NOVEL PRE-TREATMENT TECHNOLOGY FOR WASTEWATERS FROM WOOD-PANEL MANUFACTURING FACILITIES

A Deligiannis, P Gikas and D Chatzopoulos†

Delmar Technology Hellas S.A.Them. Sofouli 88, 551 31 Thessaloniki, Greece

† author to whom correspondence should be addressed

SUMMARY

DELMAR technology is a cost-efficient and highly effective chemical process for the pretreatment of industrial wastewaters containing recalcitrant dissolved organic and inorganic pollutants amenable to chemical reduction, and large concentrations of solids. The process utilises an inexpensive reagent/catalyst system capable of "softening" complex and oxidised organic pollutants, removing particulate and colloidal solids in the form of sludge, removing large fractions of environmentally targeted pollutants and increasing the overall biodegradability of wastewater streams. As a result, the system is ideal for the pre-treatment of industrial effluents, such as those from wood-panel manufacturing, which may be subsequently treated more fully, more effectively and at lower cost by conventional anaerobic and aerobic biological treatment processes.

DELMAR technology is highly versatile in its application. It may be applied as a stand-alone treatment to allow partial effluent reuse, overcome problems associated with the acceptance of effluent discharge into local municipal wastewater treatment works and minimise the cost associated with it. It may also be incorporated as a pre-treatment into full treatment schemes in order to improve the efficiency of downstream treatment, and decrease the required capital expenditure and operating cost.

This paper discusses the main features/advantages of the technology and presents results from a series of case studies from wood panel production mills around the world where the effectiveness of the treatment was demonstrated with laboratory and on-site pilot trials.

INTRODUCTION

Wood panel manufacturing utilises medium to large quantities of water in various production stages, typically, glue kitchens, thermal baths, gas exhaust scrubbers, chip washing, equipment washing, steam production etc. Effluents generated by these processes may be heavily contaminated, typically containing: large loads of "hard" COD which is too complex in structure to be biodegraded readily (e.g., tanins, lignins, terpenes, etc.); solids; and a host of pollutants, including nitrogenous organics, oils, free phenols, formaldehyde, semi-polymerised resins and resin additives, wood preservatives such as creosote, heavy metals and dyes etc. These attract the particular interest of local authorities because they are particularly toxic to microbes, animals and human populations.

In MDF and hardboard production, where water consumption is particularly high, effluent re-use is dictated not only by environmental but, in some parts of the world, also by economic considerations. Extensive on-site treatment is implemented, often at a high operating cost using advanced treatment technologies, such as reverse osmosis, evaporation, ozone oxidation and activated carbon adsorption. These approaches incur high maintenance and running costs in order to generate the effluent quality required for re-use in the production process. However, portions of the effluent often need to be disposed of into the sewer or the surrounding environment (eg nearby rivers and land irrigation). Most other wood panel mills (eg chipboard and plywood) with smaller water consumption typically apply minimal on-site treatment, often targeting only the removal of suspended solids, and dispose of the effluent into the sewer.

Biological degradation of organic contaminants associated with process water effluents from wood panel mills is invoked in one form or another either on-site as part of an organised effluent treatment scheme or off-site at local municipal treatment plants or directly into the natural environment, e.g. the soil and the natural watercourses. Because of the toxic and non-biodegradable pollutants they contain, when discharged into municipal sewage treatment works (especially those of small communities), such effluents may cause large shocks to biological treatment plants, upsetting their operation for long periods. As a result, there is an ever increasing resistance on behalf of operators of such facilities to accepting effluents from wood panel mills. At the same time, maximum allowable COD levels for discharge into municipal sewers drop, charges for effluent acceptance increase and the number of quality parameters accounted for in computing such charges expand to include parameters not considered in the past. When used for the irrigation of crops or forests, toxic and recalcitrant pollutants contained in these effluents remain in the soil for long periods and in the worst case may even enter the plant growth cycles and the food chain. For this reason, there is a tendency to move away from such disposal practices, at least in the developed countries. In the light of the above, there is increasing pressure on wood panel producers to minimise the volume of discharged effluents and/or to improve their quality. Improvements include lowering their toxicity, making them more amenable to biological treatment and minimising the levels of pollutants based on which discharge costs are computed.

Delmar is a full-service wastewater treatment contractor owned by A.C.M. Wood Chemicals plc, a world leader in the development and manufacture of adhesive resins and additives for wood panel production. Supported by a team of engineers and technologists specialised in environmental technologies, and in collaboration with ACM's group of wood and resin technologists, Delmar has acquired an expertise in the treatment of process water effluents from wood panel plants. Using house-owned processes as well as other technologies as required, Delmar designs customised effluent treatment solutions within the capital and operating cost requirements of the client, supplies the required equipment and provides full engineering support.

The DELMAR chemical treatment process, which was developed in 1996, is a cost-efficient and effective redox process for the pre-treatment of industrial effluents containing recalcitrant dissolved organic and inorganic pollutants and large concentrations of solids. The present paper discusses the main features of the technology and presents results from a series of case studies from wood panel production mills around the world where the effectiveness of the treatment has been demonstrated with laboratory and on-site pilot trials.

