Changes in Vegetation and Soil Properties - A Case Study of a Quartz Quarry

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Summary

The paper presents results of an investigation on Technosols. The soils are located in “Podgumer” quartz quarry, village of Podgumer, district of Sofia, Bulgaria. Samples were collected upon deposit, 5 and 9 years after deposit. A phytocenological description was made 5 years after deposit and 9 years after deposit. Soil samples were taken from forty-five soil pits at a depth of 0-20 cm. The vegetation in the area is related to the rhizome - leguminous stage. There are statistically significant differences (a downward trend) in the bulk density of the samples collected 5 and 9 years after deposit. There is a statistically significant increase in total porosity after the establishment of vegetation. The presence of vegetation also results in statistically significant changes in the chemical characteristics (pH, SOM, TKN, P_2O_5, K_2O). The establishment of vegetation and the increase in plant diversity result in the increase in TKN, P_2O_5, K_2O, where existing changes have been described using reliable linear regressions.

Key words

technogenic soils, vegetation, soil physical and chemical changes, regression, quartz quarry

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INTRODUCTION

Human activities have brought about significant changes in the Earth's surface (more than 30% of the Earth's surface), with more than two thirds of these areas being located in Europe (Primack et al., 2012; Chenota et al., 2017). In the early 1980s under the pressure of local communities mainly in developed countries, the issue of landscape quality after mining activities became a matter of concern in projects (Schulz, 1996; Corry et al., 2010). The large number of disused quarries or of those being closed down in numerous countries poses a challenge for the restoration of these severely disturbed habitats (Bradshaw, 1997; Darwish et al., 2011; Mouflis et al., 2008). Different ecosystems develop as a result of the interactions among organisms and their responses to geological, topographic, hydrological and weather conditions. Any disturbance of these conditions can adversely impact the habitats (Nieman and Merkin, 1995). Mining activities are one of the oldest causes for changes in the Earth's surface (Larson et al., 2006; Hristova, 2013). Unlike underground mining where the impact is more localized (Bradshaw, 1997), open-pit mining has a greater environmental impact. The mining industry drastically changes the physical and biological characteristics of the mining areas by destroying flora and fauna, changing soil characteristics and limiting soil microbiocenoses. Thus, abandoned mine lands prove difficult to be revitalized and reused (Corbett et al., 1996). Habitats may be adversely impacted by ecological severance (Nieman and Merkin, 1995), and ecosystem degradation in most post-mining areas is mainly caused by vegetation destruction (Singh et al., 2004; De Deyn et al., 2003). The environmental disturbances that are the most difficult to reclaim are the ones caused by quartz mining. This is mostly due to their specific characteristics and to the light colour of the terrain, which greatly reduces landscape quality and makes it visible even from a very far distance (Pietro et al., 2006; Prieto et al., 2005). Ensuring the sustainable development of ecosystems requires a study of all ecosystem components (Bradshaw and Hüttl, 2001), particularly the soil (Heneghan et al., 2008), being an important, and non-renewable resource (Van-Camp et al., 2004). The diversity of plant species is limited by soil characteristics (Bogdanov, 2013; Bogdanov, 2014a; Hristov, 2020), a vital aspect of which are the physical characteristics of substrates (Romana, 1985). The soil structure in mining areas can easily be damaged. A reduction in porosity results in poor soil aeration, poor drainage and increased resistance to root penetration. This subsequently suppresses plant growth (Bowen et al., 2005; Geissen et al., 2013, Stahl et al., 2002). A positive correlation exists between the availability of nutrients such as C, N, P (total quantities) and the diversity of species. There is an increased accumulation of organic matter when the species are more diverse (Berendse et al., 1998). Microclimate change also affects the decomposition of organic matter (Torreta and Takeda, 1999; Deng et al., 2009). However, the content of organic C, N, P, K doesn't change up to 7 years after mining activities have ceased. The composition of the self-established vegetation includes mainly grass species (Jian-Gang Yuan et al. 2006). The active soil acidity on the territory of quarries is from highly acidic to acidic (3.76- 6.21). There is low nutrient availability (organic C, total N, and total P) (Zhuang, 1997), but it is higher in the surface 0-5 cm layer than in the 5-10 cm layer, where the values vary over time (Sourkova et al., 2005; Pietrzykowski and Krzaklewski, 2007).

