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Ranking of ecotoxisity tests for underground water assessment using the Hasse diagram technique

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HIGHLIGHTS

- The Hasse diagrams served to rank biotests applied for water quality assessment.
- The sensitivity of the ecotoxicological tests were determined and compared.
- Possibility of using advanced chemometrics was proven for landfill risk management.

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ABSTRACT

The present study deals with the novel application of the Hasse diagram technique (HDT) for the specific ranking of ecotoxicity tests capable of assessment of underground water quality. The area studied is a multi-municipal landfill in the northern Poland. The monitoring network of the landfill constitutes of 27 piezometers for underground water monitoring and two observation points at surface water courses. After sampling, chemical analysis of various water parameters was performed (pH, conductivity, temperature, turbidity (TURB), color, taste, smell and atmospheric conditions: temperature, precipitation and cloud cover, heavy metals content (Cu, Zn, Pb, Cd, Cr^{6+}, Hg), total organic carbon (TOC), sum of Polycyclic Aromatic Hydrocarbons (PAHs), Na, Mg, K, Ca, Mn, Fe, Ni, alkalinity (Alkal), general hardness, total suspended matter (SUSP), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), chlorides, fluorides, sulphides, sulphates, ammonium nitrogen, total nitrogen, nitrate and nitrite nitrogen, volatile phenols, ether extracts (ETHER), dry residues (DRY_RES), dissolved compounds). Parallel to the chemical parameters assessment six different ecotoxicity tests were applied (% root length(PG)/germination(PR) inhibition of *Sorghum saccharatum* (respectively PGSS/PRSS), *Sinapis alba* (respectively PGSA/PRSA), *Lepidium sativum* (respectively PGLS/PRLS), % bioluminescence inhibition of *Vibrio fischeri* (MT), % mortality of *Daphnia magna* (DM), % mortality of *Thamnocephalus platyrus* (TN)). In order to determine the applicability of the various ecotoxicity tests, a ranking of samples from different monitoring levels according to the test used (attributes) is done by using HDT. Further, the sensitivity of the biotests was determined and compared. From the sensitivity analysis of the both monitoring levels was evident that the choice of ecotoxicity tests could be optimized by the use of HDT strategy. Most reliable results could be expected by the application of root growth inhibition of *Sorghum saccharatum* (PGSS test).

In order to clarify the relationship between the chemical parameters measured and each of the ecotoxicity tests a optimized similarity analysis between Hasse diagrams for the ecotoxicity tests for different levels of monitoring and Hasse diagrams obtained by the use of the chemical parameters was performed. Finally, it could be concluded that for reliable monitoring of underground waters passing a dump collector following chemical parameters are of significance: water hardness, dissolved matter, total nitrogen (ammonia and nitrate nitrogen), nickel, chlorides, alkalinity, total organic carbon and ether extract and the proper battery test could include PGSA, PGSS and PRSS.

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1. Introduction

Landfill management is unequivocal with the necessity of determining numerous chemical parameters that are difficult to correlate. Possibility of using advanced scientific tools enabling finding such correlations is of great importance for risk management and planning. Application of biotests may serve as a source of additional information in this field and give knowledge about interactions between chemicals determined. Selecting proper battery of biotests – after considering their sensitivity to specific source of pollution – may be very beneficial for local communities and authorities that manage municipal landfills. It may also help monitoring changes in the content of given landfill wastes.

The big drawback of environmental quality assessment based on chemical monitoring is inability to easily determine biological effects of complex composition of pollutants eluting from landfills and other point sources of hazardous materials. The danger increases when bioavailability of chemicals is being considered and due to fact that wide spectrum of unknown chemicals may reach underground waters due to release from landfill. Toxicity of such mixtures is of huge concern to local societies and authorities.

Application of biotests may serve as a source of additional information in this field and give knowledge about interactions between chemicals determined.

Selecting proper battery of biotests – after considering their sensitivity to specific source of pollution – may be very beneficial for local communities and authorities that manage municipal landfills. It may also help monitoring changes in the content of given landfill wastes and reflect impact of these changes on the condition of surrounding underground water bodies.

Previous works in the area of impact of large municipal landfills (Biswas et al., 2010; Regadío et al., 2012; Liu et al., 2013) indicate that there are large discrepancies in ecotoxicological and chemical quality classification of underground water bodies. It has been stated that good chemical quality of water bodies according to traditional parameters measured does not find prove in ecotoxicological classification system.