DELMAR CHEMICAL TREATMENT TECHNOLOGY

Process description

The process is based on an inexpensive reagent/catalyst redox system that promotes a network of chemical reactions and physical mechanisms which allow for the removal of a wide spectrum of dissolved pollutants and suspended matter from the wastewater. Chemical reactions promoted include the reactive "softening" of non-readily biodegradable and toxic dissolved pollutants which are too complex in structure (e.g. resins, tannins, lignins etc.) or overly oxidized (e.g. halogenated, S-containing pollutants) into more easily biodegradable species of lower molecular weight. Other reactions remove a broad range of specially targeted pollutants, such as dyes, odour, heavy metals, phenols, nitrogenous pollutants and phosphate.

In addition to chemical reactions acting on dissolved pollutants, certain reaction products of the reagent employed promote the coagulation of suspended matter and, particularly, the destabilisation of colloidal suspensions which may then be removed in the form of sludge, thus providing an inherent solids removal mechanism. In most applications, the process removes solids quite effectively down to the colloidal level with no need for extra coagulation aids. However, in some applications, especially for streams containing strong colloidal suspensions, small doses of extra inorganic or organic coagulants may be beneficial. In such cases, the prior application of the DELMAR process typically substantially decreases the required dosage for extra coagulants or even enables simple coagulants that would otherwise not be effective to function.

The net effect of the above two functions is the production of a wastewater with typically substantially lower concentrations of COD and BOD_5, targeted organic and inorganic pollutants, particulate and colloidal solids and overall toxicity. Because of the removal of "hard COD" associated with suspended matter, the "softening" of non-readily biodegradable pollutants and the removal of potentially toxic pollutants, such as heavy metals and phenols, the biodegradability of DELMAR pre-treated industrial effluents is typically substantially higher than that of the untreated streams. As a result, the system is ideal for the pretreatment of industrial wastewaters which may be subsequently treated more fully, more effectively and at a lower cost by conventional anaerobic and aerobic biological treatment processes.

The features of the DELMAR treatment process include:

1. Chemical "softening" of complex pollutants into more-readily biodegradable species.
2. Strong solids coagulating capacity with no or minimal requirement for extra coagulants.
3. Higher biodegradability and lower COD:BOD ratio of the treated effluent.
4. Improved solids settling, lower volume and higher dewaterability of primary sludge.
5. High colour and odour removal.
6. Significant removal of ammonia, nitrite, nitrate, phosphate, phenols, heavy metals, halogenated organics and other target pollutants during primary treatment.
7. Effective at a pH range from highly acidic to highly basic with an inherent capacity for pH correction towards neutral which reduces costs for downstream pH adjustment.
8. Emulsion break up.
9. Low capital and operating cost.
10. Easy operation by unskilled personnel.

Process Implementation

The DELMAR process is highly versatile in its application. It may be applied equally well in a batch or continuous-flow mode depending on the available space and the particular application. Figure 1 shows a conceptual flow sheet for a common continuous configuration. As shown, the plant consists of a reaction stage followed by the separation of pre-existing newly formed solids. The reactor comprises a mixing tank equipped with one or more DELMAR towers which contain a reagent/catalyst fixed bed, submerged in the aqueous phase. An air-lift mechanism promoted by air blowing at the bottom of the towers is employed to continuously recirculate the liquor through the reagent/catalyst fixed beds in the reactor. Alternatively, the tower(s) may be external to the mixing tank with liquid recirculation via surface-mounted pumps. The reactor effluent is directed to solids removal, typically, by sedimentation. However, other technologies (e.g., filtration, centrifugal decanting etc.) could also be used instead. In some applications, the addition of small quantities of extra coagulants prior to solids removal may be beneficial (inexpensive inorganic coagulants are often sufficient).

