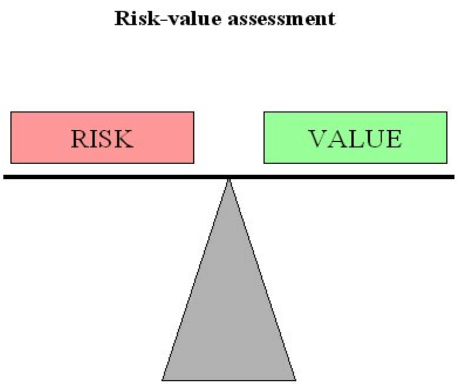


Figure 1 Environmental risk management scheme of waste reuse and recycle

Nowadays another shortcoming is, that the numerous applications described in literature are all single cases. The successfully used wastes and applied technologies have not been collected in a database, have not been utilized systematically or consciously. Communication of the successful cases and keeping the records in a database is an essential tool for efficient waste management including waste reuse, recycle or waste reduction.



A Risk Based approach combined with a Value Based evaluation of wastes makes possible the matching of certain wastes with degraded or low quality soils and finding a technology to utilise the waste in soil remediation, amelioration and sustainable soil use, or utilising certain soils (as an active reactor) for waste elimination in a sustainable and eco-efficient way. The ratio (weight) of the risk and value (Figure 2) of waste utilisation on soil can be calculated only on the basis of quantitative “risk” and “value” data.

Figure 2 Risks and values of waste utilisation on soil

The essential management tools are based on comparative evaluation and verification of waste utilisation, soil amelioration and remediation technologies. Verification is performed based on demonstration projects employing a well fitting, targeted, integrated technology- and environment-monitoring during the waste utilisation on soil, including physico-chemical, biological and environmental toxicity testing.

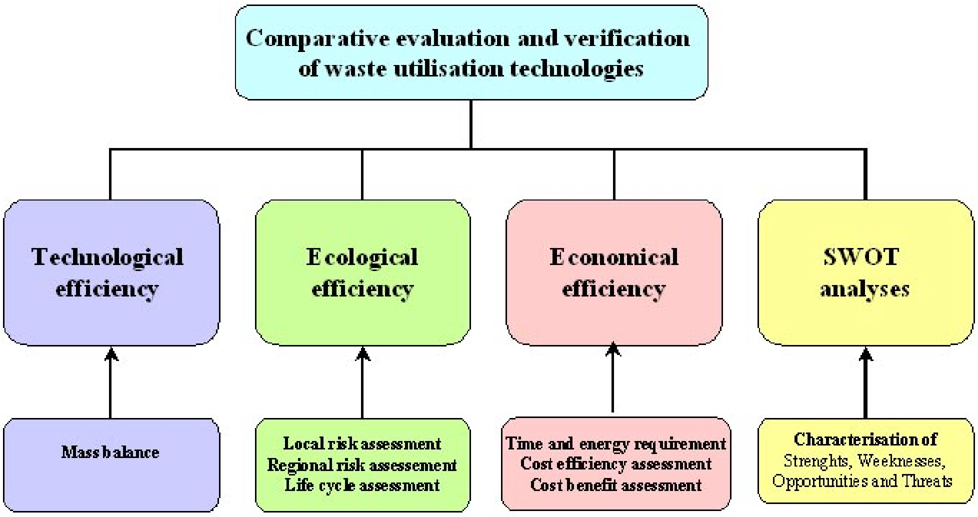


Figure 3. Evaluation of waste utilisation technologies on soil

The verification and comparison tool consists of four compartments: 1) technological efficiency is evaluated considering the mass balance, 2) ecological or environmental efficiency have three further elements, the local risks, which consist of an increasing (waste "discharge") and a decreasing (better soil quality) component, the regional risks (lower waste disposal and incineration, etc.) and the Global risks (green-house effects, ozone depletion, etc.). 3) The economic assessment and comparison is based on monetarized values. 4) SWOT is able to complement the characterisation with qualitative point of views.

