HOW TO SUPPORT FIRM ENVIRONMENTAL INNOVATION: THE CASE OF THE VOCLESS MECHANICAL PULPING PROJECT

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ABSTRACT

One of the most discussed issue is the environmental sustainability. The increase depletion of natural sources, the high level of pollution, also in emergent countries, will push the economic world towards more environmental friendly decisions and actions. Eventually, the environment dimension will play an important role in the decision making in future. But the environment, as the sustainability in general, must face, today, other dimensions such as economic and short term competitiveness. Not always it is possible to show the advantage, especially in the long term of an environment oriented investment. It is necessary to develop an environmental solution in order to show its feasibility. It is important so, to study how to effectively integrate environmental issues with company strategy making the right trade-offs between strategic and environmental goals. It is important to focus on procedure by which it is possible to show the economic viability of environmental investment. In the paper an interesting case is discussed: the VOCless project. This project thanks to the support of the EU within Life program which has allowed to demonstrate that solutions like regenerative catalytic incinerator and moreover biofiltering are effective in VOC emission control of Mechanical Pulping processes. Results are shown and the feasibility and transferability to other sector are discussed.

Keywords: VOC abatement, Biofiltering, catalytic incineration, Environamental Management

1. INTRODUCTION

Nowadays there are still strong barriers to implement a real environmental friendly policy. This for many reasons: there is not a global support to environment problems, markets do not always gives value to green policies, there is a tight worldwide competition.

Nevertheless some improvement in the green dimension is starting. EU and US policy in favor of renewable energies is one example. Market promotion of environmental friendly products is another. But one of the barrier further environmental industry improvement is due to the risk of environmental investment. Sometimes environmental investments are just a cost, which do not improve any impacts. This is also not good in the case companies are acting proactively towards the environment and they are looking towards improvements below legislation limits. So, even if there are theoretically possible improvements with traditional and new technologies, very often companies does not really implement anyone of them. So limits to the investments are not only financial but also because there are not certain environmental returns. In this sense it is important to be able to activate some industrial research and/or pre-competitive development in order to show the feasibility of one investment. In this manner it is possible to give evidence about achievable results and support better environmental decision making. In the following of the paper this issue is discussed referring to a particular case, the "VOCless Pulping", VOCless, project, funded by European Union under LIFE-Environment Demonstration projects 2006 (website http://voclesspulping.com/front-page). Thanks to VOCless it was possible to demonstrate the feasibility of VOC abatement in the Mechanical Pulping industry.

Mechanical Pulping companies were interested in the VOC abatement, even if it is not compulsory by the EU law. The problem has been about the effectiveness of VOC abatement solutions. There was not any study concerning the most viable techniques or hybrid combination of them. In VOCless project it was possible to investigate through measurements and literature survey several techniques and give the right suggestions to the companies. In particular one traditional technique, such as regenerative catalytic incinerator and one more innovative technique, a new biofiltering were tested and compared. VOCless project is an example of how to proceed in order to improve the environmental performances of the companies.

Sometimes the barriers to the innovation in the companies rely on the fact that there are not possibilities to show the feasibility of a solution. The support of research and demonstrative actions could give good results in many fields of industrial engineering.

In the following, after a brief related research, a description of the VOCless project is made, a description of the Mechanical Pulping industry is made, with VOC emissions. Afterwards a description of regenerative catalytic incineration and biofiltering is made and an evaluation, based on the pilot plant test

results was made. In the conclusions final considerations and future development are discussed.

2. RELATED RESEARCH

There has been a growing interest about the environmental management strategies since at least the last 2 decades, as in (Graedel and Allenby 1995; Hart 1997; Porter 1990; Russo and Fouts 1997). The Strategic Environmental Management links to the neoclassical Economy theory and Capabilities Based theory was discussed (Goldstein 2002). Governmental decisions, starting from EU and Japan, support the Sustainable Development by promoting Environmental Industries and Management (Elder 2007). This is in order to stimulate innovation and increase efficiencies. But the needs of economic growth of the developing countries can limit the environmental management in multinational corporations (Chaiporn 2009). But the problem on how to quantify the benefits of a good environmental management is still under debate. (Bhat 1999) thinks that it seems that green management means to make more profit, also because there is a low risk in a green company. But (King 2001) it has been shown that even if statistically seems that green firms make more profits, it can not be stated that this is due to environmental management. In synthesis (Lankovsky 2008), Environmental Management belongs to Corporate Responsibility activities. For those activities there are three possible outputs: learning, reputation and Corporate Responsibility Outputs. The three outputs must be taken into account not only for sustainability but also from the economic performance.