MATERIALS AND METHODS

The object. Technosols (WRB, 2014) occurring on the territory of "Podgumer" quartz sand quarry, located next to Podgumer village, district Sofia, Bulgaria. The object is in the lower forest vegetation zone (0 - 600 m a. s. l., Zahariev, 1979).

Methods of study. Forty-five soil pits at a depth of 0-20 cm (in the year of deposit: sample plot 1 – fifteen pits; 5 years after deposit: sample plot 2 – fifteen pits; and 9 years after deposit: sample plot 3 – fifteen pits) were dug at representative plots. A systematic sampling design was used (Petersen & Calvin, 1996). The following soil characteristics were analyzed by using the respective methods:

- Bulk density (BD, g.cm^{-3}), according to the DIN ISO 11272:1998, 2001;
- Total porosity (TP, %) according to the Lorraine & Flint (2002);
- Soil texture (Sand - 2 mm - 63 μm, %; Silt - 63 μm - 2 μm, %; Clay < 2 μm, %) using the sedimentation method (ISO 11277);
- Soil acidity (pH in water extraction 1:5 w/v) – measured potentiometrically (WTW 720 pH meter) (ISO 10390:2002);
- Soil Organic Matter (SOM, %) according to the ISO 14235:1998;
- Total Kjeldahl Nitrogen (TKN, %) content with a modified version of the classic Kjeldahl method (ISO 11261:2002);
- P_2O_5 (mg.100g^{-1}) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (Ivanov, 1984);
- K_2O (mg.100g^{-1}) – extraction with Ammonium Acetate and Calcium Lactate-pH 4.2 (Ivanov, 1984).

The plant species composition was studied. The methods of study included an assessment of the floristic composition, followed by an analysis of the origin and ecological peculiarities of the species. Species identification was carried out according to Delipavlov et al., 2011. Species origin was determined following Walter (Assyov et al., 2012). The experimental plots were of size 4 x 4 m. Floristic affinity among the sites studied was calculated using Sørensen-Dice coefficient (Sørensen, 1948).

The box-plot graphics were created with SPSS 26 (SPSS for MacOS). The linear regressions were done with SPSS 26 (SPSS for MacOS).

The soil parameters ware analysed by Analysis of Variance (ANOVA) and Post Hoc LSD ($p \leq 0.05$) test using SPSS 26 (SPSS for MacOS). Different letters are significantly different with level of significance ($p \leq 0.05$).

RESULTS AND DISCUSSION

Plant characteristics. The total number of plant species recorded on the studied sites is 40 as presented in Table 1.

The plant species in our study or research belong to 36 genera and 11 families. The most numerous families are *Poaceae* (30% of species), *Fabaceae* (25%) and *Ateraceae* (23%). Many families (7) as *Boraginaceae, Caryophyllceae* etc. are represented by a single species (less than 3%).