3. PRACTICAL APPLICATIONS OF WASTE ON SOIL

In the mutual process of reducing waste and increasing soil value, large variety is drawn up by methodologies from eliminating hazardous components of the carbon-cycle to ensuring fertility of soil as a result of the activity of the complex bio-cycle of the ecosystem. Some examples from our own developments:

1. Waste pre-treatment technologies, to increase suitability of waste for utilisation on soil;
2. Geotechnical constructions from waste, such as: draining layers, capillary barriers, permeable capillary layers under and above covers, vertical and horizontal filter layers, underground reactive barriers and reactive soil zone fillings, stabilised top or underground soil for geotechnical or construction purposes,
3. Remediation of degraded soil and rock: chemical stabilisation using waste materials to improve permeability and water supply of weathered, leached or sulphidic mine wastes;
4. Remediation of contaminated soil by immobilisation/stabilisation of toxic metals within dumped mine wastes and its environment or contaminated soil and sediment using waste mixtures as stabilisers;
5. Rehabilitation of land by a cultivation medium based on the addition of pre-treated waste-composite
5. Amelioration and nutrient supply of soil by using wastes with adequate components to fulfil special soil needs;
6. Waste elimination in/on soil: using a certain soil volume as a quasi-reactor for (gas, liquid or solid) waste elimination/conversion/detoxification applying different scale of control from natural attenuation of the added waste until the fully controlled soil-filled reactor techniques. The monitoring of wastes and their fate and behaviour in soil, CO_2 trapping and element life cycles and their modification in case of utilisation on soil, are necessary activities.

3.1. Waste utilization for increasing soil quality of highly degraded soil

Successful applications all over the world justify the application of valuable waste on soil. Both organic and inorganic waste may increase soil quality, including texture, water- and air-economy and nutrient content, even plant-specific nutrient-content. Busby *et al*. (2007) published improvement of highly degraded soil using organic waste with and without composting after separation from municipal waste. Price and Voroney (2008) reported about the soil improving effect of the paper industry waste, and López-Piñeiro *et al*. (2008) about the beneficial effect of the oil industry waste on degraded soil. The scale mud from water treatment was successfully applied as nutrient in soil by Cavaleri (2004). The soil improving effect of wood ash and fly ash has been reported by many authors, among others Pathan *et al*. (2000) and Patterson *et al*. (2004).

From our experience we can mention two successful applications: the revegetation of mine waste rock with fly ash amendment and the direct application of vegetable oil production waste on low nutrient soil.

3.1.1. Revegetation of barren waste rock by the application of fly ash – field demonstration

Material of a one million tons mine waste rock dump with medium and low toxic metal content was treated in an experimental plot with fly ash as metal stabilising and plant nutrient amendment. On the effect of fly-ash treatment the plot has been habitated by seeded grasses then successively by the native flora (MOKKA, 2009). Table 1 shows the effect of fly-ash treatment on the mine waste (As: 214; Cd: 7.8; Zn: 1295; and Pb: 749 mg/kg) by measuring the changes in its water soluble metal-contents and metal uptake measured both by laboratory bioassay using test-plants and naturally growing grass.

Table 1 Fly-ash treated barren waste rock: water soluble metal concentration and metal uptake by plants

	Water extract (mg/kg soil)				Plant bioaccumulation in bioassay (mg/kg dry plant)				Naturally grown grass metal uptake (mg/kg dry plant)			
Treatment	Cd	Zn	Pb	As	Cd	Zn	Pb	As	Cd	Zn	Pb	As
Control	0.24	25.7	0.56	132.0	1.9	345	11.3	0.8	2.8	561	117	13.0
5% fly ash	0.01	0.06	0.06	40.5	0.3	85	3.5	0.8	0.5	190	2.0	0.8

3.1.2. Utilisation of wastes for increasing soil activity and trapping CO_2 – microcosm experiments

The addition of 5% sunflower-oil production waste with 8–10% vegetable oil- and phospholipid-content increased the soils cell number and microbial activity both in aerated (flow-through) and closed microcosms. Table 2 shows the results of total measured CO_2-emission from the 500 g soil containing flow-through reactor, the bacterial cell concentration and their specific contribution to the measured outflow of CO_2, which is only part of the total produced amount when lime is applied, given that lime is able to react *in situ* with part of the bacterially produced CO_2. The addition of lime to the soil ensured the trapping of the increased CO_2 produced by the soil microbes when degrading the waste, as the results show. Results are introduced by Klebercz *et al*. (2010) in detail.