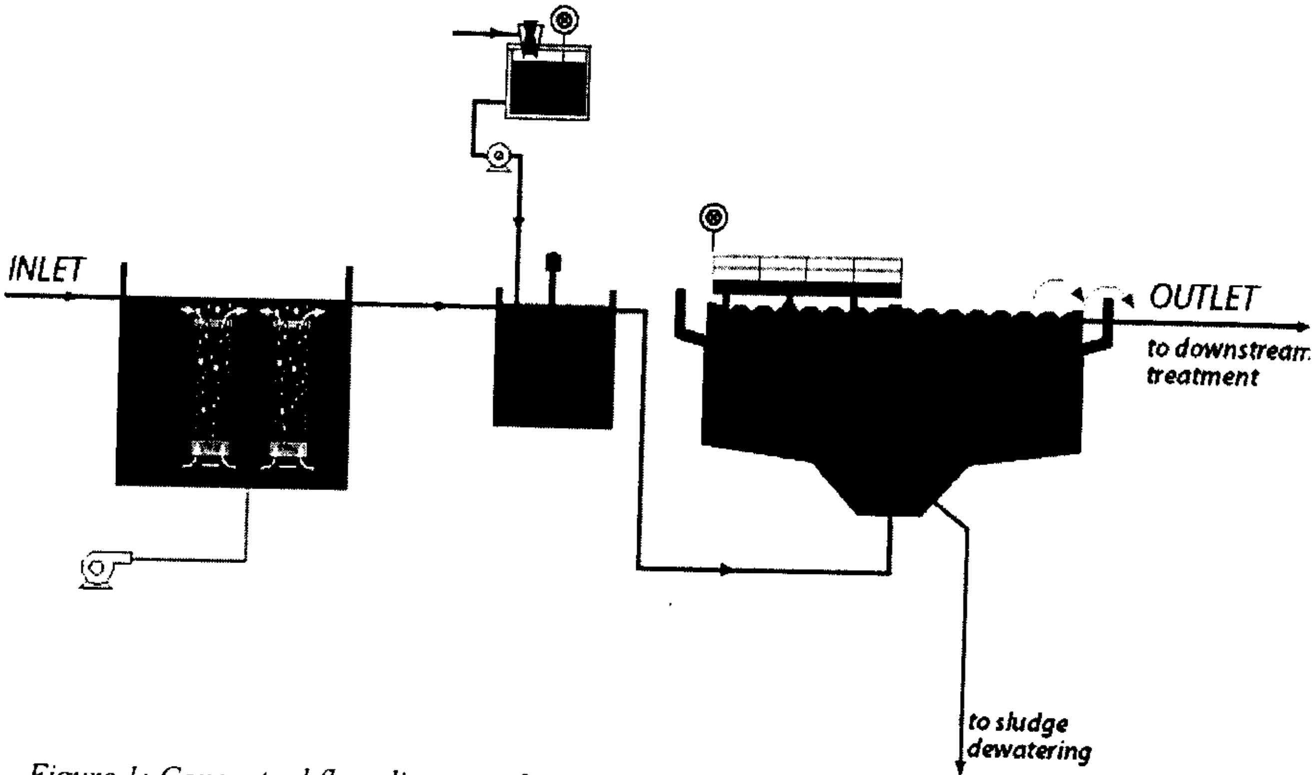

Figure 1: Conceptual flow diagram of a continuous-flow DELMAR plant configuration.

The number, size and design of the towers, the type of solids removal technology to be employed and the operating mode of the plant (continuous or batch) are selected to fit the particular requirements of each application.

As shown in Figure 1, the effluent from the DELMAR plant may be directed for downstream treatment on or off site. However, in many cases, it may also be suitable for reuse in applications such as glue mixing, equipment washing, chip washing, thermal baths etc. where the dissolved organics load of the water used is not important. In applications where the reused effluent should be of high quality (e.g. as boiler feed water) or the scope is to provide a more complete on-site treatment prior to discharging into the sewer or a nearby river, the effluent from the DELMAR plant may be directed for appropriate biological and/or physico-chemical treatment to meet the desirable final effluent quality. Such technologies may involve aerobic/anaerobic biodegradation followed by sand filtration, membrane filtration (eg ultrafiltration, reverse osmosis etc.), ozone/peroxide oxidation, adsorption etc.

The sludge produced by the treatment may also be reused in the production line. Given its high caloric value, an obvious use for this sludge after dewatering to 30-40% w/w solids is burning to heat up dryers or boilers. Depending on its composition and water content, this sludge may also possibly be used in plywood and chipboard production.

SELECTED FEASIBILITY STUDIES

Bench-scale laboratory and on-site pilot trials have confirmed the feasibility of the Delmar process for the treatment of effluents from wood panel mills. Figure 2 shows a pilot plant used for on-site trials. Effluents from chipboard, hardboard, plywood and MDF plants around the world have been tested. This section presents results from several case studies.

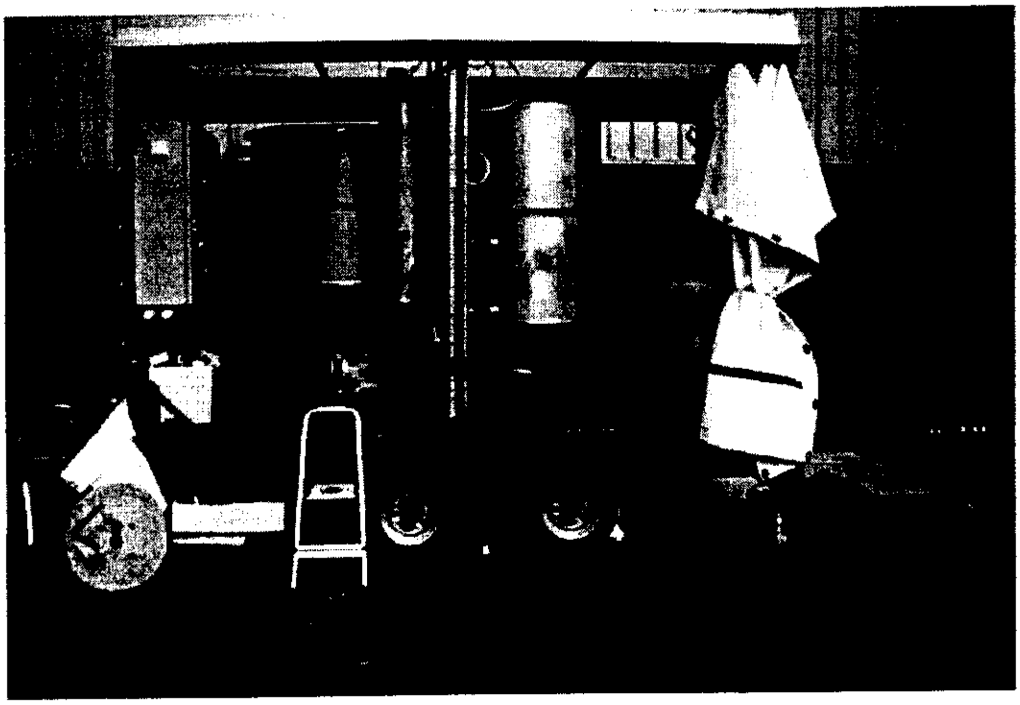

Figure 2: Photograph of a pilot plant used in on-site trials.