Table 1. List of plant species on the area of Podgumer quarry

Plant species/Coverage	SP 2	SP 3
	70%	80%
Achillea milefollium L.		+
Acinos arvensis (Lam.) Dandy		+
Agrostis capillaris L.	+	
Aegilops triuncialis L.		10%
Bromus mollis L.		+
Bromus squarrosus L.	+	10%
Bromus tectorium L.	+	
Carlina acanthifolia All.	+	
Centaurea rhenana Boreau	+	
Cichorium inthybus L.	+	+
Cirsium arvense (L.) Scop.	+	
Coronilla varia L.		+
Cynodon dactylon (L.) Pers.	+	
Dorycnium herbaceum Vill.	+	
Echium vulgare L.	+	+
Equisetum arvense L.	+	
Erysimum diffusum Ehrh.	+	
Euphorbia niciciana Borb.	+	+
Festuca valesiaca Scheich ex Gaud.		20%
Filago vulgaris Lam.	+	
Holcus lanatus L.	+	
Lolium perenne L.		+
Lotus corniculatus L.	1%	+
Medicago lupulina L.	30%	5%
Melilotus alba Medic.		+
Petrorhagia prolifera (L.) P. W. Ball. et Hey.	+	
Poa annua L.		+
Ononis arvensis L.	5%	
Rumex acetosella L.	+	+
Sanguisorba minor Scop.		+
Taeniatherum asperum Nevski		10%
Dasypyrum villosum (L.) Cand.		10%
Thlaspi arvense L.	+	+
Tragopogon dubius Scop.	+	
Trifolium repens L.	10%	10%
Trifolium strictum L.		+
Tussilago farfara L.	20%	
Vicia cracca L.	+	
Vicia sativa L.	+	
Xeranthemum annuum L.	+	

At SP 3 projective coverage is 80% and 22 plant species are observed. SP 2 has a 70% projective coverage and 27 plant species.

Experimental plots differ substantially from each other - Sørensen (1948) coefficient of similarity between plots is 0.33.

The vegetation on embankments goes through different stages of recovery. The formed vegetation on the embankments may be assigned to one of the following stages: 1-weed-ruderal; 2-cereal-ephemeral; 3 – rhizome-leguminous.

At SP 2, most of the observed species are characteristic of the rhizome-leguminous stage. These are species such as: *Holcus lanatus* L., *Cynodon dactylon* (L.) Pers. of cereals and *Medicago lupulina* L., *Lotus corniculatus* L. of legumes. The participation of species from other stages is quite limited.

At SP 3 the predominant species are of rhizome-leguminous stage such as *Trifolium repens* L., *Melilotus alba* Medic. of the legumes and *Festuca valesiaca* Scheich ex Gaud., *Lolium perenne* L. of the rhizome, but at the same time species of the cereal-ephemeral stage are observed, such as *Taeniatherum asperum* Nevski, *Dasypyrum villosum* (L.) Cand.

The analysis of the ratio of biological plant types shows the prevalence of perennial herbaceous plants (55-74%), followed by the group of annual herbaceous plants (36-22%).

There is a normal reduction in the number of annual herbaceous plants at SP 3 to SP 2 since most of them are ruderal species characteristics of the early stages of plant cover formation. Shrubs and tree species are not observed.

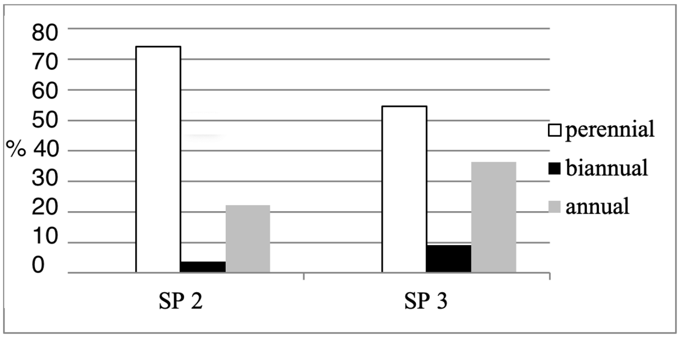

Figure 1. Share (%) distribution of species biological type

The analysis of the phytogeographical structure of the studied plants reveals that 13 floristic elements are present (Fig. 2). Distribution of species according to their phytogeographic origin shows as most numerous the European geoelements – 25% of species. Other groups with larger participation (about 13% each) are: Eur-Sib, Eur-Med, subMed. There are 5 groups represented by one species (around 3%), such as: EursubMed, PontMed, Pont, Med and CSEur. Adventitious species were not observed and other groups with greater participation - about 13% each are: Eur-Sib, Eur-Med, subMed.

