Title

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Journal

Journal of Environmental Engineering, 142(4)

ISSN

0733-9372

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Publication Date

2016-04-01

DOI

10.1061/(asce)ee.1943-7870.0001057

Peer reviewed

Discussion of "Optimization of Phenol Removal Using Ti/PbO$_2$ Anode with Response Surface Methodology" by C. García-Gómez, J. A. Vidales-Contreras, J. Nápoles-Armenta, and P. Gortáres-Moroyoqui

DOI: 10.1061/(ASCE)EE.1943-7870.0001057

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Newly developed optimization algorithms have been applied in several domains of water resources systems, such as reservoir operation (Ahmadi et al. 2014; Bolouri-Yazdeli et al. 2014; Ashofteh et al. 2013a, 2015a), groundwater resources (Bozorg-Haddad et al. 2013; Fallah-Mehdipour et al. 2013a), conjunctive use operation (Fallah-Mehdipour et al. 2013b), design–operation of pumped-storage and hydropower systems (Bozorg-Haddad et al. 2014), flood management (Bozorg-Haddad et al. 2015a), water project management (Orouji et al. 2014), hydrology (Ashofteh et al. 2013b), qualitative management of water resources systems, (Orouji et al. 2013; Bozorg-Haddad et al. 2015b; Shokri et al. 2014), water distribution systems (Seifollahi-Aghmiuni et al. 2013; Soltanjalili et al. 2013; Beygi et al. 2014), agricultural crops (Ashofteh et al. 2015c), sedimentation (Shokri et al. 2013), and algorithmic developments (Ashofteh et al. 2015b). However, there is a lack of studies dealing with phenol removal using Ti/PbO$_2$ anodes with response surface methodology, which was addressed in the discussed paper.

García-Gómez et al. (2016) used the response surface methodology (RSM) to investigate the effects of different operating conditions on phenol removal via electrooxidation with a Ti/PbO$_2$ anode. The authors used a central composite design (CCD) to evaluate the individual and interaction effects of current intensity (X_1; A), electrolysis time (X_2; min), and recirculation flow rate (X_3; mL/min) to optimize phenol removal. The coupled model was used to achieve the optimal conditions required to remove phenol from synthetic wastewater with a phenol concentration equal to 10 mg/L. The results for phenol removal involved a 1.12-A current intensity, 40-min electrolysis time, and 188-mL/min recirculation flow rate, in which a removal of $78.97 \pm 1.72\%$ was achieved. García-Gómez et al. (2016) concluded that the proposed procedures are a promising approach for wastewater treatment. The approach proposed by Garcia-Gomez et al. (2016) presents novel ideas for wastewater treatment; however, there are a few remarks that might improve the discussed paper's results.

For the sake of clarity, this discussion was organized into three main categories: (1) arithmetic errors, (2) undefined functions, and (3) optimization model.

Arithmetic Errors

1. The García-Gómez et al. (2016) paper used a second-order polynomial regression model represented in Eq. (1) to predict the phenol removal efficiency (Y_1; %)

$$Y_1 = -20.38 + 89.44X_1 + 3.30X_2 - 0.39X_3 - 0.05X_1X_2 - 0.013X_1X_3 - 1.49X_2X_3 - 24.44X_1^2 - 0.02X_2^2 + 7.65X_3^2 \qquad (1)$$

   Assigning values to the dependent variables (X_i) within their acceptable range does not lead to a feasible Y_1. This assertion is demonstrated by observing that neither the given arrays of dependent variables presented in Table 3 of the discussed paper nor their optimized values cause the regression model in Eq. (1) to generate Y_1 values between 1 and 100 (these are percentages).
2. The last six rows of Table 3 in the discussed manuscript list the dependent variables, yet the corresponding values of the dependent variables presented in the predicted removal efficiency column are not equal to each other. In other words, the regression model of Eq. (1) can generate more than one outcome given a single input value.
3. Six computational errors might have been made in Table 3 of the discussed manuscript. In its relative deviation column, the following attributes: −2.28, 3.07, 3.52, 0.44, −1.84, and 2.81 should be replaced with 0.72, −1.62, 1.52, −1.33, 1.84, and 1.81, respectively. These plausible miscalculations might have been caused by errors in the linked attributes listed in the relative deviation column of Table 3.