Table 2 Changes in CO_2 production and cell numbers on the effect of the oily waste application on soil

Treatment	CO_2 production (mmol)	Cell concentration (cell/g soil)	Specific CO_2 production (mmol/cell 10^{10})
Control	1.0	9.0×10^6	2.0
5% oily waste	1.9	7.5×10^7	0.5
5% oily waste + lime	1.2	2.3×10^8	0.1

3.2. Topsoil for seeding embankment slopes and low quality agricultural soils

Typically in Hungary the extensive tailings ponds and waste disposal sites are covered by good quality materials, living soil originating from earthworks, excavation for underground railway constructions etc. There were some trials to cover waste storage sites (red mud dumps) by artificially produced cultivation medium. These initiatives however often fail due to the incorrect planning of the utilized waste mix and of the implementation of the methodology. In general, these practices did not result any publication and were not preceded by extensive research.

Takahashi *et al.* (2010) used several kinds of waste in field experiments to produce „topsoil" for seeding embankment slopes. The „topsoil" was made by mixing four kinds of waste material (waterworks sludge, composted sewage sludge, crushed wood and sawdust from a mushroom bed and waste dust from the cognac-making process. The results of the experiment showed that the produced „topsoil" material could be used to maintain the natural cyclic function of plants by forming the topsoil layer on an embankment slope and the „topsoil" promoted vegetative growth.

Sewage sludge in a proper ratio has both reduced the mobility of heavy metals in the soil and has a positive effect on the produced plant as published by Theodoratos, in 2000. The soil amelioration effect of composted sewage sludge prevails mainly on soils with unfavourable hydrophysical properties, low organic matter, and decreased biological activity. Mixing composted sewage sludge into the soil is successful in sandy soils with poor colloid content, in acidic soil types, and in soils with shallow rooting depth. In heavy textured soils it takes effect by loosening the compacted soil structure and increased water retention capacity. A Hungarian study by Bihariné (2002) has demonstrated that sewage sludge can reduce both the water deficit in the growing season and the rate of soil erosion. In Hungary, 131,248 tons dry matter sewage sludge is produced yearly in sewage farms, about 100,000 from it is suitable for utilisation on soil, but only 30,000–40,000 tons of sewage sludge (dry matter) is used per year, mostly on agricultural fields.

From our own practice we can introduce a demonstration case on the creation of fertile cover layer on the red-mud tailings dump in Almásfűzitő, Hungary (BÁNYAREM, 2008). Composted agricultural and municipal wastes mixed with waste rock was utilised for the creation of the artificial cultivation medium, which fulfilled the role of and successfully substituted normal soil: plant growth was intensive, plant cover ensured tight closure of the surface and normalisation of the waste-based artificial soil on long term (MOKKA, 2009; Murányi, 2008).

These examples show the need for a risk based management and a database including new case studies besides the existing successful applications. Taking into account the soil quality requirements the database would offer larger possibilities for waste utilisation.

3.3. Reduction of metal mobility in contaminated soil using wastes

Toxic metals are widely contaminating our large floodplain soils and the proximity of industrial sites, where the pollution is diffuse and derives from air. Excavation, soil removal and its substitution with "new" soil is not feasible at these sites. Risk of metals at diffusely polluted large areas can be reduced by decreasing the mobility and bioavailability of metals in soil. According to the literature survey on this subject the following inorganic and organic industrial by-products and wastes have been used as immobilising agents: various fly ashes, red mud, precipitate from potable water treatment, red gypsum, phosphogypsum, dolomite residues, steel shots, sugar foam, sewage mud, sulphates, lime, calcium sulfate, iron sulfate, Ca-carbonate, Ca-hydroxide, Na-carbonate, chloride, sulphate, sulphur, carbon, permanganate, perchloric acid, persulfates, etc.

3.3.1. Reducing metal mobility in agricultural soil from a flooded hobby-garden – microcosm

The soil of a hobby garden exposed to regular floods at a catchment area diffusely contaminated with toxic metals due to mining activities was treated with wastes in microcosms with the aim of immobilising toxic metals in soil. The total metal concentration in soil was Cd: 6.7; Zn: 1131 mg/kg, which from 16% is water-soluble under natural conditions. The utilised wastes were flay ash A (pH=12.6), fly ash B (pH=9.7), and Fe-Mn-precipitate, the residue of drinking water treatment. All of the wastes efficiently reduced Cd and Zn mobility in the soil, resulting in decreased water solubility and plant metal uptake.

