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Project Number	**LIFE15 ENV/IT/000332**

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Dissemination level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Revision Chart and History Log		
Version	Date	Comment
1		Rev 1 submitted to partners for internal review
2		Approved

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Sommario

1. Introduction

This report aims to demonstrate the economic feasibility of the proposed technology for the treatment of TMAH and photoresist effluent, BOE and SEZ according to mass and energy balance as reported by the deliverable B5.1_ *Report on whole mass and energy balance of a* *full-scale plant* and the LCC analysis has been already presented in the deliverable C1.3 *_Environmental impact assessment including LCA and LCC results conclusions and recommendations*.

A plant using Life Bitmaps technology would be designed to treat three type of wastewaters:

- TMAH and photoresist wastewater
- BOE wastewater
- SEZ wastewater

The first effluent is treated by biological process, instead the other two wastewaters are treated by chemical/physical ones adding lime in the presence of coagulant to remove the impurities.

Financial indicators as payback period (PBP) and Return on Investment (ROI) have been calculated. The PBT is the time required for a project to return the initial investment. It is computed by calculating the cumulative return for each year and comparing it to the investiment; the time at which this sum exceeds the investiment is the payback time.

ROI is a performance measure used to evaluate the efficiency of an investment or compare the efficiency of a number of different investments. ROI tries to directly measure the amount of return on a particular investment, relative to the investment's cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment. Because ROI is measured as a percentage, it can be easily compared with returns from other investments, allowing one to measure a variety of types of investments against one another.

2. Business case of the proposed technology

2.1 Materials and methods

Input data for economic feasibility of the proposed technology has been already reported in the Annex B5.1 (**Report on whole mass and energy balance of a full-scale plant)** and in Annex C1.3 (**Environmental impact assessment, including LCA and LCC results, conclusions and recommendations).** Financial indicators have been estimated to study the economic aspects of the processes, considering the cash flow. In simple terms, a net cash flow in any given year is the amount of money remaining after all income has been received and all expenses have been paid. For the highest accuracy, income and expenses should include the impact of taxes (in the specific case it has been considered tax at 37%). Money received at the present time is worth less than money received at the present time, because money that is received at the present time can be invested to earn a return. The return rate of this alternative investment is known as the opportunity cost of the founds. Cash flows that occur in the future are therefore discounted to reflect their reduced value at the present time. The rate at which they are discounted is the subject of many volumes, but it should initially reflect the opportunity cost of funds for the investor. Cash flows that occur uniformly over the project life should use a continuous discount rate. The following equation (1) is a commonly used formula for continuous discounting:

$$DFn = \frac{(e^{r} - 1)x(e^{-rn})}{r} \quad (1)$$

Where DF_n is the discount factor for cash flow in year n, and r is the discount (or interest) rate. After that, it is possible to calculate the present value of the single cash flow. The sum of the discunted cash flows generated in all years that the project id actived is called the net present value (NPV). The NPV indicates the total cash flow that a project would generate if all revenues and costs associated with the project were reduced to a single instant in time, namley the present. NPV is calculated by equation 2:

$$NPVn = \sum_{1}^{n} DCF \quad (2)$$

Where n is the number of periods of evaluation. The interpretation of NPV is relatively simple: if NPV > 0, the project will return more than the opportunity cost of founds; if NPV <0, the project will not return the opportunity cost of founds. When evalutating a portfolio of projects one should choose those that have the highest NPV, based on the same discount rate, term and risk.

In Eq. (1), a nominal interest rate, r, must be specified. The equation can be rearranged to compute the value of r for the explicit case where the NPV = 0. NPV is zero if the product breaks even (discounted investiment = discounted returns) for a given discount rare. This rate is referred to as the discounted cash flow percent (DCF%) or the internal rate of return (IRR). Another financial indicator is the payback time (PBT). The PBT is the time required for a project to return the initial investiment. It is computed by calculating the cumulative return for each year and comparing it to the investiment; the time at which this sum exceeds the investiment is the payback time. Payback period can be calculated using either discounted or undiscounted results. When undiscounted cash flows are used, the result is called the simple payback period. When discounted cahs flows are used, the result is called the discounted payback period.

