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Assessing the seasonal influence on the quality of seawater using fuzzy linear programming

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Abstract

The aim of this paper is to apply a fuzzy/possibilistic approach focus in the context of the Caribbean. The fuzzy model is obtained taking into account the behaviour of salinity and total dissolved solids content according to the season (dry or hurricane season). The methodology is based on the fact that minimal/maximal values of these parameters are target values along the year rather than fixed real numbers. The results of this paper indicate that the operating costs of any desalination plant based on reverse osmosis can change up to 30% in one year.

Keywords: Possibilistic; Necessity indexes; Fuzzy coefficients; Desalination; Linear programming

1. Introduction

In the past decade, seawater has found several applications for the production of drinking water. Currently over 15,000 industrial scale units are operating worldwide. Continuous progress in desalination succeed in competitive operating costs when compared with other plants in the production of drinking water, making it the prime although reverse osmosis (RO) is not the only technology actually used. The lifetime of the membranes in the reverse osmosis desalination plant can be serious affected for the quality of the seawater or the quality of the pre-treatment unit.

The quality of seawater is very important in the design of the pre-treatment unit of any RO desalination plant. It is worth noting that the operational parameters (salinity, TDS, inlet temperature) depend on the seasons (dry and rainy) such that they are not constants along all year. The fuzziness allows us to adapt the model to different conditions along the year where the use of non-linear programming can result in restric-

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tiveness. The fuzzy programming guarantees the operation of the plant at minimum cost independently of the operating and environmental conditions all time. Several optimization models using different techniques have been developed for optimizing RO desalination plants; however, the seasonal influence cannot be considered.

Maska [1] performed an analysis of a dual-stage RO system. This analysis was restricted to tubular modules. These results are not adequate for the majority of RO plants because they use mainly spiral-wound modules. Other studies [2,3] optimized operating conditions of individual reverse osmosis modules and did not optimize the RO plant as global system. The 90% of them pay more attention to the overall design aspect. They assured that the optimum rate is generally the maximum possible as limited by the brine osmotic pressure and brine flow considerations; nevertheless it may be not be true in all cases. On the other hand, few papers have illustrated a deep study of the seasonal influence and any reference about optimization of RO seawater plants in the Caribbean and South America were not found. The most important papers are focussed over the Mediterranean Sea and Arabian Gulf.

The aim of the investigation is to evaluate the seasonal influence of the environmental conditions (salinity, TDS, temperature, etc.) on operating costs of desalination plants. In the rainy or hurricane season (June–December) TDS values used to increase due to material from flooding of the cities and the salinity decreases due to dilution. In the same manner, in the dry season (January–May) the salinity used to increase, so membranes should be replaced more frequently.

In traditional designs, the optimization problem is stated in precise mathematical terms. However, in many real world problems, the design data, objective function and constraints are stated in vague and linguistic terms. It appears that it is more reasonable to have a transition state from absolute permission to absolute non-permission. This implies that the constraint is to be stated involving vague and imprecise information. In the literature several applications of the fuzzy logic in optimization have been reported [4–7].

A historical review about fuzzy mathematical programming points to Bellman and Zadeh [4] in a first category treating decision-making problem under fuzzy goals and constraints for first time. The fuzzy goals and constraints represent the flexibility of the target values of objective functions and the elasticity of constraints. From this point of view, this type of fuzzy mathematical programming is called flexible programming. The second category in fuzzy mathematical programming treats ambiguous coefficients of objective functions and constraints but does not treat fuzzy goals and constraints. Dubois and Prade [8] treated systems of linear equations with ambiguous coefficients suggesting the possible application to fuzzy mathematical programming for the first time. A remarkable development was made by Kuzmin [9]. He introduced four inequality indexes between fuzzy numbers based on the possibility theory into mathematical programming problems with fuzzy coefficients. Since the fuzzy coefficients can be regarded as possibility distributions on coefficient values, this type of fuzzy mathematical programming is usually called the possibilistic programming.

In fact, using a possibilistic optimization approach, a solution can be achieved that provides a maximum degree of overall satisfaction [10–12]. To determine an optimal solution, decision problems may be formulated as a fuzzy decision model, particularly when the available data are known exactly though varying within a tolerance limit. The coefficients of some constraints may be fuzzy numbers and the original fuzzy problem is transferred into a crisp satisfactory model [13]. In this paper, a fuzzy linear programming (FLP) model subjected to some linear fuzzy constraints [12,14,15] as well as some crisp constraints have been developed and transferred into a crisp model.