Soil characteristics

There are statistically significant differences in the bulk densities of the materials deposited in the different years, where the change is expressed as a statistically significant correlation (Fig. 3). Total porosity increases with time and the change is statistically significant (Fig. 4).

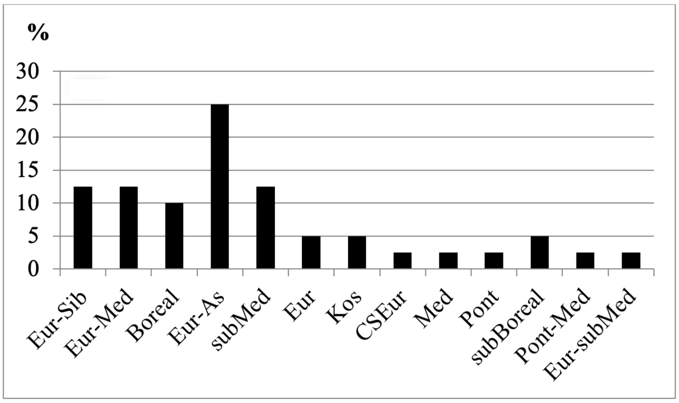

Figure 2. Share (%) ratio distribution of floristic elements

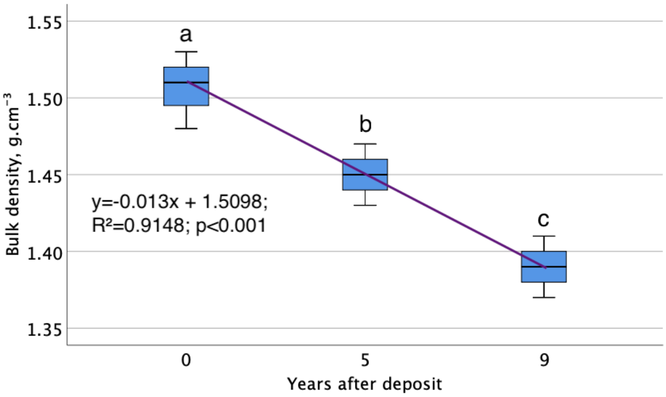

Figure 3. Box-plot graph and a linear regression of BD depending on the year of deposit

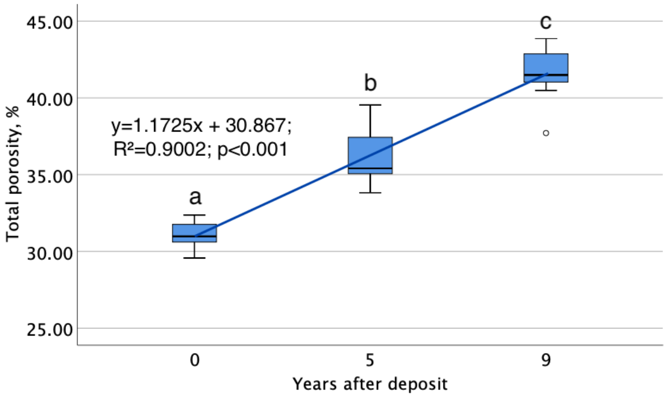

Figure 4. Box-plot graph and a linear regression of TP depending on the year of deposit

There are statistically significant differences in the three fractions of the soil texture in the different years of deposit. The decrease in the sand fraction (Fig. 5), results in the increase in the silt and clay fractions, where the silt fraction has a greater rate of change than the clay fraction. Similar trends (decrease in the sand fraction, increase in the silt fraction and lesser rate of change in the clay fraction) were reported by Bogdanov (2014b). Nevertheless, soil texture is considered to be stable and can change very slowly with time (Atanasov, 1987).

