

Universitat Rovira i Virgili
Escola Tècnica Superior d'Enginyeria

MASTER THESIS

A multicriteria decision aid approach for the management of biosolids generated at wastewater treatment plants

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Tarragona, 2009

1. Introduction

The research conducted in this Master Thesis is part of the Spanish project (CTM2007-64490/TECNO): “*Desarrollo de un modelo de evaluación de exposición y riesgo por la aplicación de fangos de depuradoras en suelo agrícola, basado en un sistema experto integrado en SIG*”, funded by the “*Programa Nacional de Ciencias y Tecnologías Medioambientales*” of the Environmental Ministry. The project is 3 years long, it started at 2008 and it is going to finish at the end of 2010.

In this research project, a multi-disciplinary team studies all the factors to take into account in the decision process of selecting the best use of sewage sludge produced at waste water treatment plants. The following groups are involved in this project.

- *Anàlisi i Gestió Ambiental* (AGA), Department of Chemist Engineering on ETSEQ, URV.
- *Laboratorio de Toxicología y Salud Medioambiental*, Department of Medical Sciences, FMCS, URV.
- *Laboratorio de edafología*, Faculty of Pharmacy, Universitat de Barcelona (UB).
- *Análisis Territorial i Estudios Turísticos* (GRATET), Pre-departmental unit of Geography, FLL, URV.
- *Intelligent Technologies for Advanced Knowledge Acquisition* (ITAKA), Department of Computer Science and Mathematics, ETSE, URV.

This funded research project is separated in some stages. The following are the main objectives of this project:

1. A laboratory study of the major processes governing the mobility, bioavailability and toxicity of contaminants (heavy metals and organic compounds).
In this stage different analysis on soils and sludge are done.
2. Field-level study to determine the soil-vegetation-transfer leaching and toxicity.
3. Development and validation of models of transmission and distribution. This stage is composed by the elaboration of a tridimensional (Neuro-fuzzy) model of flow and transport through the subsoil and groundwater pollutants in diffuse by the application of sludge in agricultural soils.
4. Modeling of exposure and risk for population and ecosystems
5. Development of vulnerability indices based on soil characteristics, type of sludge and crop type. Development of a vulnerability index that includes the characteristics of soil, sludge and vegetation.

6. Prepare a guide of recommendations

In this Master Thesis we have been working on the design and implementation of a tool for supporting the points three and five, where fuzzy methods and a vulnerability index (utility) are required. Finally the decision tool will be used to build a set of recommendations for the usage of biosolids in agricultural soils.

The management of sewage sludge generated in wastewater treatment plants is a complex problem. This problem has a lot of associated costs at an economical level, but also important impacts to humans and ecosystems.

Before presenting the goals of this Master Thesis in detail, a brief explanation of the environmental problem of sewage sludge management is given.

1.1. Biosolid management

Biosolids, also referred as sewage sludge, are residues generated at wastewater treatment plants (WWTP), obtained from solids removal on various parts of the treatment system. In Spain the generation of biosolids increased in a 39% from 1997 to 2005 [PNLD, 2008]. Since the application of the legislation [RDL 11/1995] which requires building new plants in towns with a population higher than 2000 inhabitants, more than 1000 WWTP have been build in all Spanish region.

Once treated, the amount of sludge can be recycled or disposed using three main routes: disposal on agricultural soil, incineration and landfill. Any of these three scenarios leads to different impacts to humans and ecosystem.

The sewage sludge application on soil improves fertility and exempt fertilizers use. Furthermore the nitrates content of soil increases crop production. For these reasons, the Spanish government wants that at least 70% of the WWTP sludge is applied into agricultural soils. In 2005 the recycling of sewage sludge to agriculture represented a 65% of the total disposal of biosolids [PNLD, 2008], but it should be studied how this percentage may be increased. Even so, biosolid application on soils may lead to groundwater nitrification as a result of nitrogen movement through lixiviate. The nitrates content of biosolids is a variable related to application dose. Some studies have proven that biosolids application improves soil fertility along the years [Fuentes et al., 2007]. However, care must be taken on areas that are vulnerable to nitrogen pollution, as recommended on EC Nitrate Directive 91/676.

The application of sewage sludge as a combustible is another possibility to take into account for the rest of the sewage sludge not used in agricultural soils. This option is especially interesting for cement plants because they can use instead of other fuel types. In order to be incinerated, sewage sludge must have a drying treatment, which increases the costs.

Finally the last and less preferred destination for sewage sludge is to be disposed in a landfill. Usually it happens when the level of metal contaminants present in the sludge exceed the maximum level required by the Spanish legislation for the application on agricultural soils, or even to incineration.

However, legislation is not concerned on any other kind of impacts to humans and ecosystem, such as the exposition to organic contaminants through different routes

(inhalation, ingestion and dermal contact), the lifecycle, and the field properties. For this reason, in the Spanish project mentioned before, are in charge of doing a more completed analysis of biosolids disposal.

1.2. Aims of the Master Thesis

The purpose of this Master Thesis is to design and implement a software tool for aiding in the management of biosolids.

As it has been explained in the previous part, three possible destinations of sludge can be considered: agriculture lands (like a fertilizer), cement plants (like a combustible) and landfills. They are listed by preference from best to worst. In fact, sewage sludge disposal on landfills is encouraged by the governments in order to achieve a sustainable life cycle of wastewater.

As the main concern is about having a good procedure for the distribution of biosolids into the different agricultural soils, this master thesis has focused on this problem.

Using a multiple criteria decision aid (MCDA) approach, we want to define a decision support system to aid in the process of deciding the degree of suitability of the possible agricultural soils where a particular WWTP sewage sludge could be disposed.

These MCDA techniques allow considering all properties that can influence in the decision process and permit to use quantitative and qualitative information for each factor.

This main goal can be divided into the following specific sub-goals:

1. Make an exhaustive study of the existing multi-criteria decision aid tools and methods. They will be classified according to several criteria, for example, the type of methodology (Multi attribute Utility theory, preference relations, multi-objective optimization ...), the available analysis (sensitivity, robustness ...) or the technical support, among others.
2. Determine which of those methods is the most appropriate to model the problem of sewage sludge application on agricultural soils.
3. Participate in a knowledge engineering process together with the environmental experts of the research project in order to help to create a data model. That means, participate in the determination of the alternatives and criteria, and its formalization.
4. Use an existing software tool, or develop it, to assist the environmental experts in the analysis of a few specific cases.
5. Make an analysis of the results and the performance of the system.