Aging and Energy Cost in WWTPs

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Overview

- This paper sets out to predict energy cost of WWTPs as a function of age of facility, size of WWTP, and type of WWTP

Why:

- A large portion of the operating costs of a WWTP are associated with energy costs
- Mitigate environmental impact of WWTPs

A B S T R A C T

Wastewater treatment plants (WWTPs) are aging and its effects on the process are more evident as time goes by. Due to the deterioration of the facilities, the efficiency of the treatment process decreases gradually. Within this framework, this paper proves the increase in the energy consumption of the WWTPs with time, and finds differences among facilities size. Accordingly, the paper aims to develop a dynamic energy cost function capable of predicting the energy cost of the process in the future. The time variable is used to introduce the aging effects on the energy cost estimation in order to increase the accuracy of the estimation. For this purpose, the evolution of energy costs will be assessed and modelled for a group of WWTPs using the methodology of cost functions. The results will be useful for the managers of the facilities in the decision making process.

The Data

- 966 Observations (322 WWTPs)
- All WWTPs from Spain, data from 2010, 2011, 2012
- Variables: energy cost, volume of WW treated, amount of contaminants, chemical oxygen demand (COD) removed from the WW, design flow, equivalent inhabitants

Table 1
Sample description.

	2010		2011		2012	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Energy cost (€/year)	79,867	202,709	78,739	201,226	73,269	188,567
SS Removed (kg/year)	265,154	782,100	236,899	708,380	227,144	671,204
COD Removed (kg/year)	524,012	1,482,234	515,601	1,457,401	500,302	1,401,494
Treated Flow (m^3/year)	954,467	2,640,931	888,163	2,443,864	862,130	2,363,451
Design Flow (m^3/day)	4063	10,168	4063	10,168	4063	10,168
Equivalent inhabitants	13,326	38,395	13,089	37,908	12,876	36,839

The Data Used in the Model

- Technology groups:
  T1: Oxygen supply systems (activated sludge & extended aeration)
  T2: Non-oxygen supply systems (biodisk technology)
  Note: T1 is much more energy demanding than T2
- Both technology groups show an increase in energy cost over time, but only T1 has a statistically significant increase in our time period:

Table 3
Energy cost of the wastewater treated (€/m^3) differentiating two groups depending on the technologies applied for the period 2010–2012 and Kruskal-Wallis Test.

Energy Cost (€/m^3)				
	2010	2011	2012	Kruskal-Wallis Test
Group: T1				
Mean	0.117	0.145	0.150	0.001
Minimum	0.019	0.028	0.028	
Maximum	0.620	0.807	1.027	
Group: T2				
Mean	0.063	0.074	0.089	0.184
Minimum	0.033	0.046	0.038	
Maximum	0.132	0.154	0.164	

The Data Used in the Model (cont.)

- Volume of Wastewater Treated Groups:
  D1: facilities that treat up to 55,000 m^3/year,
  D2: . . .between 55,000 and 275,000 m^3/year,
  D3: . . . more than 275,000 m^3/year.
- They see statistical signifance in D2 and D1

- Data subset: D1/D2 "size" facilities that are also T1 (102 out of 322 WWTPs)

The Model

- Models aging of WWTP in an interesting and more robust way than the previous literature
- Energy cost model variable desciption:
  $EC =$ energy cost per year,
  $V =$ volume of wastewater treated (m^3/year),
  $M =$ COD removed (kg/year),
  $J =$ aging.

- Final EC model:

$$EC = 0.125 \cdot V^{0.791} \cdot \exp(5.38 \times 10^{-8} \cdot M + 0.103 \cdot J)$$

- Good fit: $r^2 = 0.890$

Notes on the Model

- Effect of volume of wastewater treated on energy cost increases at a decreasing rate
  This may be explained by:
  (1) larger facilities present better maintenance of the equipment
  (2) smaller facilities tend to be oversized and deteriorate more rapidly, so differences in the energy consumption over time are more notable in these cases

- Coefficent on COD removed is **very** small
  This is due to the unit of measure

Key Takeaways

- Energy costs make up a large portion of the cost associated with maintaining a WWTP
- Energy costs increase with time, especially with smaller WWTPs
- Advise towns to invest in non-oxygen supply systems and to keep up on maintenance to avoid high energy costs