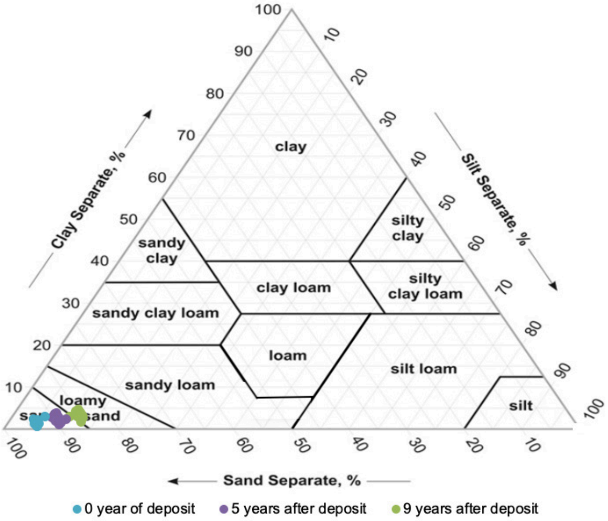

Figure 5. Soil texture changes (USDA 2017)

There are no statistically significant differences in the active soil acidity between the year of deposit and 5 years after deposit, but there is a statistically significant difference 9 years after deposit (Fig. 6).

There are statistically significant differences in SOM and TKN in different years of deposit (Fig. 7, Fig. 8), where the changes in the two indicators are expressed by statistically significant linear relationships. The positive correlation between the ages of the site for these two indicators has been discussed by other authors (Frouz et al., 2008).

The plant-available P and K increase with every following year of deposit, where these changes in both indicators are expressed by statistically significant linear correlations (Fig. 9, Fig. 10), which is consistent with studies done by other authors (Frouz et al., 2008), who report statistically significant positive correlations between the age of the site and forms of P and K.

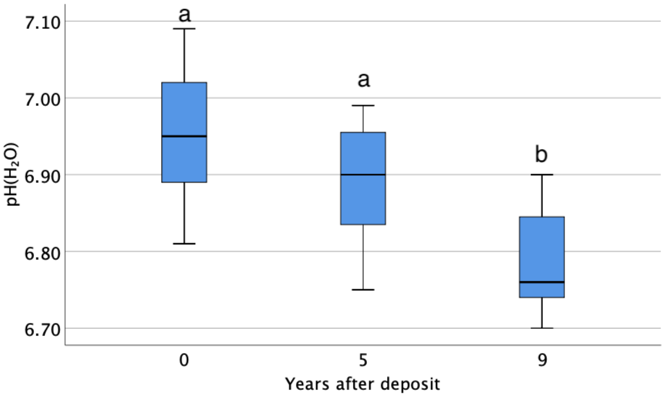

Figure 6. Box-plot graph of pH in the different years of deposit

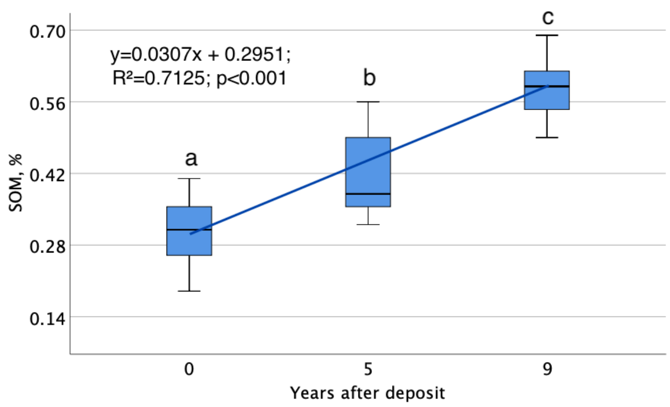

Figure 7. Box-plot graph and a linear regression of SOM depending on the year of deposit