2.2. Results and discussions

2.2.1 Economic Evaluation for the treatment of TMAH and photoresist wastewater (S1) by biological process

Table 1 summarizes the already discussed results about the process analysis upon the choice for the full-scale configuration for the removal of TMAH by biological process (Annex b5 - **Report on while mass and energy balance of a full-scale plant).** It was assumed a flow of 800 L/h and for the equipment design it has been used the kinetic parameters found during pilot experimental activity.

Table 1 shows the results of the simulations.

Configuration	Useful volume (80%) of the total volume
Single bio reactor	982 m3
Single bio reactor with partial recirculation of bacteria	196 m3

Bioreactors in series	R101 = 80 m3 R102 = 59 m3 R103 = 35 m3 Vtot= 174 m3
Bioreactors in series with partial recirculation of bacteria in R101	R101 = 29.50 m3 R102 = 30.62 m3 R103 = 29.41 m3 Vtot= 89.52 m3

Table 1: Results of the simulation for the design of the full biological plant to degrade TMAH (S1)

From results, it is possible to observe that to have a total removal of around 99% of TMAH (0.02 g/L TMAH) at the discharge point can be used:

- single bioreactor with a volume of 982 m^3;
- bioreactor with partial recirculation of bacteria the volume is 196 m^3 (volume reduction of 80%);
- three bioreactors in series with a total volume of 174 m^3 (volume reduction of 82%);
- three bioreactors in series with partial recirculation of bacteria in R101, total volume of 89.52 m^3 (volume reduction of 90%)

It has been chosen the fourth alternative, as shown in Fig. 1.

