Procedure and Amounts Used for the Evaluation of Costs

Information and data reported in this supplementary file are drawn from [1] where further details can be found if of interest of the reader.

In order to estimate costs two main categories were accounted for: investment/capital costs and operating costs.

Each category was divided in two specific parts: fixed costs, regardless to the quantity of wastewater processed, and variable costs that are dependent on quantity of wastewater processed (Table 1).

Table S1. Costs categories.

Fixed Costs	**Variable Costs**
Investment costs/capital costs	
civil works	
electromechanical works	
operating costs	*operating costs*
staff	energy costs
maintenance	reagents

Source: [1]

To evaluate the additional costs for upgrading wastewater plants from T1 and T2 to T3 the following scheme (Table 2) was adopted:

Table S2. Fixed and Variable Costs.

Upgrading from T1 to T3	**Upgrading from T2 to T3**
investment /capital costs	*investment /capital costs*
civil works	-
electromechanical works	electromechanical works
operating costs	*operating costs*
staff	staff
maintenance	maintenance
energy costs	energy costs
reagents	reagents

Source: [1]

In order to calculate the capital costs of upgrading wastewater plants all elementary parametric costs for each type of process and work were estimated.

For each process of wastewater treatment, all the specific cost items that contribute to the full costs were analyzed. The processes considered in the study are: biological treatments (nitrogen removal) and physical-chemical treatments (de-phosphatization, suspended solids removal, disinfection).

The following treatment units have been considered: coagulation, oxidation, filtration (pressure and gravity) and disinfection.

In order to estimate all the elementary parametric costs, for each type of process, values were reported from real design cases, including price lists of public works of Puglia (from the official Chamber of Commerce regional price list in 2012) and of the neighboring Basilicata region, integrated by market researches that allowed to define an average cost for each feature.

The cost of the coagulation treatment for suspended solids removal depends on the cost of reagents, civil works and electromechanical works.

The cost of the oxidation treatment for nitrogen removal depends on the cost of civil works (oxidation tanks) and electromechanical works (ventilation systems).The biological reactor for nitrogen removal was calculated on the basis of biological activity of heterotrophic denitrification and nitrification by autotrophic

microbial species, determined using the Monod kinetics relations [2] and through the resolution of a set of mass balance equations (reactors input and output). The reactors' volume was calculated considering two values of air temperature: 20° C for annual operating conditions and 15° C for winter operating conditions.

The ventilation system costs are strongly related to the flow treated and the size of the oxidation basin. The main elements which define the installation costs are: oxygen diffusers, air blowers, mixer and pumping station for the recycle of the aerated mixture.

For filtration, gravity filters and pressure filters depending on the usable area of filtering and including pumps, backwash pumps and the civil works were considered.

The disinfection costs accounted for two main typologies: use of chemical reagents (sodium hypochlorite) and ultraviolet-rays system combined with peracetic acid. In both cases, civil works costs, plant costs and operating costs (cost of reagents) were considered.

The costs considered necessary to upgrade a treatment plant from T1 toT3 are summarized in Table 3.

Table S3. Unit costs for upgrading a treatment plant from T1 to T3.

Type Cost	Unit of Measure	Unit Cost €
Civil works		
Excavations, fills, storage tanks, paving, asphalt, fence	€ / m^3	400
Pressure filters	€ / m^3	600
Gravity filters	€ / m^3	600
Electromechanical works		
Oxidation		
Blowers	€/Nm^3/g	min 0.39–max 7.33
mixer	€/N	min 12.5–max 47.7
pumps for the air mixture	€/Kwh	min 1234–max 5909
Pressure filtration		
filters	€/m^2	min 8890–max 12,166
Pumping for filtration	€/kwh	min 1688–max 3250
Pumping for blackwash	€/kwh	min 1150–max 2855
Blowers	Nm^3/g	min 0.39–max 7.33
Gravity filtration		
nozzles	unit	1.5
hydraulic valves	€/filter	25
electrical systems	€/filter	5
Pumping for filtration	€/kwh	min 1.688–max 3.250
Pumping for blackwash	€/kwh	min 1150–max 2855
Blowers for filters	nm^3g	min 0.39–max 7.33
filling material	€/m^3	10
lamps UV	unit	min 1.470–max11.073
electromechanical works connected with the reagents:		
batching plant	unit	2

Source: [1]

Depending on the potentiality of the plant, the estimate of investment accounts for the different costs of the works related to filtration by gravity and / or pressure.

Based on these assumptions the cost of investments of civil works and electromechanical works were evaluated as a function of PE shown in Table 4.

Table S4. Unit costs for upgrading a treatment plant from T1 to T3.