Objective Functions

Two criteria were introduced in the discussed paper to assess the desirability of its results, one being the phenol removal efficiency (Y_1) and the other the amount of energy consumption (Y_2; kWh/m^3). The discussed paper stated that the results of its optimization depended on the mathematical functions represented by each of these criteria. Even though attention was given to the phenol removal efficiency regression model, less attention was dedicated to the regression model of energy consumption. For instance, García-Gómez et al. (2016) did not report the regression equation of energy consumption, even though the optimization model relies heavily on that function in searching for optimal results. Introducing both criteria might prove useful to further studies and help readers gain a better grasp of the paper's methodology.

Optimization Model

Optimizing only one criterion or objective function (OF) is the basic principle of single-objective optimization. The aim of such problems is to search the decision space for the best feasible solution of the OF, called global optimum, or in some cases to settle for solutions near the optimum. However, problems with two or more OFs, called multiobjective optimization, require different

J. Environ. Eng., 2017, 143(9): 07017001

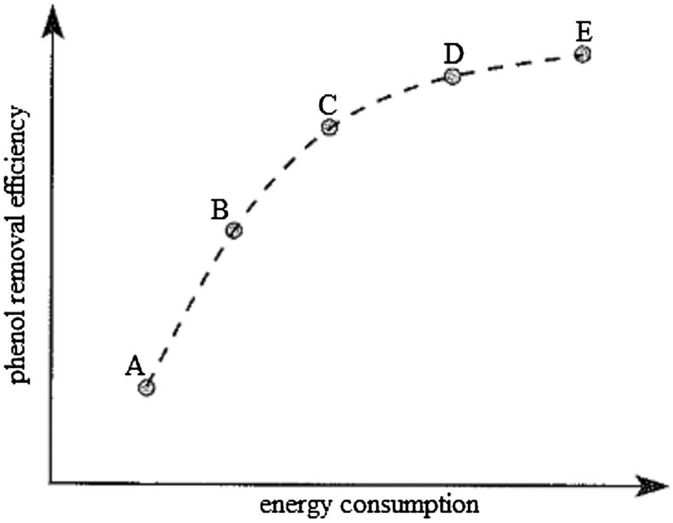

Fig. 1. General decision space of original manuscript

mathematical approaches (e.g., Deb 2001). In such problems, the very notion of an optimal solution does not apply (Coello 2006).

To illustrate this point, consider the discussed paper's optimization problem. The objective functions are the maximization of phenol removal efficiency while minimizing energy consumption for this operation. The decision space of this optimization problem is illustrated in Fig. 1. All the given points in this figure are equally desirable because none of them has a clear superiority over the others. In other words, each point shown in Fig. 1 that represents a higher quality of phenol removal efficiency (a desirable trait) also requires more energy (an undesirable trait) and vice versa. Or, using optimization jargon, none of the points depicted in Fig. 1 dominates the others. It is well established in multiobjective optimization that when there are conflicts among various OFs, the solutions to the optimization problem must be obtained in the form of Pareto possibility frontiers (PPFs) that contain combinations of decision variables that express the most efficient tradeoffs among the various objectives of the optimization. Because each of these combinations of decision variables has no clear desirability over the others, a set of criteria are available for decision makers to choose the optimal combination according to each situation. However, the optimization presented in the discussed manuscript avoided the PPF approach and instead assigned a specific weight to each of the OFs, causing the optimization to find one solution associated with the chosen weighting scheme. To achieve better solutions, one could try multiple weights for each OF and solve the optimization problems for each combination of weights to arrive at a set of solutions for the various assigned weights. The OFs of the discussed manuscript's optimization model were unclear. Therefore, two mathematical functions, as given in Eqs. (2) and (3), are used as OFs in an example optimization problem to illustrate solutions for multiple weights

$$\mathrm{OF}_1 = \text{minimize}\{x^2\} \tag{2}$$

$$\mathrm{OF}_2 = \text{minimize}\{(x-2)^2\} \tag{3}$$

where OF_1 and OF_2 = objective functions; and x = independent variable defined over the interval $0 \le x \le 2$. The functions OF_1 and OF_2 are multiplied by nonnegative weights w_1 and w_2, respectively, and added to form a single objective function equal to $w_1\mathrm{OF}_1 + w_2\mathrm{OF}_2$. The resulting single-objective minimization problem has the solution