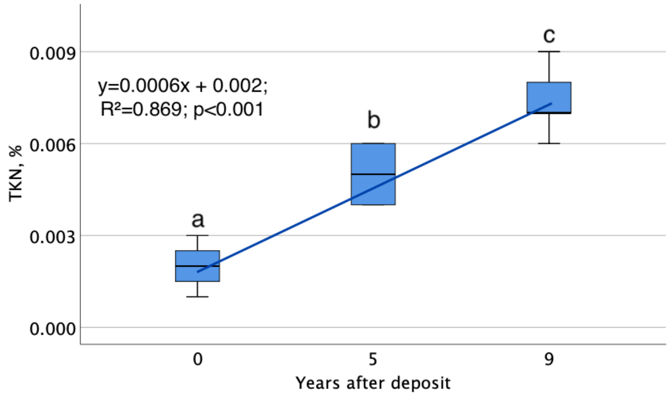

Figure 8. Box-plot graph and a linear regression of TKN depending on the year of deposit

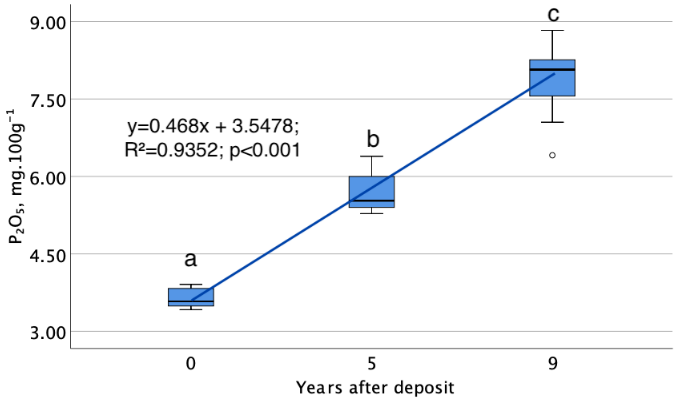

Figure 9. Box-plot graph and a linear regression of P_2O_5 depending on the year of deposit

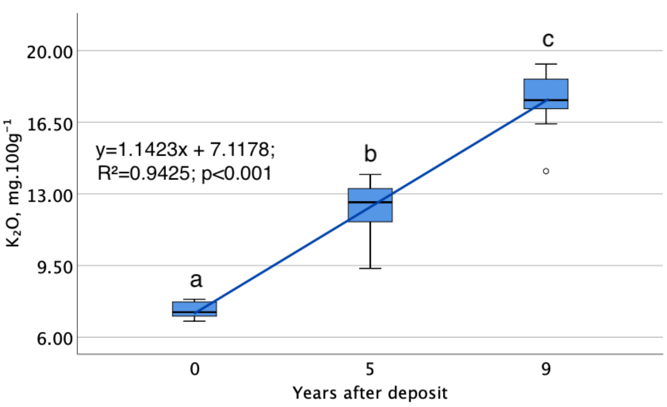

Figure 10. Box-plot graph and a linear regression of K_2O depending on the year of deposit

The natural restoration of a site is a long process and it is sometimes advisable to study the dynamics for a certain period of time before we adopt measures for the management of post-mining areas (Letheren, 2009, Rao et al., 2000). The changes in plant cover (pioneer species to begin with) are consistent with the observations made by other authors (Harris et al., 1998; Tomlinson et al., 2008; Walker and del Moral, 2003). However, spontaneous succession is difficult to predict in the context of global change. For that reason, it is not considered to be an acceptable rehabilitation strategy for post-mining areas (Cullen et al., 1998). The rehabilitation of ecosystems and ecological functions in a sandy landscape requires soil reconstruction (Jim, 2001) and therefore landscape planning measures should be taken (Bradshaw, 1997).

CONCLUSIONS

The establishment of rhizome-leguminous plants and the changes in physical and chemical properties point to the presence of an early soil formation process. The vegetation had a significant impact (statistically significant) on bulk density (decrease) 5 years and 9 years after deposit (described by reliable linear regressions). There was a statistically significant increase in total porosity after the establishment of vegetation (described by reliable linear regressions).

The establishment of vegetation resulted in statistically significant differences in the chemical characteristics (SOM, TKN, P_2O_5, K_2O). The establishment of vegetation and the increase in plant diversity resulted in increased levels of SOM, TKN, P_2O_5, K_2O, where these changes were described by reliable linear regressions.

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