For this reason application of ecotoxicological studies with properly selected battery of biotests should be more and more widely applied by local authorities for municipal landfill impact assessment. The aim of the study described was to evaluate sensitivity of several biotests to fully reflect the impact of chemical and effluents from multi-municipal landfill site located in Gdańsk (northern Poland).

2. Experimental

2.1. Sampling site

The Szadółki landfill studied is a multi-municipal landfill located in the northern Poland. It is situated on post-gravel pit and was officially open in 1973. There are two waterbearing levels in the site bed – upper one (QI) and lower one (QII) which is also the basic useful waterbearing level. Three waterbearing layers are present in the QI: surface layer (QI1), middle (QI2) and first useful (QI3) (see Table 1 for details) (Tyszecki, 2006). Next to communal also construction and industrial (including dangerous) wastes reach the landfill. It is estimated, that *ca* 70Tg of wastes is being stored at the site currently, every year *ca* 210 000 tones of municipal, 40–50 000 of industrial, over 20 000 of construction wastes reach the landfill together with *ca* 600 tonnes of wastes for biodegradation, pyrolysis or deposition in the thumbs. Due to lack of sealed bed there is a possibility of pollutants migration to the surface and underground water (Tyszecki, 2006).

2.2. Samples collection

The monitoring network of the Szadółki landfill constitutes of:

- 27 Piezometers for underground water monitoring (P7, P8, P9, P10, P10A, P11A, P11B, P12, P12A, P13, P13A, P14, P14A, P14C, P15, P15A, P16, P16A, P17, P17A, P18A, P18B, P19A, P19B, P19C, P20C, P21C).
- 2 Observation points at surface water courses (WP1 and WP2, at Kozacki Stream respectively before and after the landfill).
- Effluents storage tank (Nyga-Głuch, 2008; Nowak, 2008).

Sampling was conducted on 27–28.11.2007 (I round), 11–12.03.2008 (II round), 10–11.06.2008 (III round), 9–10.09.2008 (IV round), 25–26.11.2008 (V round), 7–8.04.2009 (VI round).

Underground water samples were collected in accordance to PN-ISO 5667-11:2004. Immediately after sampling the pH, temperature and conductivity measurements were done. Surface water samples were taken in accordance to PN-ISO 5667-6:2003. After sampling the following parameters were determined: pH, conductivity, temperature, turbidity, color, taste, smell and atmospheric conditions: temperature, precipitation and cloud cover (Tyszecki, 2006; Nyga-Głuch, 2008). Water samples were collected to dark glass bottles and kept in fridge till final measurements.

2.3. Chemical analyses

The following chemical and physicochemical parameters were determined (Tyszecki, 2006; Wiczyński et al., 2006; Ciechanowska-Żurek, 2007; Wojewoda Pomorski, 2007; Nyga-Głuch, 2008): pH, conductivity, heavy metals content (Cu, Zn, Pb, Cd, Cr^{6+}, Hg), total organic carbon (TOC), sum of PAHs, Na, Mg, K, Ca, Mn, Fe, Ni, alkalinity, general hardness, total suspended matter, turbidity, color, smell, BOD, COD, chlorides, fluorides, sulphides, sulphates, ammonium nitrogen, total nitrogen, nitrate and nitrite nitrogen, volatile phenols, ether extracts, dry residues, dissolved compounds.

2.4. Toxicity tests

The following battery of biotests has been used to assess ecotoxicological status of the samples collected: *Vibrio fischeri* – Microtox®, *Daphnia magna* – Daphtoxkit F™, *Thamnocephalus platyurus* – Thamnotoxkit F™, *Sorghum saccharatum*, *Lepidium sativum* and *Sinapis alba* – Phytotoxkit F™.

In Table 2 the general characteristics of the applied microbiotests is given.

In the Electronic Supplementary material Material all details of toxicity procedures are given.

Table 1
Location of piezometers and their water bearing range (Stangret and Walczyk, 2004; Walczyk, 2004a,b,c; Nowak, 2008 – all positions, Wiczyński et al., 2006; Ciechanowska-Żurek, 2007).

Location of piezometers	Input	Output
QI1 (level 1)	P9, P10, P10A, P11A, P19A	P7, P13A, P14A, P15A, P16A, P17A, P18A
QI2 (level 2)	P8, P11B, P19B	P12A, P13, P14, P15, P16, P17, P18B
QI3 (level 3)	P19C, P21C	P12, P14C, P20C