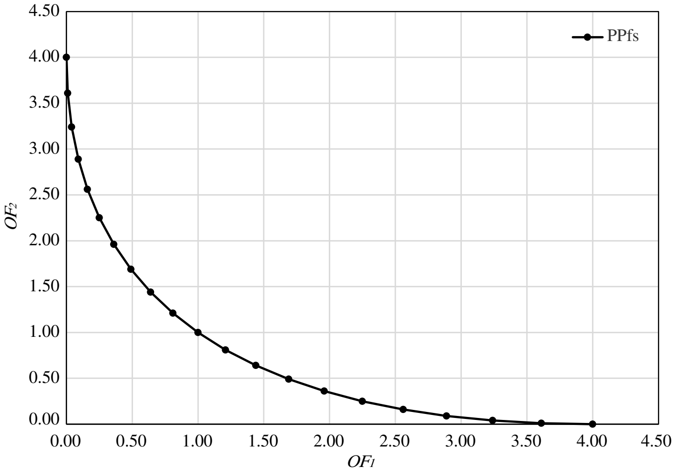

Fig. 2. PPF of the bi-objective problem [Eqs. (2) and (3)]

Table 1. Example Multiobjective Optimization Results Corresponding to Various Weights

Weight for OF_1	Weight for OF_2	Optimum x	OF_1	OF_2
1	1	1.00	1.00	1.00
2	1	0.67	0.44	1.78
1	2	1.33	1.78	0.44
3	1	0.50	0.25	2.25
1	3	1.50	2.25	0.25
3	2	0.80	0.64	1.44
2	3	1.20	1.44	0.64

$$x^* = 2w_2/(w_1 + w_2) \tag{4}$$

The values of OF_1 and OF_2 are obtained for each x^* associated with chosen weights w_1 and w_2. Fig. 2 shows the various combinations of OF_1 and OF_2 evaluated at x^* corresponding to the weights listed in Table 1 and others not listed there. The graph in Fig. 2 represents the Pareto possibility frontier associated with the minimization problem involving the functions in Eqs. (2) and (3). The choice of a particular solution on the PPF represents the preference of the decision maker. The solution of more complex multidimensional (i.e., those with two or more decision variables) or multiobjective optimization problems (i.e., those with two or more objective functions) is routinely accomplished nowadays with special optimization evolutionary algorithms (MOEAs; Deb et al. 2003) rather than with weighted multiobjective functions. The phenol removal problem of García-Gómez et al. (2016), which has three decision variables and two objective functions, is well suited for solution with MOEAs, in which case the solutions would be expressed in terms of PPFs.

References

Ahmadi, M., Bozorg-Haddad, O., and Mariño, M. A. (2014). "Extraction of flexible multi-objective real-time reservoir operation rules." *Water Resour. Manage.*, 28(1), 131–147.

Ashofteh, P. S., Bozorg-Haddad, O., and Loáiciga, H. A. (2015a). "Evaluation of climatic-change impacts on multi-objective reservoir operation with multiobjective genetic programming." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)WR.1943-5452.0000540, 04015030.

Ashofteh, P.-S., Bozorg-Haddad, O., Akbari-Alashti, H., and Mariño, M. A. (2015b). "Determination of irrigation allocation policy under climate change by genetic programming." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000807, 04014059.

Ashofteh, P.-S., Bozorg-Haddad, O., and Mariño, M. A. (2013a). "Climate change impact on reservoir performance indices in agricultural water supply." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000496, 85–97.

Ashofteh, P.-S., Bozorg-Haddad, O., and Mariño, M. A. (2013b). "Scenario assessment of streamflow simulation and its transition probability in future periods under climate change." *Water Resour. Manage.*, 27(1), 255–274.

Ashofteh, P.-S., Bozorg-Haddad, O., and Mariño, M. A. (2015c). "Risk analysis of water demand for agricultural crops under climate change." *J. Hydrol. Eng.*, 10.1061/(ASCE)HE.1943-5584.0001053, 04014060.