Case Study A – Chipboard plant in Central Europe

Similar to many such plants around the world, this chipboard plant in Central Europe is equipped with an exhaust gas scrubber to reduce gas emissions and produce energy. The steam condensate from the scrubber is highly contaminated and undergoes on-site treatment by flotation before it is finally disposed of into the sewer. Prompted by a pending reduction in the COD limit for disposal and the high effluent discharge costs, the plant tested the ability of the Delmar process to decrease the COD and BOD_5 in the flotation effluent.

A series of bench-scale batch trials were carried out on a sample from this effluent. The initial values of the various quality parameters are shown in Table 1 and the results are shown in Figure 3 (parameter values are normalised by their corresponding initial value). As is shown in Figure 3, the DELMAR treatment was able to remove approximately 30% of the COD, 50% of the BOD_5 and 40% of the suspended solids of the original sample. In addition, the treatment also removed 49% of the organic nitrogen, 6% of the NH_4-N, 40% of the NO_2-N, 25% of the total phenols and more than 95% of the PO_4-P. It was also able to remove small quantities of metals from the original sample, some of which, such as copper, may be particularly toxic to biological systems at relatively low concentrations.

Table 1: Initial quality of untreated flotation effluent sample

Parameter	Units	Value	Parameter	Units	Value
COD	[mg/L]	3,680	NH_4-N	[mg/L]	33
BOD_5	[mg/L]	2,235	NO_3-N	[mg/L]	48.5
BOD ARAS	[mg/L]	1,250	NO_2-N	[mg/L]	7.8
Filterable Solids	[mg/L]	150	PO_4-P (mg/L)	[mg/L]	2.4
Settleable Solids	[mL/L]	0.1	Total phenols	[mg/L]	26.5

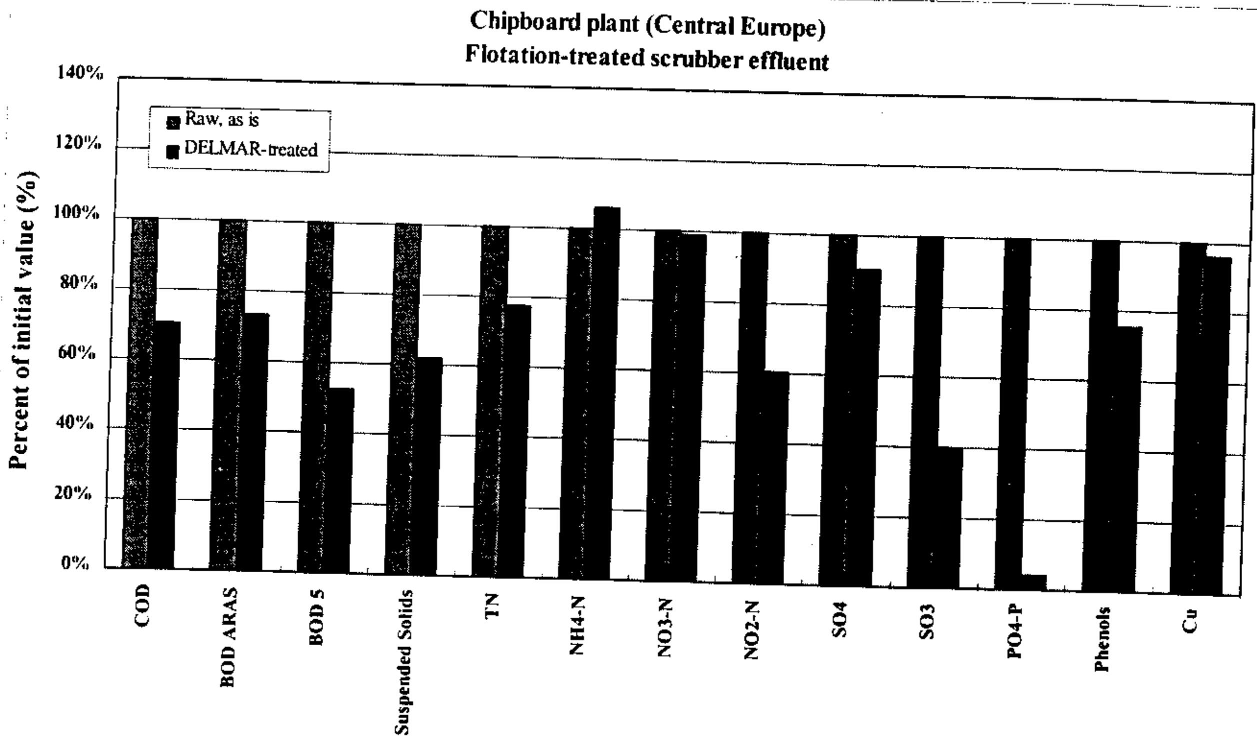

Figure 3: Efficiency of bench-scale treatment of a flotation-treated scrubber effluent from a chipboard plant in Central Europe.