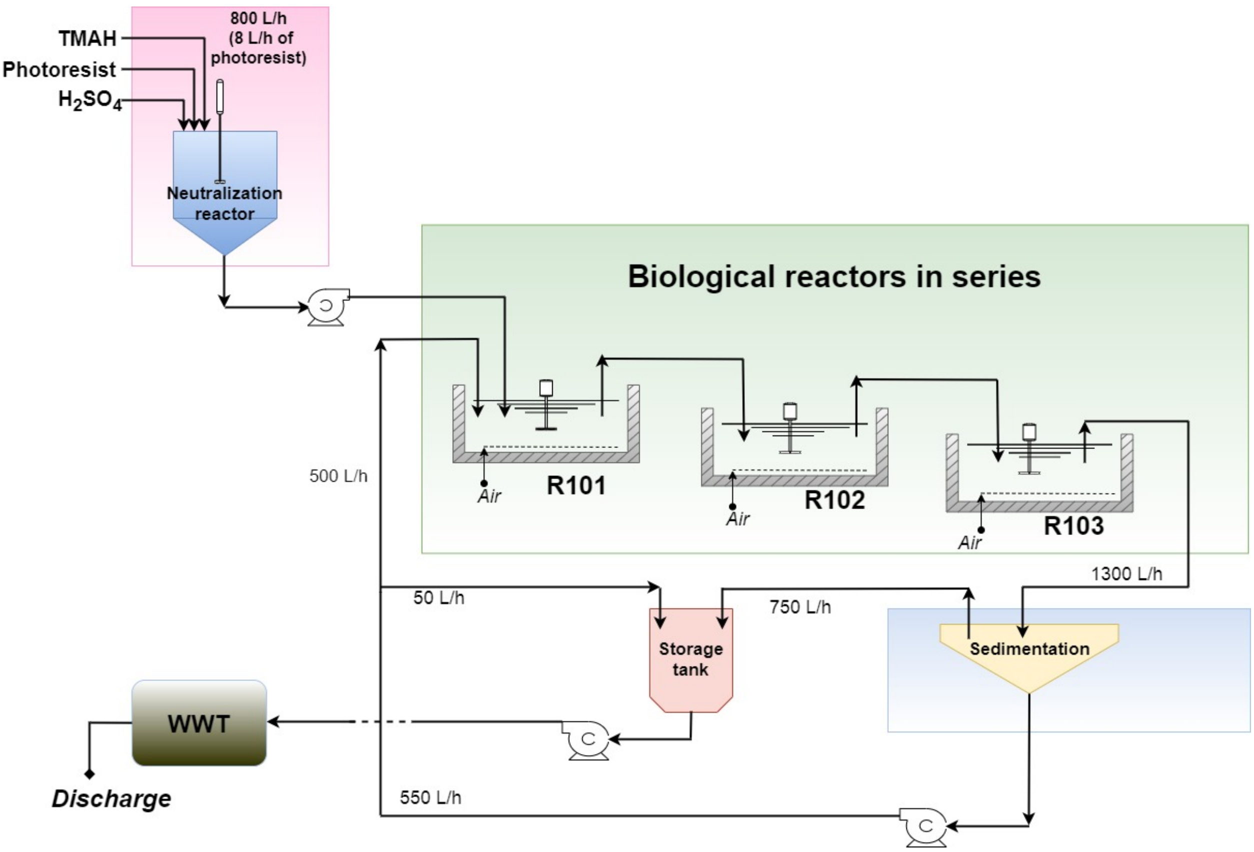

Figure 1: Block scheme for the treatment of TMAH and photoresist effluent (initial concentration of TMAH 2-2.5 g/L)

A basis of 330 days per year (7920 h) operating time is used for economic analysis. The main equipment are the three biological reactors in series and a clarification step.

The initial flowrate of TMAH wastewater is equal to 800 L/h. The main item costs considered for the analysis were: (1) equipment cost, (2) raw material purchase, (3) energy cost (4) labour cost and (5) disposal of solid waste that include also the transport cost.

The Direct Fixed Capital (DFC) is fixed to 900,000.00 € (equipment cost, piping, engineering, …) (real quotation). Straight line depreciation over 10 years is considered with an index of 7.7.

Table 1 shows the operating and waste management cost for the TMAH and Photoresist wastewater treatment.

Item	**€/year**	**€/m³**	**Note**
Raw materials	€ 3,570	€ 0.56	Sulfuric acid (0.15 €/kg); water 0,0001 €/kg.
Personal costs	€ 17,500	€ 2.76	Estimated
Disposal cost	€ -	€ -	No production of residual solid to disposal
Power	€ 63,360	€ 10.00	Energy cost (0.1 /kWh)

Table 1: Operating variable costs data for the treatment of TMAH and Photoresist wastewater (per m³ of residual solution)

Applying the formula reported in Eqs. 1 and 2 for the calculation of the cash flows, it is possible to estimate the three parameters: the NPV_{10} over 10 years is equal to 157.079,69 €, IRR is 4% and finally the positive cash flows begin after seven years, hence payback time is between the seventh and eighth year.

The total annual cost is to 33.31 €/m³ of TMAH effluent including OPEX, depreciation and contingency, instead the actual disposal cost is 45.6 €/m³. Table 2 shows the summary in terms of economic evaluation.

Annual production of TMAH and Photoresist wastewater		6336	ton/year
Actual disposal cost	€	289,048	per year
LIFE BITMAPS cost	€	211,033	per year
Net saving	€	194,570	per year
PBT		**4.6**	years
PBT (actualized)		**7.8**	**years**
IRR		**4%**	10 year
VAN (discount factor at 10%)	**€**	**157,080**	10 year
IRA		**1.175**	10 year

Table 2: Economic parameter estimation for TMAH and Photoresist wastewater treatment (S1)

The same procedure is repeated for the treatment of BOE and SEZ alone, and after that the economic analysis has been carried out for the treatment of all three wastewaters.

2.2.2. Economic Evaluation for the treatment of BOE wastewater by chemical process

The treatment for the removal of pollutants from BOE includes a precipitation with lime in presence of a coagulant, aluminum sulfate, to remove nitrates and phosphates. The time of reaction is equal to 1 h.

After this time the suspension is filtered using a filtration system (filter press), two outputs are recovered: the residual solid that needs to be disposed and the liquid that can be sent to a storage tank before to be discharge or to achieve the biological section of the existent plant. Fig. 2 shows the block scheme of the process.

