Chapter 20
Decision Making Under Deep Uncertainty With Fuzzy Algorithm in Framework of Multi-Model Approach:
Water Pollution Risk Assessment Using Satellite Data

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ABSTRACT

Task of soft computing for decision support in field of risk management is analyzed in this chapter. Multi-model approach is described. Interrelations between models, remote sensing data and forecasting are described. Method of water quality assessment using satellite observation is described. Method is based on analysis of spectral reflectance of aquifers. Correlations between reflectance and pollutions are quantified. Fuzzy logic based approach for decision support in field of water quality degradation risk is discussed. Decision on water quality is making based on fuzzy algorithm using limited set of uncertain parameters. It is shown that this algorithm allows estimate water quality degradation rate and pollution risks. Using proposed approach, maps of surface water pollution risk from point and diffuse sources are calculated. Conclusions concerned soft computing in risk management are proposed and discussed. It was demonstrated, that basing on spatially distributed measurement data, proposed approach allows to calculate risk parameters with resolution close to observations.

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INTRODUCTION

Modern development of applied mathematics and computational methods allows to formulate and solve new problems in mechanical and civil engineering, first of all tasks in the field of control and decision theory including tasks, aimed to risk management and security control. New types of data and new monitoring instrument can be harnessed, more wide areas of human activity and life may be analyzed. Since innovative technologies should serve to increasing of life quality, applied computing approaches in engineering directed to risk assessment toward disaster threats is important task.

Water pollution is one of the biggest environmental problems, as well as linked with it soil and air pollution. Nitrate is among the most common and widespread pollutants in surface water and groundwater. Diffuse pollution through soils and air from agricultural activities and livestock are the main sources of increased nitrate concentrations in groundwater and surface water bodies (European Commission, 2005). Nitrogen is a vital nutrient to enhance plant growth, which has motivated intensive use of nitrogen-based fertilizers to boost up the crop production. But increased fertilizer use also has social and environmental costs. The fertilizers deteriorate the water quality inducing economic and ecological problems. In the last century automation of agriculture and the introduction of high yield crops has raised the use of fertilizers, increasing nitrate concentration in groundwater.

In some cases, when through the natural and artificial circumstances the nitrogen application exceeds demand and the denitrification capacity of the soil, nitrogen can leach to the water, usually as nitrate.

The nitrogen average fertilizer use in Europe is 70 kg/ha (EEA (European Environment Agency, 2003). In some regions with intensive irrigation the water bodies reach nitrate concentrations between 50-100 mg/l (Martínez, Albiac, 2006). The monitoring studies in Ukraine indicate that about 50% of groundwater suffers nitrates concentration over 50 mg/l, and 70% over 25 mg/l. Nitrogen from agricultural sources accounts for from 50 to 80% of the nitrates entering Europe's water (European Commission, 2005).

Therefore, the assessment of water pollution and water quality is an urgent task of socio-ecological security. In this task, from viewpoint of applied mathematics, the situation of uncontrolled uncertainty is frequent.

It is quite easy to control one selected parameter with required accuracy. But, if we need control large set of spatially distributed parameters on the long-time intervals, the uncertainties – both aleatorical and epistemical - are increasing critically. This is a typical situation for water quality analysis, where wide range of parameters should be controlled simultaneously. In this situation, the decision making and risk analysis are complicated problems (Polasky et al., 2011).

There are few methods of uncertainty control, including uncertainties, generating by complex multi-physics systems (Ermoliev et al., 2012). But also, may be formulated task about using the soft computing method for assessment of risk with limited set of parameters. In such cases we can reduce a number of controlled variables without neglecting the systems processes, drivers and feedbacks.

This approach should include formulation of correct methodology, method of variables selection, indicators selection method, and method of risk assessment with limited set of parameters.

This chapter is dedicated to soft computing application to water pollution risk assessment and water quality analysis using data of satellite observation of water bodies, soil cover and air pollutant transfer.