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Assessing the Environmental Risk of Silver Nanoparticles in Aquatic Ecosystems

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Abstract **–** As well known, silver nanoparticles (AgNPs) are being increasingly used in many different sectors due to their particular biocidal characteristics. The existence of these substances in many day life products leads to the presence of AgNPs in different environmental compartments. In particular, the aquatic ecosystem is one of the reservoirs that receive more silver nanoparticles. The affectation of different living organisms by AgNPs has been proved through several studies. Therefore, in this paper a methodology to assess the risk of AgNP for the aquatic ecosystems is presented. The methodology is based on the fuzzy logic theory, which is a proved method to deal with variables that have associated uncertainty. This is the case of many of the variables related to the AgNPs. A selection of input and output variables has been carried out after a deep research. Once the variables are identified, the fuzzy inference systems can be established. From inputs such as the size, the shape and the coating of the AgNPs, it is possible to determine the toxicity. This variable together with the media concentration will provide the final assessment of risk. To prove this methodology, a case study based on an accident has been presented. The results show how the risk of AgNPs vary with the pollutant front advance, arriving to a high risk situation. This tool can be adapted to different situations and types of nanoparticles, making a very appropriate for the decision makers.

Keywords**:** Silver nanoparticles, risk assessment, aquatic ecosystems, fuzzy logic

1. Introduction

The rapid development of nanotechnology has stimulated the use of nanoparticles (NPs) in various fields. Due to their small size, NPs possess unique physicochemical and catalytic characteristics, compared to their bulk counterparts. These properties have attracted enormous scientific and technological interest for use in functional materials and devices [1] There exist many types of NPs (i.e. Carbon-based, metal oxides, zero-valent metal) with numerous applications [2]. In particular, silver nanoparticles (AgNPs) have very attractive physicochemical properties such as high thermal and electrical conductivity, chemical stability, and catalytic activity [3]. In addition, they can have different morphologies, such as spheres, rods and cubes [4] and they present coating agents or stabilizers (e.g. PVP-polyvinylpyrrolidone or citrate). All this variety offer AgNPs the ability to be used in a wide range of new commercial and technological applications [5].

As a consequence of this wider use of AgNPS, there is an increase in their production, which involves their potential release into the environment. There exist different pathways in which the AgNPs may arrive to the environment during all the steps of their life cycle from production to waste. In addition, their liberation maybe intentional (e.g. discharges from waste water treatment plants) or unintentional (e.g. accident). The aquatic ecosystem is one of the main environmental compartments that receive AgNPs [6]. For this reason, this paper focuses on the study of the risk of AgNPs in aquatic ecosystems.

2. Methodology

In order to conduct to research a new method to evaluate the risk of AgNPs have been developed using Fuzzy Logic. It is a type of multi-valued logic that represents a way of addressing uncertainty and vagueness and is an alternative to classic or Aristotelian logics [7]. Whereas for the classic logic one fact is true or not true, for the fuzzy logic an affirmation is never totally true or false, instead of that it will be true or false with a certain degree of membership [8]. To address environmental problems, which generally involve several conflicting variables, Fuzzy Logic is very appropriate since it can deal with the uncertainty associated to some variables and provide qualitative output (e.g. a water quality index, environmental risk etc.).

Fuzzy logic has successfully been used in the environmental field to deal with uncertain data [9]. There exist different procedures to implement the fuzzy principles. The most used nowadays are the Fuzzy Inference System (FIS) which are capable to assign output variables to input variables using fuzzy logic [10]. All this process is carried out using MATLAB. The scheme with the selection of variables involved in the environmental risk assessment of silver nanoparticles in aquatic ecosystems is shown in figure 1.