It is not easy for companies to evaluate environmental performances, even if it seems that there are benefits. It became very important to be able to effectively invest in environmental actions. In this sense innovative solutions are particularly risky. Firms that have in any case difficulties in evaluating the economic benefits of environmental management, can not stand under performing investments. It is important to find a way to support such industrial innovations. In this manner it will possible to take into account the risk of the innovation. This is relevant in any environmental investment. In Modeling and Simulation, M&S, environment is becoming a very important component. We are moving from classical problems, where the aim of M&S were in essence to improve production perfomances (Guash and Piera 2005), towards new models (Longo and Mirabelli 2008), based also on other aspects, such as security (Longo and Massei 2008) and, of course the green dimension (Bruzzone and Merkuriev 2009), (Bruzzone, Tremori, Massei and Tarone 2009).

The case considered in the paper concern a VOC abatement study for Mechanical Pulping in Europe. VOC emissions, a very wide spectrum of organic compounds and are naturally generated or are emitted especially from industries using traditional solvents (Seinfeld and Spyros 1998;EU 1999; Mannschereck Mannschereck, Bächmann, Becker, Kurtenbach, Memmesheimer, Mohnen, Obermeier, Poppe, Steinbrecher, Schmitz, Volz-Thomas and Zabel 2002; Schnitzler, Bauknecht, Brüggemann, Einig, Forkel, Hampp, Heiden, Heizmann, Hoffmann, Holzke, Jaeger, Klauer, Komenda, Koppmann, Kreuzwieser, Mayer, Rennenberg, Smiatek, Steinbrecher, Wildt and Zimmer 2002).

Their impact depend on the particular organic compound but generally all VOC emissions contribute to the photochemical pollution. Governmental legislation concern essentially limits on the anthropogenic VOC emissions like solvent based paintings, but not other emissions concerning, for instance natural wood or some food and beverage industries. This because those VOC emissions are biogenic, generated from nature. Biogenic emissions are considered mainly for other issue and mainly odour abatement (Revah and Morgan-Sagastume 2005) (Kleinheinz and Wright 2009). Mechanical Pulping belongs to biogenic emissions. Mechanical Pulping is a studied subject, but, since very often pulping production is integrated with paper production, there are studies that considers the environmental impact of pulp and paper all together. Mechanical Pulping environmental studies concerns mainly the wastewater effluent (Zuo, Qun 2009), (O'Connor, Kovacs and Voss 1992), (Johnsen, Grotell and Tana 2000). Another aspect of Mechanical Pulping considered is the energy consumption (Hart, Waite, Thibault, Tomashek, Rousseau, Hill, Sabourin 2009; Rausdepp 2009). There are not relevant studies concerning VOC abatement and Mechanical Pulping, excepted (Sueiro and Gill 1995). In this paper VOC emissions are analyzed in the case of Thermomechanical Pulp. In particular the inventory of VOC emissions is considered. The refining stage and chip washing contribuite to VOC emission rate. The are not any measurement about any control techniques for the abatement.

There several abatement techniques that could be used for the VOC abatement (Moretti and Mukhopadhyay 1993) (Moretti 2002), but there are not any study concerning VOC emissions in Mechanical Plant, event if this emissions are relevant. In VOCless project the aim has been to study which are the best VOC abatement techniques for Mechanical Pulping processes.

In particular two technologies were tested. First one is a regenerative catalytic incineration, that is common in pulp and paper industries. The other was a biofiltering, that is new for Mechanical Pulping. Biofiltering is one of the more promising techniques for its sustainability in term of environmental protection and also safety. For a success in biofiltering is important to keep the good operating conditions that allows bacteria eliminate VOC from the inflow air. More on biofiltering can be found in (Adler 2001; Boswell 2002; Deshusses, Shareefdeen 2005; Kim 2004).