Beygi, S., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2014). "Bargaining models for optimal design of water distribution networks." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)WR.1943-5452.0000324, 92–99.

Bolouri-Yazdeli, Y., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2014). "Evaluation of real-time operation rules in reservoir systems operation." *Water Resour. Manage.*, 28(3), 715–729.

Bozorg-Haddad, O., Ashofteh, P.-S., Ali-Hamzeh, M., and Mariño, M. A. (2015a). "Investigation of reservoir qualitative behavior resulting from biological pollutant sudden entry." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000865, 04015003.

Bozorg-Haddad, O., Ashofteh, P.-S., and Mariño, M. A. (2015b). "Levee layouts and design optimization in protection of flood areas." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000864, 04015004.

Bozorg-Haddad, O., Ashofteh, P.-S., Rasoulzadeh-Gharibdousti, S., and Mariño, M. A. (2014). "Optimization model for design-operation of pumped-storage and hydropower systems." *J. Energy Eng.*, 10.1061/(ASCE)EY.1943-7897.0000169, 04013016.

Bozorg-Haddad, O., Rezapour Tabari, M. M., Fallah-Mehdipour, E., and Mariño, M. A. (2013). "Groundwater model calibration by meta-heuristic algorithms." *Water Resour. Manage.*, 27(7), 2515–2529.

Coello, C. A. C. (2006). "Evolutionary multi-objective optimization: A historical view of the field." *Comput. Intell. Mag.*, 1(1), 28–36.

Deb, K. (2001). *Multi-objective optimization using evolutionary algorithms*, Wiley, West Sussex, U.K.

Deb, K., Mohan, M., and Mishra, M. (2003). "A fast multiobjective evolutionary algorithm for finding well-spread Pareto-optimal solutions." *KanGal Rep. 2003002*, Indian Institute of Technology, Kanpur, India.

Fallah-Mehdipour, E., Bozorg-Haddad, O., and Mariño, M. A. (2013a). "Extraction of optimal operation rules in aquifer-dam system: A genetic programming approach." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000628, 872–879.

Fallah-Mehdipour, E., Bozorg-Haddad, O., and Mariño, M. A. (2013b). "Prediction and simulation of monthly groundwater levels by genetic programming." *J. Hydro-Environ. Res.*, 7(4), 253–260.

García-Gómez, C., Vidales-Contreras, J., Nápoles-Armenta, J., and Gortáres-Moroyoqui, P. (2016). "Optimization of phenol removal using $\mathrm{Ti/PbO_2}$ anode with response surface methodology." *J. Environ. Eng.*, 10.1061/(ASCE)EE.1943-7870.0001057, 04016004.

Orouji, H., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2013). "Modeling of water quality parameters using data-driven models." *J. Environ. Eng.*, 10.1061/(ASCE)EE.1943-7870.0000706, 947–957.

Orouji, H., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2014). "Extraction of decision alternatives in project management: Application of hybrid PSO-SFLA." *J. Manage. Eng.*, 10.1061/(ASCE)ME.1943-5479.0000186, 50–59.

Seifollahi-Aghmiuni, S., Bozorg-Haddad, O., and Mariño, M. A. (2013). "Water distribution network risk analysis under simultaneous consumption and roughness uncertainties." *Water Resour. Manage.*, 27(7), 2595–2610.

Shokri, A., Bozorg-Haddad, O., and Mariño, M. A. (2013). "Reservoir operation for simultaneously meeting water demand and sediment flushing: A stochastic dynamic programming approach with two uncertainties." *J. Water Resour. Plann. Manage.*, 139(3), 277–289.

Shokri, A., Bozorg-Haddad, O., and Mariño, M. A. (2014). "Multi-objective quantity-quality reservoir operation in sudden pollution." *Water Resour. Manage.*, 28(2), 567–586.

Soltanjalili, M., Bozorg-Haddad, O., and Mariño, M. A. (2013). "Operating water distribution networks during water shortage conditions using hedging and intermittent water supply concepts." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)WR.1943-5452.0000315, 644–659.