Table 3 Effect of fly-ashes and water-works waste on water solubility and plant uptake of Cd and Zn

	Water extractable metal (mg/kg soil)		Plant uptake in bioassay (mg/kg plant)	
Treatment	Cd	Zn	Cd	Zn
Control	1.1	181	2.99	743
5% fly-ash A	0.004	0.32	0.87	218
5% fly-ash B	0.070	2.8	1.25	196
Fe-Mn precipitate	0.004	0.10	0.85	94

3.3.2. Reducing metal mobility in agricultural soil from a flooded hobby-garden – field experiment

Field experiments were carried out on the soil of the flooded hobby-garden (average contamination: Cd: 5.2 and: Zn 1102 mg/kg soil) to demonstrate the beneficial effect of metal-immobilising wastes. Table 4 shows the results of fly-ash application on the soil of the hobby-garden, resulting in a decrease of water soluble Cd and Zn and plant uptake by the plant species grown on the experimental plots.

Table 4 Water-extractable and plant available Cd / Zn from flooded garden soil on the effect of fly-ash

	Water extract (mg/kg)		*Sorghum sudanense* mg/kg		*Zea mays* (mg/kg)		*Sorghum vulgare* (mg/kg)	
Treatment	Cd	Zn	Cd	Zn	Cd	Zn	Cd	Zn
Control	0.05	4.1	3.0	348	5.3	665	6.6	503
Fly-ash	<0.004	0.3	0.9	104	1.6	301	0.7	108

3.4. Remediation of contaminated land degraded soil due to industrial activity

Former industrial areas, brown-fields, surfaces and soils of historical mining sites, surroundings of waste disposal facilities, areas with secondary and dispersed pollution, diffusely polluted areas exposed to erosion and flooding by contaminated sediments are in the worst condition.

There are unique solutions to contaminated land degraded due to industrial activity, the earliest in Europe was Vangronsveld *et al*. (1995a, 1995b and 1997) who have demonstrated that considerable risk reduction is possible to be achieved by in situ chemical stabilisation of diffusely metal-polluted sites. Vangronsveld primarily applied successfully fly ash and organic wastes. The group of the Budapest University of Technology and Economics has achieved perfect stabilisation of toxic metals in mining wastes with the addition of fly ash and lime mixture in field conditions (Feigl *et al*., 2009).

From our practice we introduce some microcosm and field results, whereby the risk of the contaminated soil or rock was successfully decreased and plant growth was accelerated by the addition of different wastes to the metal contaminated mine waste.

3.4.1. Effect of fly ashes with and without lime for metal immobilisation in acidic mine waste – microcosm

Fly ashes T (pH=7.2) and V (pH=6.4) were applied individually or together with lime to immobilise Cd and Zn in acidic mine waste. The mine waste was a highly weathered sulfidic rock, derived from a mine waste disposal site, with Cd: 5 mg/kg and Zn: 1180 mg/kg contents. Water extractable Cd and Zn and plant uptake from the soil was followed in long-term (2,5 years) laboratory microcosm experiments. The final results are shown in Table 5.

Table 5 Effect of fly-ashes on water solubility and plant uptake of Cd and Zn from mine waste

	Water extractable metal (mg/kg soil)		Plant uptake in bioassay (mg/kg plant)	
Treatment	Cd	Zn	Cd	Zn
Control	0.34	57.0	0.7	190
5% fly-ash T	0.09	11.6	0.5	100
5% fly-ash T + lime	<0.004	0.22	0.5	104
5% fly-ash V	0.08	9.5	0.5	100
5% fly-ash V+ lime	0.04	0.42	0.5	90

The fly-ashes efficiently decreased the mobility of Cd and Zn in the acidic mine waste, the addition of lime further lowered the extractable amount of the metals.

3.4.3 Red-mud for metal immobilisation in contaminated soil and acidic mine waste – microcosm

Cd- and Zn-contaminated agricultural soil and acidic mine waste was treated with 5% red-mud and the effect on metal solubility and plant uptake were measured in samples taken from long-term microcosms.

Table 6 Effect of red-mud on water solubility and plant uptake of Cd and Zn from soil and mine waste

	Water extractable metal in soil (mg/kg)		Contaminated soil plant uptake in bioassay		Acidic mine waste water extract mg/kg		Acidic mine waste plant uptake in bioassay	
Treatment	Cd	Zn	Cd	Zn	Cd	Zn	Cd	Zn
Control	0.01	0.48	2.2	119	0.02	0.63	2.1	217
5% red-mud	<0.004	0.10	0.35	88	<0.004	0.10	2.6	191

The results in Table 6 show that red-mud is able to decrease water solubility in both soil and mine waste, it was able to lower plant uptake of Cd and Zn from soil but not from acidic mine waste.