It is evident that the DELMAR process substantially improved almost all quality parameters of the sample and has, thus, outperformed the existing flotation method employed by the mill. The process is an effective alternative to flotation for the pre-treatment of scrubber effluents from chipboard plants with lower projected costs of disposal into the sewer. The DELMAR effluent is practically free of solids and contains mostly organic contaminants of wood origin. As a result, it may also be reused in the production line for applications where high-purity water is not required (e.g., as make-up water for glue production, equipment washing etc.).

Case Study B – Wood panel mill in Southern Europe

This mill in Southern Europe produces a number of products, including plywood, chipboard, veneer, post-forming and coated panels. Plywood production contributes over 60% of the total industrial effluent. The process water effluents from the various production lines are collected in separate sumps from where they are collected every few days by a road tanker and are transported for treatment off site at an effluent treatment plant for the entire industrial estate.

The discharge of a truckload of highly contaminated and toxic wastewater into the treatment sequence introduces severe shocks to the biological treatment within a few minutes and upsets its operation. As a result, the authorities are reluctant to continue taking in the mill effluent unless its COD, solids and toxicity levels decrease drastically.

The DELMAR process was evaluated as an option for providing on-site pre-treatment to the combined effluent prior to disposal into the effluent treatment works of the industrial estate. Table 2 shows typical results from bench-scale batch feasibility trials. As is evident, the treatment decreased the COD of the raw effluent sample by 60% and almost eliminated its solids content. At the same time, the readily biodegradable organic load dropped by only 22% increasing the BOD:COD ratio and the biodegradability of the effluent.

Table 2: Results of lab trials on the raw effluent from a hardboard mill in Southern Europe

Parameter	Units	Before	After	% Decrease
COD	[mg/L]	21,700	9,000	59
BOD ARAS	[mg/L]	1,040	810	22
Total phenols	[mg/L]	985	635	36
Filterable Solids	[mg/L]	7,400	210	97

Following the results of the laboratory trials, the DELMAR process was tested on site by pilot trials on the combined effluent. Typical quantitative results for six different days over an operating period of two weeks are summarised in Figure 4. Figure 5 shows a photograph comparing the visual appearance of typical samples from the inlet and outlet of the pilot plant.

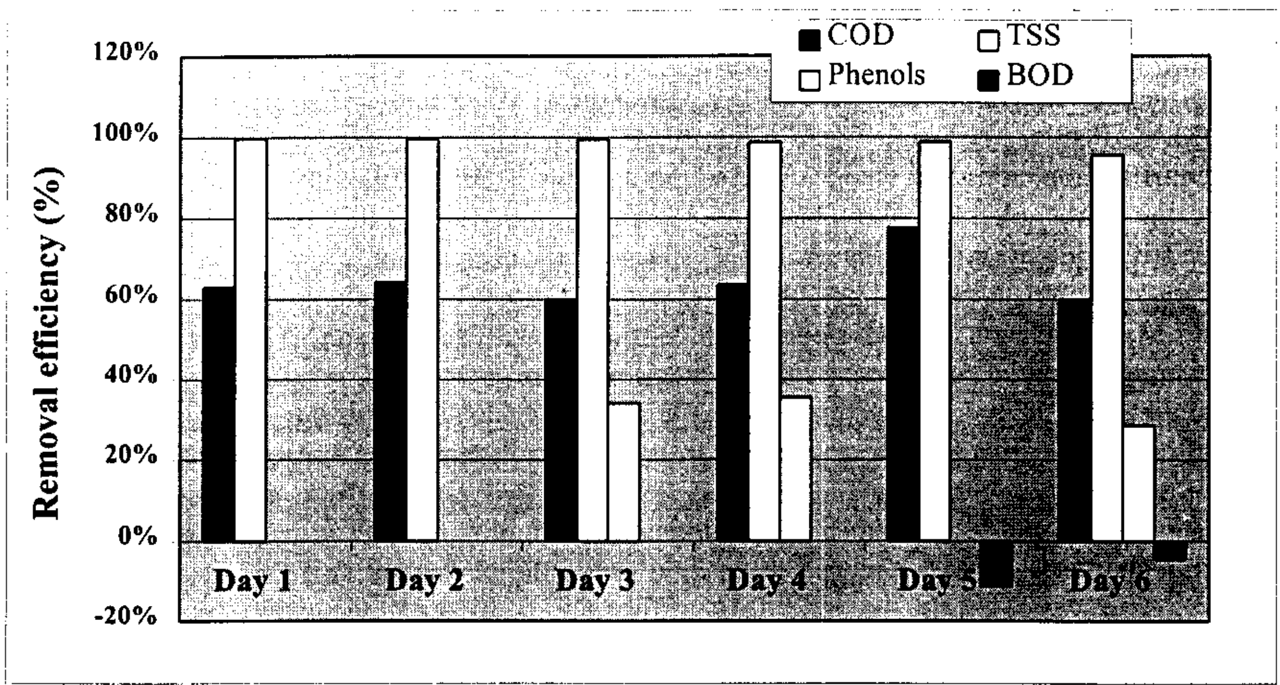

Figure 4: Efficiency of continuous-flow pilot trials on the combined effluent from a wood panel mill in Southern Europe.