The two abatement techniques, one considering catalytic incineration and the other considering

biofiltering, were tested and compared on technical, environmental and economic point of view.

3. INDUSTRIAL INNOVATION SUPPORT: THE CASE OF LIFE-VOCLESS PROJECT

3.1. Followed Procedure

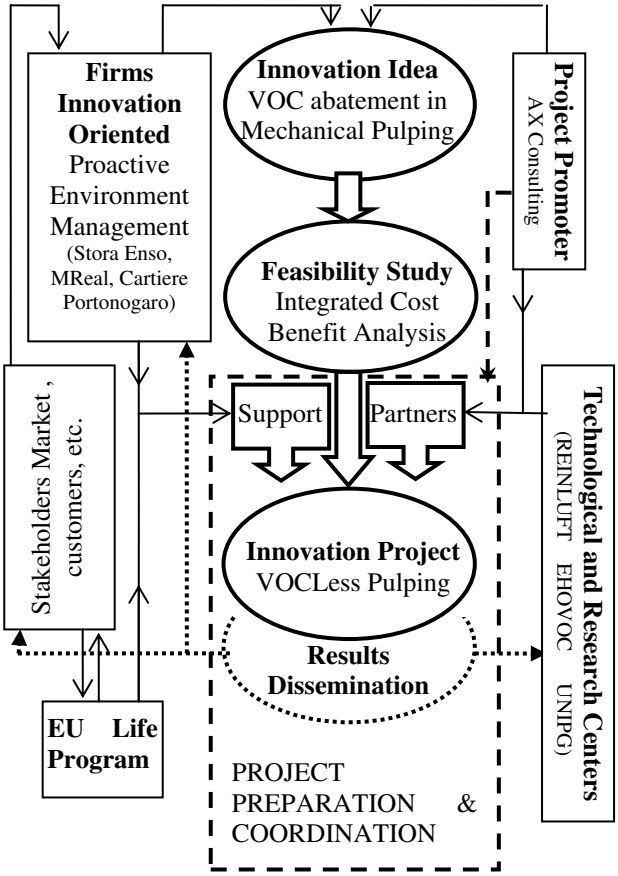

Figure 1: VOCless procedure

In Figure 1 there is a Flux diagram about the VOC less project. This represents the procedure followed to support an innovation initiative. The input and innovation idea in the case considered came out from two actors: firms and the project promoter.

Firms considered were very oriented to innovate and in environment protection. The proactive behaviour towards environment impact is due also to the action of the various stakeholders. Stakeholders, from firm owners, to government, to citizens are driving companies to anticipate environmental issues in the normal management. Main goals of firms must be economic, of course, but environment has became one of the most important driver in the global competition. It is necessary to understand as soon as possible any potential environmental impact in order to be ready before competitors and using the environment as a competition driver. In the case of VOCless project there were leading companies in pulping and in paper industry such as Stora Enso and M-Real. Also a small but dynamic company from Italy joined the project for the piloting test, the Cartiere di Portonogaro. In order to start the innovation process is then necessary to find an activator a promoter. AX Consulting, from Tampere, Finland. AX is a consulting company with experience in environmental impact and also in VOC emissions and European Research Projects. The Project Promoter in AX Consulting understood that there was the possibility to treat VOC abatement in Mechanical Pulping, even if this was not necessary, because Mechanical Pulping does not belong to any VOC abatement directive.

VOC abatement could be a future issue and could create benefits in terms for instance of odour abatement and safety. The problem was mainly to investigate what could be the better technology for the abatement. One well known technology in the paper industry is incineration, but no data about performance in Mechanical pulping VOC emissions were available. This is a risk for companies because there are not any pratical usable references. Moreover, there are other technologies and in particular biofiltering will be interesting both for CO2 emission reduction respect to catalytic incineration and also for safety issue, since there is not any risk of fire. But for firms was not possible to be confident on any solution, due to the lack of any application.