3.4.5 Arsenic immobilisation in soil – lysimeter type microcosms

Alkaline fly-ash and lime is able to mobilise arsenic, if it is present in soil and mine waste. Iron grit or elemental iron waste is able to reduce the mobility of arsenic. The effect of elemental iron was studied in laboratory lysimeters on a fly-ash treated mine waste containing As: 400 mg/kg, Cd: 5 mg/kg, Zn: 1400 mg/kg and Pb: 2000 mg/kg and metal leaching by water was measured. One-year precipitation was modelled and some results are shown in Table 7. Arsenic leaching could be reduced with elemental iron.

Table 7 Changing metal content of the leachate from mine waste on the effect of fly-ash and iron-grit

	Metals in the leachate after 1 month (μg/L)				Metals in the leachate after 10 months (μg/L)			
Treatment	As	Cd	Zn	Pb	As	Cd	Zn	Pb
Control	1.8	211	75,500	64	1.8	40	6,000	1.5
5% fly-ash (FA)	7.3	0.1	33	1.5	5.0	0.1	35	1.5
FA + iron-grit	1.8	0.6	28	1.5	1.8	0.1	14	1.5

3.4.1. Risk reduction and revegetation of degraded acidic waste rock – field demonstration

Extremely degraded, weathered, toxic metal contaminated waste rock, with no nutrient content and no vegetation was successfully remedied by the addition of alkaline fly ashes, or non-alkaline fly ashes mixed with lime. Later on, to compensate arsenic mobilisation due to alkalinity, the plots were treated with elemental iron in the second year. After the plants have been settled, the process of normalisation took place automatically, further acidification has stopped, metal leaching has been terminated, pH has been normalised, seepage and drainage water have not been contaminated any more and the soil became non toxic.

Table 8. Effect of fly-ash, lime and iron grit on metal mobility in mine waste and metal uptake of plants – monitoring results at the end of the three years long field experiments

	Water extractable metal conc. (mg/kg mw)				Plant uptake in bioassay / on the plot (mg/kg)			
Treatment	As	Cd	Zn	Pb	As	Cd	Zn	Pb
Control	0.1	0.65	109	14.5	2.3/npg	1.5/npg	250/npg	20/npg
FA + IG	<0.08	0.04	5.6	0.40	1.9/2.5	1.0/2.8	180/250	18/20
FAL + IG	0.1	<0.004	0.31	0.06	1.3/1.8	0.4/0.2	80/60	3/5

FA: fly-ash; FAL: fly-ash+lime; IG: iron-grit applied in the second year only, mw: mine-waste, npg: no plant growth

The 3 years long experiments demonstrated that the toxic metal content of degraded soils can be *in situ* immobilised, thus metal emission from the soil, metal transport through water and metal uptake by plants are appropriately restricted. The soil texture, humus formation and water circulation are improved. By plant growth stimulation the barren soil gets vegetated, therefore erosion is also considerably mitigated.

3.5. Geotechnical constructions from industrial and demolition waste

Production of geotechnical constructions from industrial by-products and wastes started during the last 4–5 year. In situ stabilisation of soft, fluid, instable soils by addition of binders of waste origin has had a large acceptance mainly in the Scandinavian countries and the Netherlands. A confined disposal facility (CDF) was constructed in the Norwegian Trondheim harbour for storage of 11 000 m^3 dredged sediment contaminated with PCB, PAH, TBT and toxic metals (2002–4). The harmful substances were stabilised in the CDF with binders of waste origin. Only cement containing stabilisation material, cement + silica and cement + fly ash was tested in laboratory. Necessary axial compression strength was estimated to be 100 kPa and the binder mixture gave strength of 250 kPa and based on the result of the leaching tests the cement 80 kg/m^3 + fly ash 40 kg/m^3 mixture proved to be the most efficient (ALLU, 2004).

The stabilisation/solidification technology may have high importance in road construction and foundation industry. An experimental investigation was performed by Papageorgiu *et al*. (2010) to test cement, flyash alone and the combinations of the two as binders to stabilise typical building sand. The compressive strength of the stabilised specimens was compared and the results indicated that where the proportion of the flyash was much higher than the proportion of cement there was almost no difference between the values of compressive strength after 7 and 28 days. However the quality of the flyash plays a vital role in the development of the compressive strength. Therefore further extensive testing is needed before any generalisation of this result can be made.