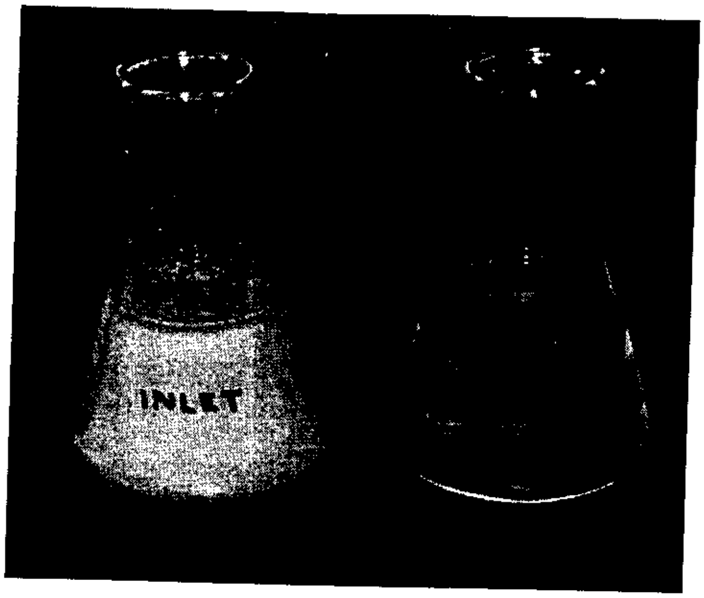

Figure 5: Typical inlet and outlet samples from the pilot trials on the combined effluent from a wood panel mill in Southern Europe.

The results fully confirmed the results of the previous laboratory trials. The application of a treatment scheme based on the Delmar process to the combined effluent from the mill reduced the COD of the effluent by 60-65%, yielding a residual COD level of the order of 3,500-8,000 mg/l. The treatment also removed more than 95% of the total suspended solids (TSS) resulting in the production of an almost clear treated effluent, removed its colour leaving a residual yellow tint, reduced by 30-40% the total phenols content (which is responsible for the increased toxicity of the effluent) and increased slightly the BOD_5 level increasing BOD_5/COD by a factor of 2 and thus significantly improved the biodegradability of the wastewater.

To demonstrate the biodegradability of the DELMAR-treated effluents, samples from the DELMAR pilot plant outlet were collected and exposed to biological treatment (consisting of denitrification, activated sludge/clarification and nitrification) followed by sand filtration in a smaller pilot plant at the DELMAR facilities. Instead of the conventional anaerobic denitrification which utilises exclusively biological mechanisms, some trials were repeated using a combined chemical and biological reductive stage by introducing a tower carrying the DELMAR reagent/catalyst system inside the denitrification tank. These trials tested a different potential application of the chemical redox system of the DELMAR process in parallel with the reducing action of anaerobic biological cultures for the reduction of complex pollutants in effluents from wood panel mills. The results shown in Table 3 confirm that, after pre-treatment by the DELMAR process, the combined effluent from the wood panel mill becomes amenable to conventional downstream biological treatment generating a final effluent which could be reused as is or after further treatment (e.g. by ozone or reverse osmosis). Moreover, by introducing a further DELMAR treatment stage (under anaerobic conditions this time) inside the de-nitrification tank, the combined chemical/biological reducing capacity of the system is augmented (as is evident by the increase of NH_4-N). This allows a more complete biodegradation of the pollutants and allows for a final effluent after sand filtration that can be reused in the production process or discharged into the sewer (and, depending on the local legislation, even into the environment) without further elaborate, costly and maintenance-intensive polishing treatment.

Table 3: Downstream biological treatment of a DELMAR pre-treated effluent from a wood panel mill in Southern Europe.

Parameter	DELMAR pre-treated inlet	Dentrification tank/only biological treatment	Dentrification tank/parallel biological & chemical treatment	Final effluent/ only biological treatment	Final effluent/ parallel biological & chemical treatment
COD (mg/L)	5,500	3,148	2,675	900	400
BOD_5 (mg/L)	1,440	28	70	6	5
NH_4-N (mg/L)	80	480	535	270	35
Phenols (mg/L)	38	29	26	15	0.5

Case Study C – Hardboard plant in Southern Africa

This mill in Southern Africa produces hardboard by a wet process. The effluent from the production line contains a high concentration of wood fibres, lubricating oils and a host of contaminants, such as phenols, lignins and tannins and extractable organics from the wood chips. The combined effluent from manufacturing and cleaning operations undergoes on-site treatment by anaerobic digestion and is then discharged into the sewer. Despite its recent construction, the anaerobic contactor exhibits an unusually low performance mainly due to the toxicity of certain contaminants such as, heavy metals, phenols, mineral oils, ammonia-N, various toxic organics of wood origin etc at its inlet, which results in an extremely high effluent COD and the emission of a foul odour. Under these conditions, the local authorities have decided to disallow the discharge of the process water effluent from the mill into the municipal sewage treatment works due to the severe shocks experienced by the activated sludge treatment of the latter.