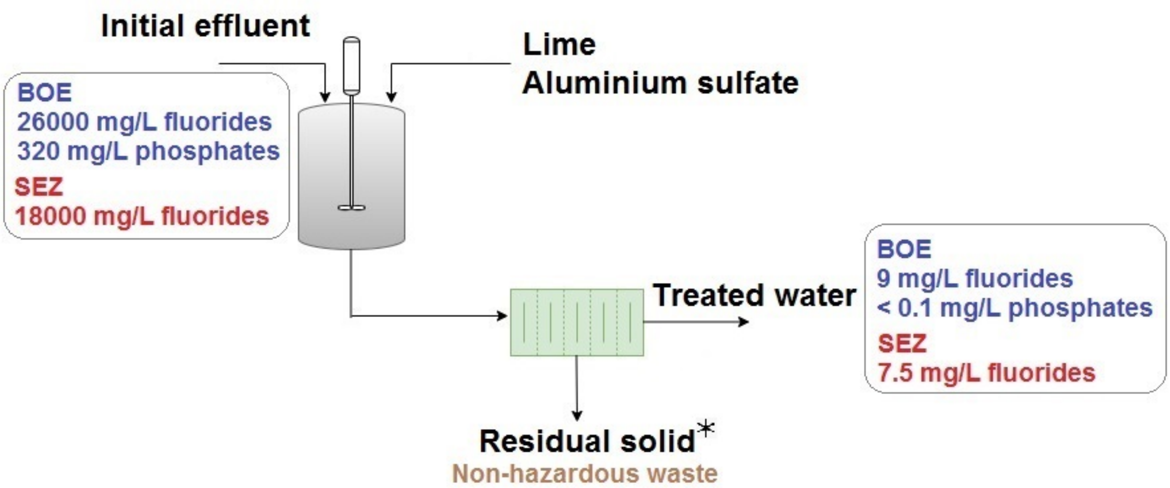

Figure 2: Block scheme for the treatment of BOE and SEZ effluent (*) Under investigation for possible recovery as fiberglass, ceramic, glass and aluminium metallurgy

The BOE effluent contains ammonium fluoride, nitric acid, phosphoric acid and water.

The economic evaluation has been performed in according to the following considerations: batch operation mode, 2900 kg of BOE wastewater per batch and 150 batch/year, annual totaling of 435 ton of BOE. The main equipment are chemical reactor and a filter press to separate the solid and liquid. The filtrate is sent to **existing active-sludge plant,** instead the solid is a residual non- hazardous waste that mainly contain CaF_2. This solid could be exploited but in the present analysis it has been considered that the solid is sent to disposal in a specific plant. The main item costs considered for the analysis were: (1) equipment cost, (2) raw material purchase, (3) energy cost (4) labour cost and (5) disposal of solid waste that include also the transport cost. In this case it has been considered a disposal cost of 80 €/ton of solid waste.

The Direct Fixed Capital (DFC) is fixed to 400,000.00 € (equipment cost, piping, engineering, …) (real quotation). Straight line depreciation over 10 years is considered with an index of 7.7. Table 3 shows the operating and waste management cost for the BOE wastewater treatment.

Item	€/year	€/m^3	Note
Raw materials	€ 6,911	€ 15.89	Lime solid (0.05 €/kg); water 0,0001 €/kg; aluminium sulfate (0.1 €/kg)
Personal costs	€ 17,500	€ 40.23	Estimated
Disposal cost	€ 17,640	€ 40.55	CaF_2 – non hazardous waste
Power	€ 750	€ 1.72	Energy cost (0.1 /kWh)

Table 3: Operating variable costs data for the treatment of BOE wastewater (per m^3 of residual solution)

Following data reports the financial indicator of the investment calculated in according to *Eqs. 1 and 2.* The total annual cost is to 228.35 €/m^3 of BOE effluent including OPEX, depreciation and contingency, instead the actual disposal cost is 253.68 €/m^3. Table 4 shows the summary of the economic evaluation.

Annual production of BOE wastewater	435.00	ton/anno
Actual disposal cost	€ 110,350	per year
LIFE BITMAPS cost	€ 99,333	per year
Scrubber	€ -	per year
Net saving	€ 62,819	per year
PBT	**6.4**	**years**
PBT (actualized)	**Over 10**	**years**
IRR	**-1%**	
VAN (discount factor 10%)	**-€ 20,742.87**	
IRA	**0.95**	

Table 4: Economic parameter estimation for BOE wastewater treatment

2.2.3 Economic evaluation for the treatment of SEZ wastewater by chemical process

The treatment for the removal of pollutants from SEZ includes a precipitation with lime in presence of a coagulant, aluminum sulfate, to remove nitrates and phosphates. The time of reaction is equal to 1 h.