The construction debris is widely used in road constructions (Pitzini-Duée and Rentz, 2001), however there are many other options for reuse, such as covering of waste disposal surface. Harder and Martin

(2001) studied the use of construction debris as permeable wall material instead of sand or gravel. The fine grained material obtained concrete crushing can be used according to Moebius and Mueller (2001) as hydraulic and secondary binder and fabrication of insulation material. The dehydrated calcium sulphate obtained as by-product of the lime burning furnaces turns into solidified gypsum after water uptake and was applied for strengthening of roads, construction of drainage channel ditches or covering of mud storage reservoirs (Tonks *et al*., 2007). The waste glass foam was used as light weight fill for increasing the resistance of slopes and for the construction of the retaining walls by Onitsuka *et al*. (2001). Waste tyres were used to hinder underground erosion and seepage by Fang and Kaya in 2001.
The crushed concrete and brick aggregates were examined in laboratory by Varin *et al*. (2010) to get as high quality construction fill materials as possible and to enhance the utilisation of crushed concrete and brick products in Finland. As a result of these experiments it is recommended to separate concrete and brick during demolition in order to improve the technical properties of the recycled materials. Crushed concrete can substitute traditional aggregates in almost every type of earth structure because of its self-cementing properties. Crushed brick may be used in a sub-base layer, subject to light loading and also in landscaping. The crushed sand-lime-brick aggregate can be used as upper capillary layer, while the crushed concrete aggregate would replace the lower capillary block according to Harder *et al*. (2001).

Our own developments concentrate on the use of construction debris for geotechnical constructions with targeted capillary characteristics, after processing the debris by grinding and grain-size fractionation.
Our first development is a capillary multilayer (sandwich) between red mud and cover soil. The lower layer, made of the course fraction of concrete debris, is for hindering alkaline water uptake by the cover soil from the red mud, it functions as a capillary barrier. The upper layer is for normalizing water-household and water-holding capacity of the soil cover by retaining the water and providing supply for the plants grown on top of it, – so that it becomes able to function as habitat for plants. A special laboratory tool-box has been developed for testing and monitoring water transport, partition, distribution in and between the layers of different capillary characteristics.

Acknowledgements

The research of waste utilisation on soil in the frame of SOILUTIL Project is funded by the Hungarian National Technology Program's Liveable and Sustainable Environment subprogram (TECH 09 A4).

References

ALLU Stabilisation System, 2004, www.allu.net

BANYAREM Project (2005–2007) Risk reduction of diffuse pollution from mining activities, HU GVOP 3.1.1-2004-05-0261/3.0

Bihariné Krekó I., 2002, Komposztálás, Környezetünk Magazin, www.kornyezetunk.hu

Busby, R. R., Torbert, H. A., Gebhart, D. L., 2007, Carbon and nitrogen mineralization of non-composted and composted municipal solid waste in sandy soils, Soil Biology & Biochemistry 39, pp. 1277–1283

Fang, H.Y., Kaya, A., 2001, Use of scrap waste rubber tire as protective filters, In: The exploitation of natural resources and the consequences (eds. Sarsby and Meggyes), Thomas Telford, London

Feigl, V.; Anton, A.; Fekete, F.; Gruiz, K., 2009, Combined chemical and phytostabilization: field application, In: Land Contamination & Reclamation (Eds. Gruiz, K. and Meggyes, T.), 17 (3–4), pp. 579–586, EPP Publ. Limited, UK

Feigl, V., Atkári, Á., Anton, A., Gruiz, K., 2007, Chemical stabilisation combined with phytostabilisation applied to mine waste contaminated soils in Hungary, Advanced Materials and Research, Vols. 20–21, pp. 315–318

Feigl, V.; Anton, A.; Fekete, F. and Gruiz, K., 2008, Combined chemical and phytostabilisation of metal polluted soil – From microcosms to field experiments – In: Proceedings of the 10th International UFZ-Deltares/TNO Conference on Soil-Water Systems in cooperation with Provincia di Milano, ConSoil 2008, "CD" (3–6 June, 2008, Milano, ISBN 978-3-00-024598-5), Theme E, 823–830

Gruiz, K., 2009, Scientific and engineering ‘improvement’ of environmental risk management, In: Land Contamination & Reclamation (Eds. Gruiz, K. and Meggyes, T.), 17 (3–4), pp. 343–346, EPP Publications Limited, UK