In order to improve the quality of its effluent drastically, the mill is looking to retrofit a treatment prior to the anaerobic contactor to increase the biodegradability of the incoming wastewater and protect the contactor from its toxicity. The DELMAR process was tested for this purpose at both bench-scale and on-site pilot trials. Table 4 shows the initial quality of a raw effluent sample that was tested in the laboratory and the results are shown in Figure 6 (each parameter value is normalised by the corresponding initial value). Figure 7 shows typical results from Oxygen Uptake Rate (OUR) measurements carried out on the raw effluent and DELMAR-treated samples.

Once again, the results of the bench-scale lab trials were confirmed fully by those of on-site pilot trials. Both sets of trials demonstrated that the application of the DELMAR process in conjunction with small quantities of inexpensive inorganic coagulants to the raw effluent from the hardboard plant removes approximately 35-40% of the COD and 85% of the filterable solids while, at the same time, only minimally decreasing the concentration of readily-biodegradable and total biodegradable pollutants.

Table 4: Initial quality of the combined process water effluent from the hardboard mill

Parameter	Units	Value	Parameter	Units	Value
COD	[mg/L]	21,920	Cu	[mg/L]	90
BOD_5	[mg/L]	10,730	NH_4-N	[mg/L]	21
BOD ARAS	[mg/L]	2,450	NO_3-N	[mg/L]	100
Filterable Solids	[mg/L]	3,350	NO_2-N	[mg/L]	18
Total phenols	[mg/L]	280	Total Nitrogen	[mg/L]	130

The treatment also led to the removal of large fractions (60-90%) of a wide range of target pollutants, such as NH_4-N, nitrate, nitrite and phosphate as well as pollutants which are toxic to typical anaerobic biological systems, such as phenols and copper. As is demonstrated by the results in Figure 7, the "softening" of complex pollutants of wood-origin, the higher BOD:COD ratio and the removal of toxic contaminants, such as phenols, oils and heavy metals, rendered the DELMAR-treated sample much more biodegradable than the original one. In fact, the area under the OUR curve of the treated sample which represents the easily biodegradable organic load has increased by a factor of two over that for the untreated raw effluent sample. These results led to the conclusion that a retrofit of the DELMAR process into the existing treatment sequence prior to the anaerobic contactor should substantially increase the effectiveness of the latter and protect it in the long term from inhibitory interference due to toxic incoming pollutants.

