A MODEL FOR EFFICIENT WATER USE IN AN URBAN WATER NETWORK

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Optimization models for more efficient water use have been developed mainly in the industrial sector. The Alva-Argáez (1998) model stands out since it considers optimization of industrial unit operations as a mathematical nonlinear, integer-mixed programming problem. Bilineal terms of the mass balances, dimensioning equations and the unit-operations' cost functions are all responsible for the nonlinearities of the formulation. There are no reliable mathematical models for complex water-using urban networks where users need and discharge different water flowrates and different water compositions. This paper presents one model, under the following considerations, Mann and Liu (1999):

a) Maximum and minimum values of contaminant concentrations involved in each operation (user) are known.
b) The model design considers a fixed number of unit operations.
c) No heat-transfer processes are included.
d) The network's pressure is constant.

The model is intended to optimize all possible connections among freshwater-supply sources and unit operations and considers flowrate transfer through wastewater treatment and reuse in other water-using operations. Therefore, the model construction considers the following:

a) All water supply sources may serve all unit operations.
b) All effluent streams from all unit operations may be mixed in the discharge points.
c) All water-using operations are preceded by a node where freshwater and water from other operations is mixed to be reused.
d) All water-using operations are followed by a dividing node fed by the final mixer and all system water-using operations.

The model was tested out in the city of Puebla, located 100 km east of Mexico City, at 2,160 meters above sea level and with a surface area of about 195,147 km^2. Four contaminants were studied: biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), and settleable solids (SetS). The model allows a network configuration that meets all connected users demands and minimizes freshwater flowrate, reducing wastewater generation.

Based in the present system situation, the following scenarios are proposed:

1.- Treated wastewater reuse using the existing infrastructure.
2.- Introduction of new water supply sources.
3.- Leak reduction to 25%.
4.- Introduction of new water supply sources and leak reduction.
5.- Introduction of new water supply sources, leak reduction and municipal wastewater reuse, treated in new advanced primary wastewater treatment facilities.
6.- Introduction of new water supply sources, leak reduction and municipal wastewater reuse, treated in new secondary wastewater treatment facilities, using trickling filters.
Solving the optimization array gives the situation depicted in Chart 4, which also enables a comparison among the proposed scenarios

The proposed model allows minimizing freshwater flowrates in a water-using system and, at the same time, complies with water quality standards established both for human consumption and discharges in receiving water bodies. In order to quantify water savings, irrigated areas for different local crops were estimated (Chart 1).

Chart 1. Overview of all scenarios presented for the city of Puebla.

No.	Situation or scenario	Freshwater used by the system	Saved flowrate	Porcentage of total saved flowrate	Reaching the scenario costs	Potential irrigation area				
		L/s	L/s		$ (millions)	corn	beans	chili	tomato	alfalfa
	Present	4295	---	---	---					
1	*Deviation from* present situation	4246.98	48.02	1.12	---	*30.73*	*47.99*	*48.57*	*39.83*	*18.61*
2	Reduction to 25%	3951.88	343.12	7.99	6.31	219.60	342.89	347.07	284.60	132.99
3	Introduction of new sources	4980.00	---	---	121.27					
4	Leak reduction to 25% plus new sources introduced	4594.73	385.27	7.74	127.58	*246.47*	*384.86*	*389.55*	*319.43*	*149.27*
5	Wastewater *treatment facilities,* 1st stage	4583.59	396.41	7.96	715.99	253.70	396.14	400.97	328.80	153.64
6	Wastewater treatment facilities, 2nd stage	4515.30	464.70	9.33	880.19	297.41	464.38	470.05	385.44	180.11

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