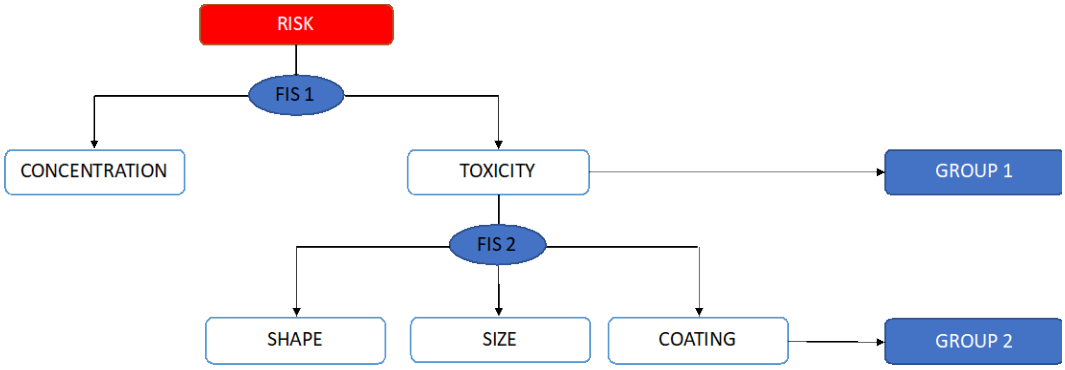

Fig. 1 – Variables definition and fuzzy model structure.

3. Results and Discussion

In order to test the developed methodology, a case study was prepared. It consisted of a truck accident in a bridge with a release of a drum of with a suspension of 20 g of AgNPs in a representative Mediterranean river (Besòs River, Catalonia). The AgNPs had a spheric shape and were recovered with citrate. Figure 2 shows the concentration in river water in a point 5 km from the accident over the time (grey line). As it can be seen, as the AgNPs arrive the risk increases, going from low risk at the beginning to achieving values of high risk at 4500 seconds (1h y 15 min) from the start of the release. Once the front has passed the study point the risk diminishes again to medium and low.

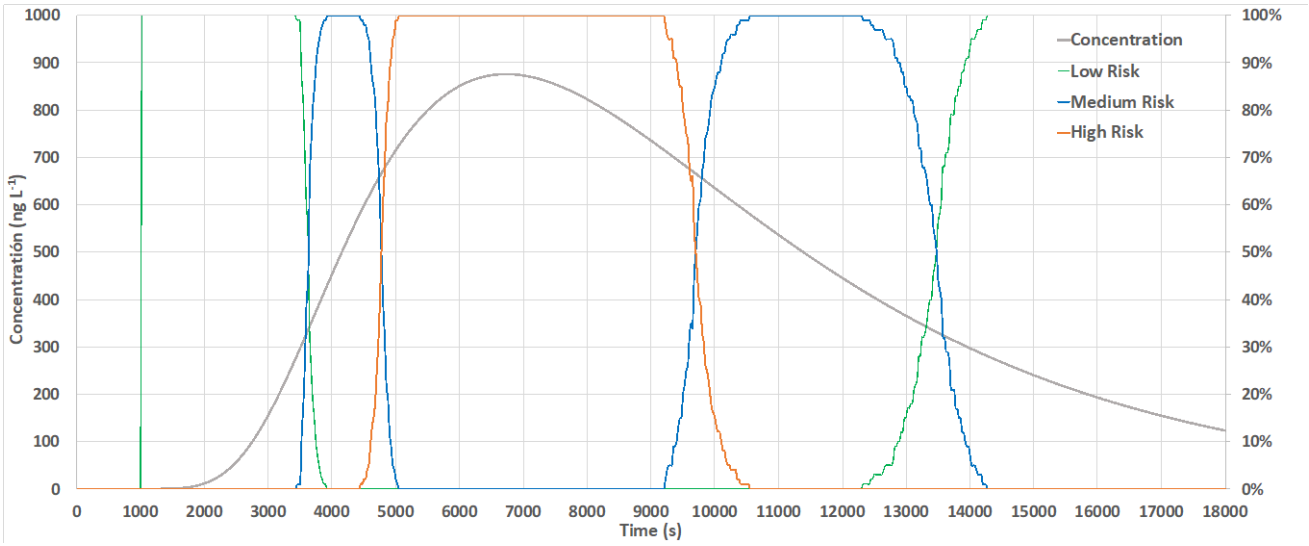

Figure 2 – Results of the risk assessment of the accident

4. Conclusion

A new application of fuzzy logic to assess the risk of AgNPs has been created and its functionality has been tested with with a case study. The new method allows to know the risk for aquatic ecosystems from an accident situation as a function function of time. The same model can be applied to intentional releases (i.e. WWTPS) and allow to design actions plans.

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