The basic idea of the Project Promoter was to activate a research project in order to create a reference for the application of VOC abatement in mechanical pulping. Project Promoter started preparing the project, by finding supporter and partners. In the case of partner there were both technological partner, as Ehovoc and Reinluft and also research center such as UNIPG, the Department of industrial Engineering of the University of Perugia. Support to the project came from the European Union, via the Life Environmental Program. In this manner has been possible, as shown in the following to activate the research and to have interesting results concerning VOC abatement in Mechanical Pulping. Results and outcome diffusion and dissemination will contribute to give the right information to the interested parties. In this manner it will be possible, for firms, for technology developers and for any stakeholder to take consciences Environmental decisions.

3.2. VOCless Project

The aim of the project is to minimise emissions of volatile organic compounds (VOC) from mechanical and semi-chemical pulping processes due to their contribution to smog formation and odour problems. The emissions minimization are obtained via a VOC and odour abatement system that takes into account the particular conditions of the pulping process. The abatement system is optimized by considering several abatement technologies and combination of them. In the working team of the VOCless project there are partners with experience in pulp industry and VOC emissions that play different roles. In particular there are: 1 university research center, 2 pulp and paper companies, and 3 companies operating in the environment protection.

Partners

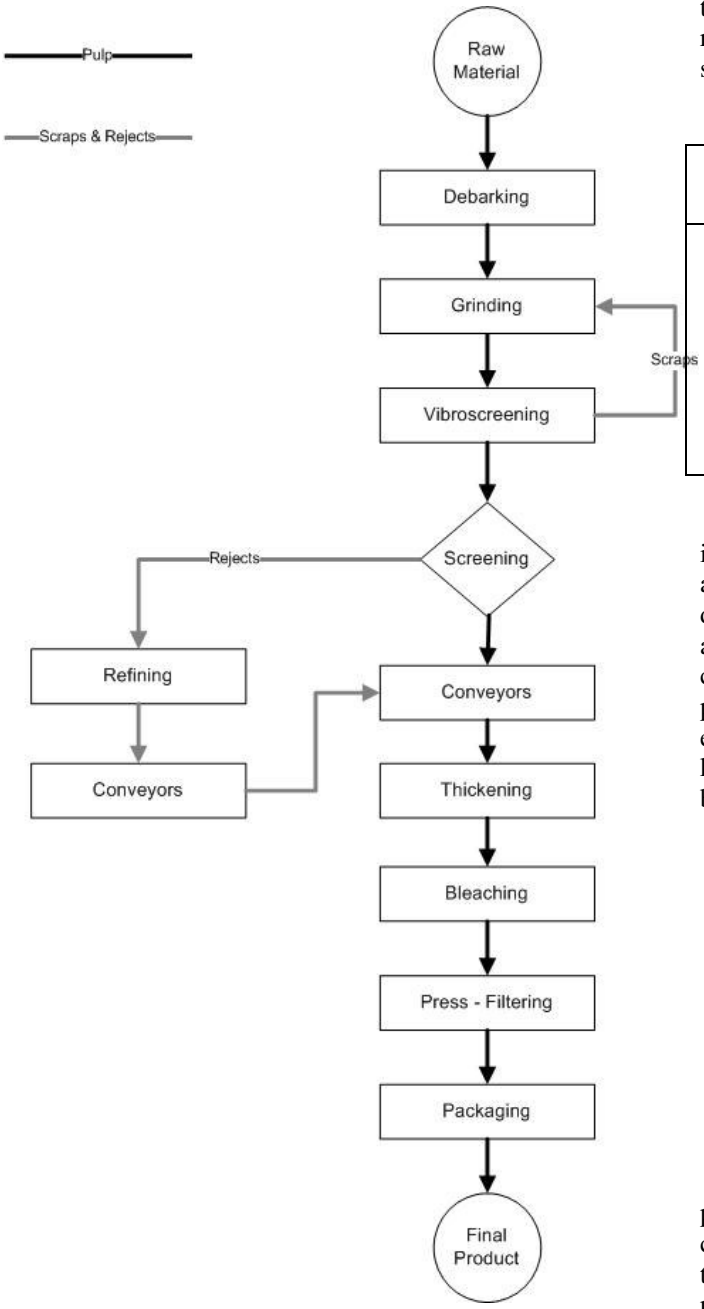

Figure 2: Process Flow of one firm involved in VOCless project

VOCless project includes several activities. First of all a Taxonomy of mechanical, Thermomechanical and chemi-thermomechanical pulping processes, with its VOC emissions.