Plant Size (PE)	Civil Works	Electromechanical Works	Total
2000	€ 99,346	€ 147,538	€ 246,884
5000	€ 248,364	€ 222,892	€ 471,256
10,000	€ 496,728	€ 272,126	€ 768,854
20,000	€ 962,687	€ 558,027	€ 1,520,714
30,000	€ 1,444,031	€ 787,763	€ 2,231,794
40,000	€ 1,843,775	€ 998,550	€ 2,842,325
50,000	€ 2,304,719	€ 1,225,451	€ 3,530,170
70,000	€ 3,226,606	€ 1,675,159	€ 4,901,765
100,000	€ 4,609,437	€ 2,236,207	€ 6,845,644
250,000	€ 14,023,503	€ 2,132,238	€ 16,155,741
500,000	€ 26,926,363	€ 3,930,682	€ 30,857,045

Source: [1]

The costs considered necessary to upgrade a treatment plant from T2 toT3 are summarized in Table 5.

The analysis of capital costs concerns only the electromechanical works (particularly those related to treatment with UV rays), systems for dosage and storage tanks. Thus, in this case, the investment costs are significantly reduced.

Table S5. Unit costs for upgrading a treatment plant from T1 to T3.

Type Cost	Unit of Measure	Unit Cost €
Electromechanical works		
Lamps UV	unit	min 1470–max11,073
Electromechanical works connected with the reagent		
Batching plant	unit	2000
Storage tank	unit	min 3500–max7000

Source: [1]

For an incoming effluent quality of T2 further costs needed to reach T3 standards involve costs due to larger amount of reagents and increased cost for electromechanical works (see Table 6), being negligible other items.

Table S6. Cost of electromechanical works as a function of PE in upgrading from T2 to T3.

Plant Size (PE)	Electromechanical Works
2000	€ 53,241
5000	€ 57,566
10,000	€ 66,145
20,000	€ 104,154
30,000	€ 131,865
40,000	€ 162,904
50,000	€ 194,171
70,000	€ 252,888
100,000	€ 337,130
250,000	€ 843,636
500,000	€ 1,395,426

Source: [1]

Management costs evaluation

The operating costs analysis covered the following items:

- Staff costs
- Cost (dosage) of reagents
- Energy consumption

- Maintenance costs and replacement parts
- Financial costs

Staff costs

Accounting costs for personnel is performed on the hypothesis that the agent who provides treatments from T1 (or T2) to T3 is of the same type (or may be the same one) that produces the T1 (or T2) effluent. In particular, in Puglia such service is provided by a joint-stock company with public capital (AQP SpA).

Reagents costs

The analysis of the additional costs of the reagents took into account the three types of reagents:
- aluminum chloride to 15% for in-line coagulation;
- sodium hypochlorite to 12% for the disinfection or
- peracetic acid to 15% with bacteriostatic function to match the treatment to UV rays.

Two techniques have been considered, a low and a high dosage of the reagents for the disinfection. On the basis we have estimated the additional cost of reagents per month in order to estimate the reagents costs for type of destination user and system capacity.

Energy costs

The costs of energy consumption were calculated according to capacity of plants and reference temperatures of the nitrification and denitrification processes (15 ° C and 20 ° C), giving a unit cost of 0.1 € / KWh.

Maintenance costs and replacement parts

The maintenance costs of the civil and the electromechanical works were estimated as follow:

- ***Civil works***: the useful life of the investment was assumed equal to 25 years, with a cost of maintenance equal to an average annual rate of 1% over the entire cost of investment;

- ***Electromechanical works***: because of the increased need of maintenance and need to replace mechanical parts, an average useful life cycle of 8 years, with an annual rate on the maintenance of 5% over the entire cost of investment was considered (Table 7).

Table S7. Maintenance costs: useful life and annual rate of maintenance.

Type of Work	life Cycle	Annual Rate of Maintenance
Civil works	25 years	1%
Electromechanical works	8 years	5%

Source: [1]

Analysis of financial costs

The capital costs enter into the operational / management costs in the form of financial charges and amortization related to the type of financing of the civil works and the electromechanical works.

In the study the financial costs have affected only the technical linear amortization, in the hypothesis of constitution of a public capital invested.

Table S8. Analysis of financial costs: useful life and Linear amortization rate.

Type of Work	life Cycle	Linear Amortization Rate
Civil works	25 years	4%
Electromechanical works	8 years	12.5%

Source: [1]

Reference

1. Piccinni, A.F.; Arborea, S.; Balacco, G. Aspetti economici. In *Progetto PON In.Te.R.R.A.: Linee Guida per il Riuso Irriguo delle Acque Reflue Depurate*, Rubino, P., Lonigro, A., Eds. Edizioni di Pagina: Bari, Italy, 2015; pp. 153–181.
2. Monod, J. The growth of bacterial cultures. *Annu.l Rev. Microbiol.* **1949**, *3*, 371–394.