Probabilistic design of wastewater treatment plants

M. Talebizadeh*, E. Belia, P.A. Vanrolleghem***

* modelEAU, Dép. de génie civil et de génie des eaux, Université Laval, Québec, Canada
** Primodal Inc., Québec, Canada

The primary goal of wastewater treatment plants (WWTPs) is to remove pollutants from wastewaters so as to reach a set of effluent standards under a set of environmental, cost, and regulatory constraints. To design a WWTP according to these criteria, design engineers usually make the initial sizing of the plant using design guidelines or a set of modeling tools under steady-state conditions. In these approaches the effect of different sources of uncertainties are taken into account in an implicit manner through the application of safety factors and/or selection of conservative design values for design inputs. In this study, a new probabilistic method is proposed for the design of WWTPs. First, a set of design alternatives with different levels of safety are produced and then the probability of non-compliance (PONC) corresponding to each design alternative is calculated using Monte Carlo simulation. The effect of influent variability is taken into account by developing an influent generator capable of incorporating the basic characteristics of the connected sewershed, local climate data, as well as the measured influent time series data into the generated influent time series. In addition, the effect of model parameter uncertainty is taken into account by characterizing the uncertainty in model parameters in terms of probability distribution functions and sampling from their corresponding distribution at each Monte Carlo run.

After the termination of Monte Carlo simulation, the PONC values corresponding to different wastewater constituents are calculated using the cumulative distribution function (CDF) of effluent time series for a specific effluent standard. Figure 1 illustrates the CDF curves for effluent NH4 concentration corresponding to different design alternatives calculated using different Monte Carlo simulation schemes including: Mixed (i.e. no distinction between the influent variability and model parameter uncertainty), Calibrated (i.e. Influent variability with model parameters fixed at their calibrated values) and “Worst Case” (i.e. influent variability with model

parameters fixed at a "worst case" value). The PONC values corresponding to a NH4 effluent standard of 2 mg/lit are calculated for different design alternatives (Table 1).

The proposed probabilistic methodology provides the design engineers with a concerted framework to utilize and incorporate into the design of WWTPs the available and future information on the characteristics of the sewershed and the climate conditions, as well as the latest advances in dynamic modeling. Moreover, the calculated PONC can be used as an objective criterion for comparing different design alternatives and help designers avoid the application of overly-conservative safety factors.

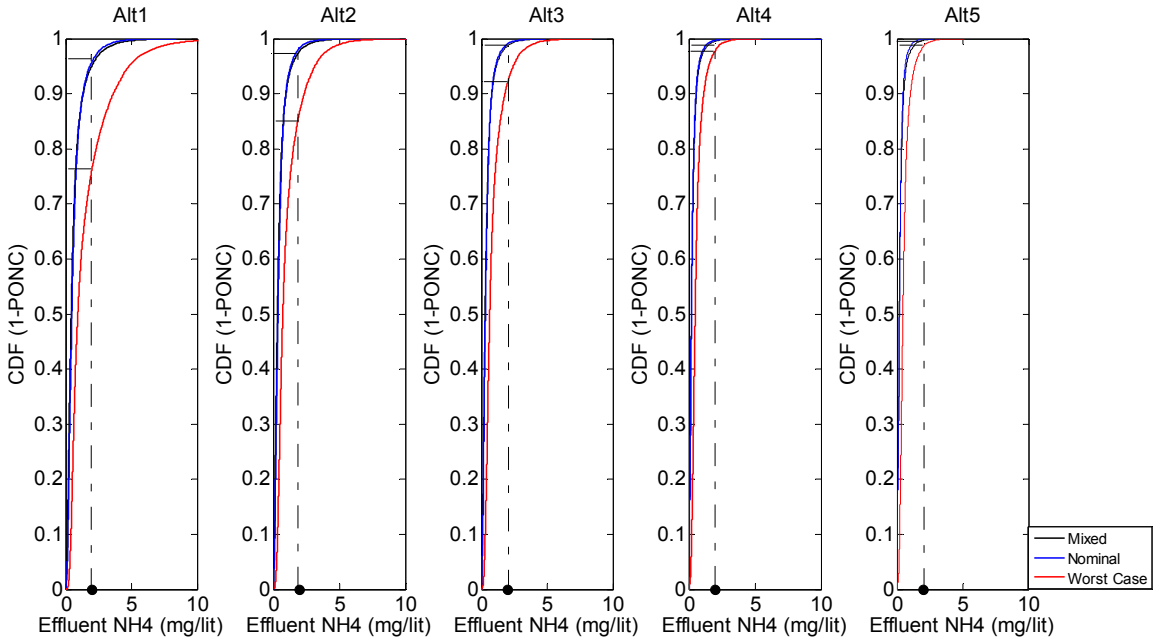

Figure 1. Effluent NH4 distribution corresponding to different design alternatives

Table 1. Probability Of Non-Compliance (PONC) for different design alternatives

Alternatives	Mixed		Calibrated		"Worst Case"	
	PONC	Days[1]	PONC	Days	PONC	Days
Alt1	0.0488	17.8	0.0414	15.1	0.2360	86.4
Alt2	0.0211	7.7	0.0170	6.2	0.1334	48.7
Alt3	0.0126	4.6	0.0094	3.4	0.0796	29.0
Alt4	0.0046	1.7	0.0029	1.0	0.0215	7.8
Alt5	0.0028	1.1	0.0007	0.2	0.0140	5.1

[1]Expected number of days with non-compliance event in a year (i.e. PONC×365)