In Table 1 is shown a classification of Mechanical Pulping. It is a well known processes but with variations due to the kind of wood used.

Starting from the taxonomy of Mechanical pulping, VOC emissions were considered and literature information was searched and also measurements were made in order to have whole information about the typology and the quantities of emissions. In Table 2 the results from measurements in 2 plants are synthetically shown.

Table 1: Mechanical Pulping processes classification

Grinding processes	**Refiner processes**
Stone groundwood pulping (SGW)	Thermomechanical pulping (TMP)
Pressure groundwood pulping (PGW)	Chemi-thermomechanical Pulping (CTMP)
	BCTMP if bleaching is integrated in CTMP

The next step in the VOCless project is the investigation about performances and limitis of VOC abatement techniques. In Figure 3 a classification of different abatement technique is shown. VOC abatement techniques may differ in many aspects, considering costs, environment and economic performance and also characteristics for VOC air emissions. Not all techniques are then usable for one kind of emission. Also it is possible to optimize results by a combination of 2 or more techniques.

Table 2: VOC from one PGW plant and TMP plant.

		PGW plant		TMP plant	
Variable	Unit	Min	Max	Min	Max
VOC	mg/ Nm^3	26	226	11	1100
Airflows	Nm^3/s	0,2	20	0,26	1,7
Temper.	°C	38	74	39	85
Relative humidity	%	30	99	83	100

Results of the measurement are used to design a pilot plant, considering 2 abatement techniques: catalytic incineration and biofiltering. Enviromental and technical results are considered in order to figure out potential benefit of VOC abatement techniques.

3.3. VOCless Project Results

VOC measurements were carried out in 3 different plant. In pulp production was integrated with paper production also the emission from drying pulp were considered in order to asses its magnitude. Sample from wastewater were considered to evaluate the VOC transfer to water. There are several sources of VOC emissions. Debarking was considered, while emissions from sawing processes before Pulping were not included.

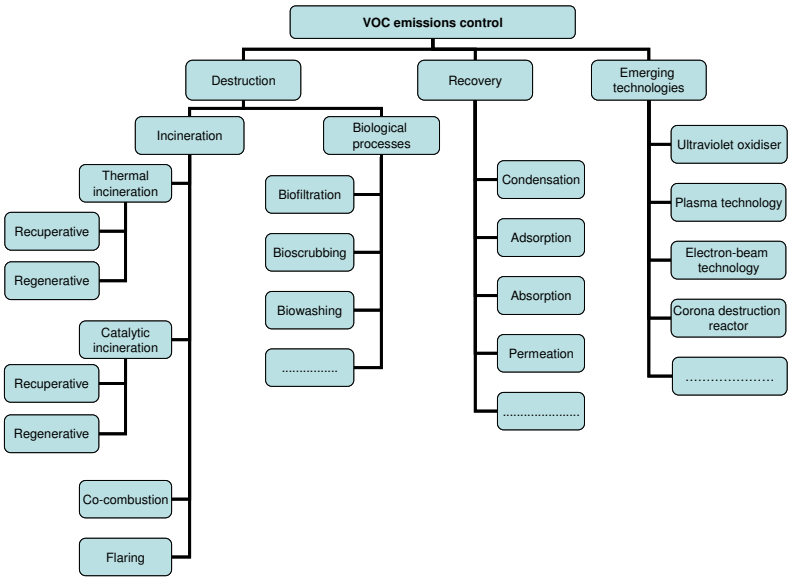

Figure 3 Different VOC abatement techniques

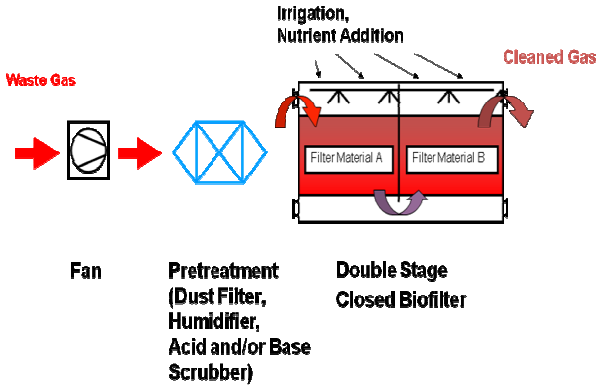

Figure 4 A schema of Biofilter for the VOC abatement

Figure 5 A real installation of a modern biofilter [REINLUFT]