After this time the suspension is filtered using a filtration system (filter press), two outputs are recovered: the residual solid that needs to be disposed and the liquid that can be sent to a storage tank before to be discharge or to achieve the biological section of the existent plant. Fig. 2 shows the block scheme of the process.

The economic evaluation has been performed in according to the following considerations: batch operation mode, 2900 kg of SEZ wastewater per batch and 50 batch/year, annual totaling of 145 ton of SEZ. The main equipment are chemical reactor and a filter press to separate the solid and liquid. The filtrate is sent to existing active-sludge plant, instead the solid is a residual non-hazardous waste that mainly contain CaF_2. This solid could be exploited for recovery but in the present analysis it has been considered that the solid is sent to disposal in a specific plant. The main item costs considered for the analysis were: (1) equipment cost, (2) raw material purchase, (3) energy cost (4) labour cost and (5) disposal of solid waste that include also the transport cost. In this case it has been considered a disposal cost of 80 €/ton of solid waste.

The Direct Fixed Capital (DFC) is fixed to 400,000.00 € (equipment cost, piping, engineering, …) (real quotation). Straight line depreciation over 10 years is considered with an index of 7.7. Table 1 shows the operating and waste management cost for the BOE wastewater treatment.

Item	**€/year**	**€/m^3**	**Note**
Raw materials	€ 2,291	€ 15.80	Lime solid (0.05 €/kg); water 0,0001 €/kg; aluminium sulfate (0.1 €/kg)
Personal costs	€ 17,500	€ 120.69	Estimated
Disposal cost	€ 6,140	€ 42.34	CaF_2 – non hazardous waste
Power	€ 250	€ 1.72	Energy cost (0.1 /kWh)

Table 5: Operating variable costs data for the treatment of SEZ wastewater (per m^3 of residual solution)

Following data reports the financial indicator of the investment calculated in according to *Eqs. 1 and 2.* The total annual cost is to 564.70 €/m^3 of SEZ effluent including OPEX, depreciation and contingency, instead the actual disposal cost is 581.8 €/m^3. Table 6 shows the summary of the economic evaluation.

Annual production of SEZ wastewater		145.00	ton/year
Actual disposal cost	€	84,359	per year
LIFE BITMAPS cost	€	81,882	per year
Scrubber	€	-	per year
Net saving	€	54,279	per year
PBT		**7.4**	**years**
PBT (actualized)		**Over 10**	**years**
IRR		**-3%**	
VAN	**-€**	**57,018.69**	
IRA		**0.86**	

Table 6: Economic parameter estimation for SEZ wastewater treatment

2.2.4 Economic evaluation for the treatment of TMAH, BOE and SEZ wastewater

In this section the economic evaluation for the treatment of TMAH, BOE and SEZ are shown in according to operative conditions described before. The financial indicators of the investment calculated have been calculated in according to *Eqs. 1 and 2.* The total annual cost is to 43.53 €/m^3 of the three effluents including OPEX, depreciation and contingency, instead the actual disposal cost is 69.95 €/m^3. Table 7 shows the summary of the economic evaluation.

Annual production of BOE wastewater		6916,00	ton/year
Actual disposal cost	€	483,757	per year
LIFE BITMAPS cost	€	301,106	per year
Scrubber	€	-	per year
Net saving	€	351,007	per year
PBT		**3.7**	**years**
PBT (actualized)		**6.3**	**years**
VAN	**€**	**479,318.14**	
IRR		**7%**	
IRA		**1.37**	

Table 7: Economic parameter estimation for TMAH, BOE and SEZ wastewater treatment

Conclusions

The estimation of the economic parameters for the proposed technology shows that for TMAH treatment there is a substantial economic advantage since treating the wastewater at the site, disposal in a specific facility shall be avoided. The investment has a PBT of around 8 years. For the other wastewater, BOE and SEZ, the PBT is greater than 10 years (considered time for the amortization of the equipment). From the analysis, it is clear that the technology is economically feasible if only TMAH is treated or if all wastewaters are processes: in these cases it is possible to balance the purchase costs of the equipment and operative costs with the revenues related to the "non-disposal" of the effluents in a specific external site. In this last scenario, the PBT is around 6 years, VAN is 479,318.14 €.