Harder, H., Martin, H., 2001, Recycled building materials as components for capillary barriers, In: The exploitation of natural resources and the consequences (eds. Sarsby and Meggyes), pp. 163–169, Thomas Telford, London

Klebercz, O.; Gruiz, K.; Feigl, V. and, Anton, A., 2010, Introducing the SOILUTIL Project, In: Proceedings of ConSoil 2010

López-Piñeiro, A., Albarrán, A., Rato Nunes, J.M., Barreto, C., 2008, Short and medium-term effects of two-phase olive mill waste application on olive grove production and soil properties under semiarid mediterranean conditions, Bioresource Technology 99, pp. 7982–7987

Moebius, A., Mueller, A., 2001, Re-use of recycled concrete sand fraction, In: The exploitation of natural resources and the consequences (eds. Sarsby and Meggyes), Thomas Telford, London

Murányi, A., 2008, Modern Engineering tools for risk-based environmental management, NKFP 3-020-05 Project Report by RISSAC

Onitsuka, K., Shen, J.N., Yokoo, M., Hara, Y., 2001, Case studies of utilization of Foamed waste Glass (FWG) as lightweight fill material, In: The exploitation of natural resources and the consequences (eds. Sarsby and Meggyes), Thomas Telford, London

Papageorgiou, G.; Hytiris, N., 2010, Effect of partial substitution of cement by pulverised fuel ash on the compressive strength material, In: Construction for a Sustainable Environment (eds. Sarsby and Meggyes), pp. 399–404, Taylor & Francis Group, London

Pathan, S.M., Aylmore, L. A. G., Colmer, T. D., 2003, Soil properties and turf growth on a sandy soil amended with fly ash, Plant and Soil 256, pp.103–114

Patterson, S. J., Acharya, S. N., Bertschi, A. B., Thomas, J. E., 2004, Application of Wood Ash to Acidic Boralf Soils and its Effect on Oilseed Quality of Cano, Agron. J. 96, pp. 1344–1348

Pitzini-Duée, B., Rentz, O., 2001, Assessment of the building stock as an alternative supply for raw materials in engineered construction, In: The exploitation of natural resources and the consequences (eds. Sarsby and Meggyes), Thomas Telford, London

Price, G. W., Voroney, R. P., 2008, Response to annual applications of de-inked papermill biosolids by field earthworms on three agricultural soils, Applied Soil Ecology 3 8, pp. 230–238

SOILUTIL Project (2009–2013) Soil amelioration by innovative waste utilisation technologies, Liveable and Sustainable Environment, TECH 09 A4, Funded by the Hungarian National Programme, Report, 2010

Takahasi, I.; Ishida, T.; Ohki, T.; Ohki, T., 2010, Recycling different wastes to produce ’topsoil’ for seeding embankment slopes, In: Construction for a Sustainable Environment (eds. Sarsby and Meggyes), pp. 177–184, Taylor & Francis Group, London

Theodoratos P. *et al*., 2000, The use of municipal sewage sludge for the stabilization of soil contaminated by mining activites, Journal of Hazardous Material 77, pp. 177–191

Tonks, D.M., Mott, A.P., Manning, D.A.C., 2007, Landfilling and re-use of calcium sulphate waste, In Geotechnical and Environmental Aspects of Waste Disposal Sites (eds: Sarsby and Felton), Taylor and Francis Gruop, London

Vangronsveld, J., Colpaert, J. V., Tichelen, K. K., 1997, Reclamation of a bare industrial area contaminated by non-ferrous metals: physico-chemical and biological evaluation of the durability of soil treatment and revegetation, Environmenatl Pollution 94, pp. 131–140

Vangronsveld, J., Sterckx, J., Van Assche, F., Clijsters, H., 1995b, Rehabilitation studies on an old non-ferrous waste dumping ground: effects of revegetation and metal immobilization by beringite, Journal of Geochemical Exploration 52, pp. 221–229

Vangronsveld, J., Van Assche, F., Clijsters, H., 1995a, Reclamation of a bare industrial area contaminated by non-ferrous metals: in situ metal immobilization and revegetation, Environmental Pollution 87, pp. 51–59

Varin, P., Kolisoja, P., 2010, Use of crushed concrete an crushed brick as structural fill, In: Construction for a Sustainable Environment (eds. Sarsby and Meggyes), pp. 421–426, Taylor & Francis Group, London