From emissions it was possible to note that:

- Numerous exhausts in the pulping processes that complicated measurements.
- Total VOC emissions per production site might be significant depending on the size of the facility.
- The VOC emissions to air from the pulping process normally consist of a group of terpenes and in some cases also methanol and ethanol. There are always also other unidentified components present.
- Fugitive sources of emissions, in which the concentrations are low but from which the total emissions might be remarkable (e. g. debarking and waste water treatment)

Other relevant results concern the piloting testing of the plant. Total results are not yet available, because testing is still going on. But some consideration can be made from the first measurements. In Particular there were 2 pilot testing measurements, one catalytic incinerator and one biofilter.

The cleaning and thermal efficiencies of the catalytic incinerator were measured before and after the incinerator.

In the PGW plant the pilot plant cleaning efficiency was an average 90% and in the TMP plant the pilot catalytic incinerator reached the cleaning efficiency of 82-94%. The "total" VOC concentration of the combined exhausts (before catalytic incinerator) in the TPM plant was measured to be 260 mg/m^3 and the total airflow was 4,0 m^3/s. The "total" VOC concentration of the combined exhausts (before catalytic incinerator) in the PGW plant was measured to be 460 mg/m^3 and the total airflow was 46,5 m^3/s.

The VOC concentrations after catalytic incinerator were up to 20 mg/m^3 both in TMP and PGW pilot plants. This cleaning performance guarantees the emission value of 50 mg/m^3 which is the normal requirement of VOC emission level according to the Solvent Directive (1999/13/EC) and which can be set as the target level for the pulping process exhausts in VOCless pulping project.

The thermal efficiency of the pilot catalytic incinerator was 90% at TMP plant. The thermal efficiency depends usually on the optimization. The higher efficiency is needed, the higher investment cost is required. The higher the thermal efficiency is, the less heat energy is needed in the oxidation process. The catalytic incinerator is working at reasonably low temperature level (300 °C) and thus does not consume as much energy as thermal incinerators (operating temperature usually 850 °C).

Results of the measurements demonstrate efficient operation and good cleaning efficiency of the catalytic incinerator pilot plant at TMP and PGW plants (Table 3).

Table 2: Cleaning efficiency of regenerative catalytic incinerator pilot plant

Pilot plant	Cleaning efficiency (%)	Thermal efficiency (%)
TMP	82-94	88
PGW	94	94

From a first estimation, not considering, in particular differences in energy costs that can affect the global performance, the total cost of abatement range from 0,4 to 1 € per ton pulp.

A pilot biofiltering plant was also considered. A schema where there are the sampling points is in Figure 5:

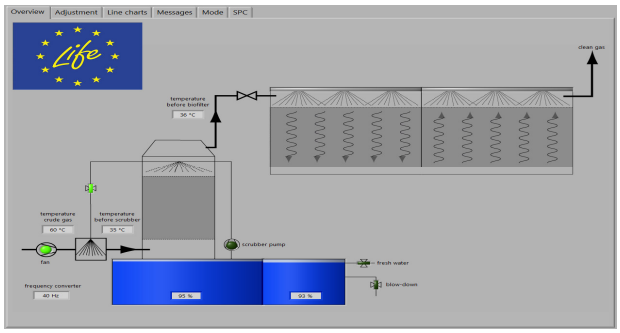

Figure 6: Sampling point in the biofilter pilot plant

Generally speaking biofiltering can give very good results, but it requires a right working conditions. This is not always easy to do. But in the case tested, probably because of concentration of VOC, results are very good. In Figure 7 is shown the FID results in terms VOC abatement in the sampling points. The efficiency is very high. Also in Figure 8 it is shown the good efficiency in VOC abatement of pilot biofiltering plant. Even if the evaluation is not complete, biofiltering should have low costs. In addition biofiltering is a good solution concerning CO_2 consumptions. It does not need fuel to work and energy consumption are quite small.

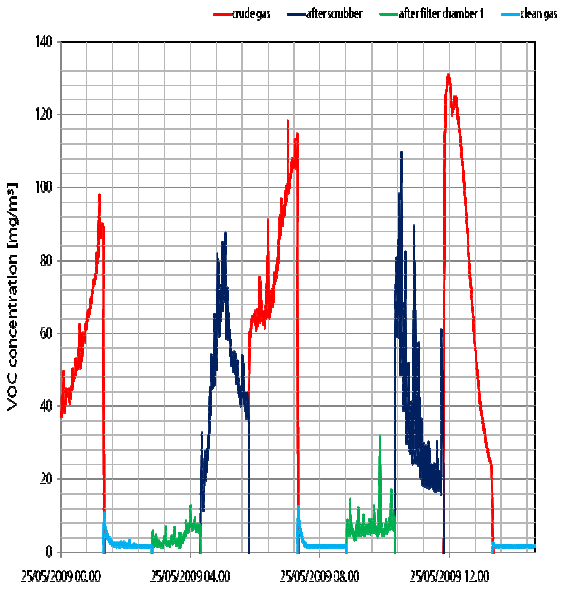

Figure 7: FID output with VOC concentration showing a good abatement

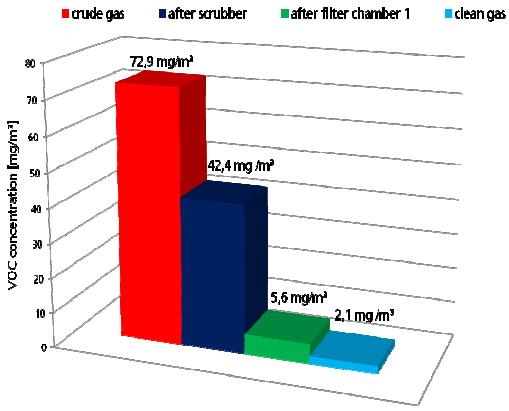

Figure 8: VOC concentration abatement with Biofilter Pilot Plant

4. CONCLUSIONS

In the paper a case of how to support innovative solution in the case of industrial engineering is shown. In particular the possibility to reduce VOC emissions in Mechanical Pulping is considered. This idea needs support because is a proactive action and there were not enough results from past experience. The evaluation of several techniques show the technical feasibility and the costs of this environmental investment can be estimated. Obtained results show the importance of such cooperation projects. Thanks to project like VOCless is possible to study new impact and to improve the knowledge about environmental issues.

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REFERENCES

Adler, Stephen F., 2001. Biofiltration--a primer. *Chemical Engineering Progress* 97: 4.

Boswell, Jim, 2002. Understand the capabilities of bio-oxidation. *Chemical Engineering Progress* 98: 12.

Bruzzone, A.G., Merkuriev, Y. 2009. Advances in Supply Chain Simulation. Proceedings of the *Third Asia International Conference on Modelling & Simulation.* May 25-26 Bandung, May 29 Bali.

Bruzzone, A.G., Tremori, A., Massei, M., Tarone, F. 2009. Modeling Green Logistics. Proceedings of the *Third Asia International Conference on Modelling & Simulation,* 543-548. May 25-26 Bandung, May 29 Bali.

Bhat, Vasanthakumar N.,1999. Does it pay to be green? *International Journal of Environmental Studies*. 56, 497-507.

Chaiporn, Vithessonthi, 2009. Corporate ecological sustainability strategy decisions: the role of attitude towards sustainable development. *Organisational Transformation and Social Change* 6:49-64.

Deshusses, M. A., Shareefdeen, Z. 2005. Modeling of Biofilters and Biotrickling Filters for Odor and VOC Control Applications. in: Shareefdeen, Z., Singh, A., eds. *Biotechnology for Odor and Air Pollution Control*, ISBN (PDF) 9783540270072

Elder, M., 2007. Making Business Green and the Environment Profitable: The Promotion of Environmental Industries and Environmental Management in the EU, Japan, and the US. *Proceedings of 48th Annual Convention of the International Studies Association.* Chicago.

EU, 1999. VOC Directive number 13/99.

Goldstein, D., 2002. Theoretical perspectives on strategic environmental management. *Journal of Evolutionary Economics* 12: 495-524.

Graedel, T. E., Allenby, B. R., 1995. *Industrial ecology*. Englewood Cliffs, NJ: Prentice Hall..

Guash, T., Piera, M. A., 2005. Preface Introduction to Special Issue. *SIMULATION* 81:611.

Hart, P. W., Waite, D. M., Thibault, L., Tomashek, J., Rousseau, M. E, Hill, C., Sabourin M. J., 2009. Selective enzyme impregnation of chips to reduce specific refining energy in alkaline peroxide mechanical pulping. *Holzforschung: International Journal of the Biology, Chemistry, Physics, & Technology of Wood* (0018-3830) 63: 418-423

Hart, S. L., 1997. Beyond Greening: Strategies for a Sustainable World. *Harvard Business Review* 75: 66-76.

Johnsen, K., Grotell, C., Tana, J, 2000. Impact of mechanical pulp mill effluent on egg hatchability on brown trout, *Bulletin of Environmental Contamination and Toxicology* (0007-4861) 64:873-9

Kim, I., 2004. The Promising World of Bio-oxidation, *Chemical Engineering Progress* 100, 1.

King, A. A., Lenox, M. J., 2001. Does It Really Pay to Be Green?: An Empirical Study of Firm Environmental and Financial Performance. *Journal of Industrial Ecology* 5: 105-116.

Kleinheinz, G. T., Wright, P. C., 2009. Biological Odor and VOC Control Process, in: Wang L. K., Pereira N. C., Hung, Y.T., eds. *Handbook of Environmental Engineering, Volume 8: Biological Treatment Processes*, Totowa, NJ: The Humana Press,.

Lankoski, L., 2008. Corporate responsibility activities and economic performance: a theory of why and how they are connected. *Business Strategy and the Environment Business* 17:536–547.

Longo, F., Massei M., 2008. Advanced Supply Chain Protection & Integrated Decision Support System,. Proceedings of The *Second Asia International Conference on Modelling & Simulation,* 716-721. Kuala Lumpur, Malaysia, 13-15 May.

Longo, F., Mirabelli, G., 2008. An Advanced Supply Chain Management Tool Based on Modeling & Simulation. *Computer and Industrial Engineering* 54: 570-588

Mannschereck, K., Bächmann, K., Becker, K.H., Heil, T., Kurtenbach, R., Memmesheimer, M., Mohnen, V., Obermeier, A., Poppe, D., Steinbrecher, R., Schmitz, T., Volz-Thomas, A., Zabel, F., 2002. A Database for Volatile Organic Compounds. *Journal of atmospheric Chemistry* 42:281-286.

Moretti, E. C., Mukhopadhyay, N, 1993. VOC Control – current practices and future trends. *CHEMICAL ENGINEERING PROGRESS* 89:20-26.

Moretti, E. C, 2002. Reduce VOC and HAP emissions. *Chemical Engineering Progress* 98.

O'Connor, B.I., Kovacs, T.G., Voss, R.H.. 1992. The Effect of Wood Species Composition on the Toxicity of Simulated Mechanical Pulping Effluents. *Environmental Toxicology and Chemistry* 11, 1259-1270.

Pietrangeli, B., Bragatto, P., Pittiglio, P., 2008. Potential of biofiltration for VOCs emission control and safety aspects. *International Journal of Environment and Pollution* 32:57-67.

Porter, M. E., 1990. *The Competitive Advantage of Nations*. New York: Free Press.

Raudsepp, W., 2009. Heat recovery in mechanical pulping. *APPITA JOURNAL* 62:179-181

Revah, S., Morgan-Sagastume, J. M., 2005. Methods of Odour and VOC Control. Shareefdeen, Z., Singh, A., eds. *Biotechnology for Odour and Air*