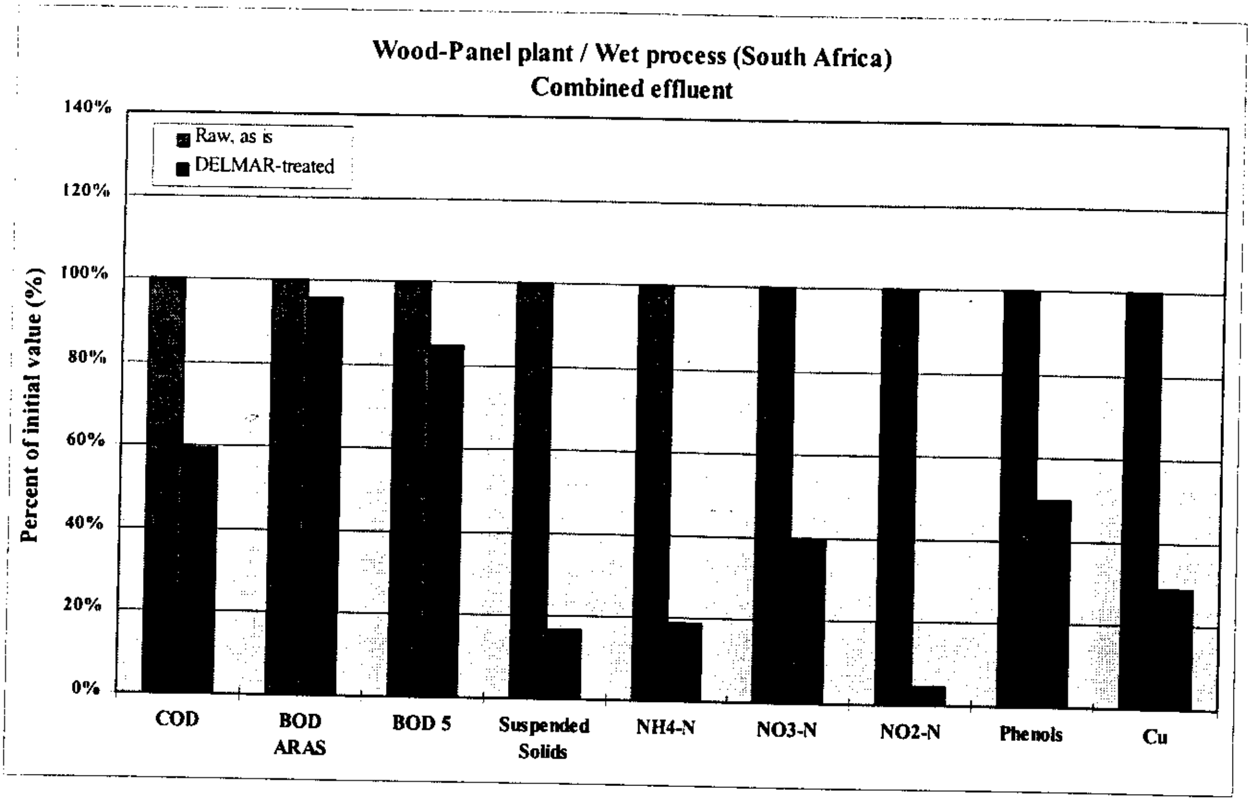

Figure 6: Efficiency of bench-scale treatment of a raw effluent sample from a hardboard plant in Southern Africa.

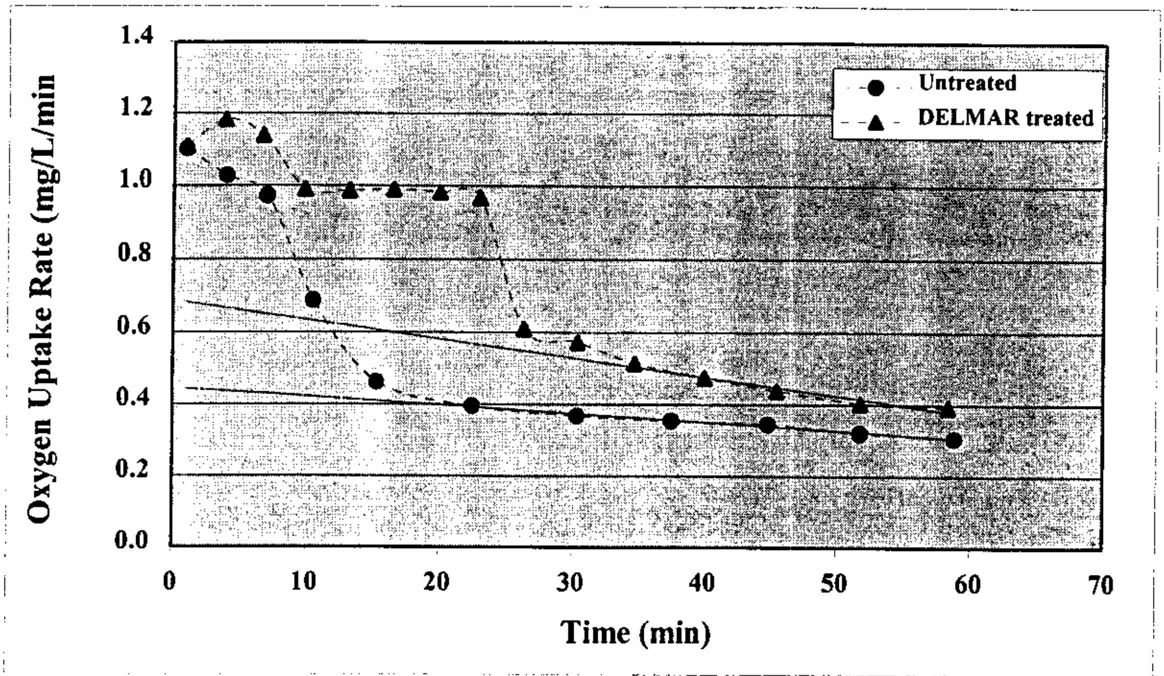

Figure 7: Comparison of Oxygen Uptake Rates measured for a raw effluent and a DELMAR-treated sample from a hardboard plant in Southern Africa.

Case Study D – MDF plant in Australia

This MDF mill in Australia employs an extensive on-site treatment of its combined process water effluent by primary clarification, aerobic biological treatment, sand filtration, ultrafiltration and reverse osmosis in order to recycle the treated effluent into the production line. While the effluent treatment plant operates without significant problems in the summer, the low temperatures, large flow-rates and high incoming COD loads upset the operation of the biological treatment plant in the winter/spring period leading to poor effluent quality at its outlet. This in turn substantially burdens the operation of the ultrafiltration and reverse osmosis plants, increasing fouling problems, maintenance and operating costs. For this reason, the mill investigated options for retrofitting a treatment plant prior to the biological treatment stage in order to stabilise the operation of the latter throughout the year, or produce an effluent that could be fed directly into the membrane plants and, thus, bypass the biological treatment.

The DELMAR process was tested for this purpose with on-site pilot trials on the raw wastewater effluent fed into the existing effluent treatment plant (Table 5) over a period of two weeks. Figure 8 shows results from a typical operating day whilst Figure 9 shows a photograph comparing the visual appearance of inlet and outlet samples from the pilot plant.

Table 5: Initial quality of the raw effluent from the MDF mill

Parameter	Units	Value	Parameter	Units	Value
COD	[mg/L]	11,200	SO_4	[mg/L]	26
BOD_5	[mg/L]	6,130	Colour (true)	[pcv]	250
Filterable Solids	[mg/L]	4,430	Turbidity	[Ntu]	1,300

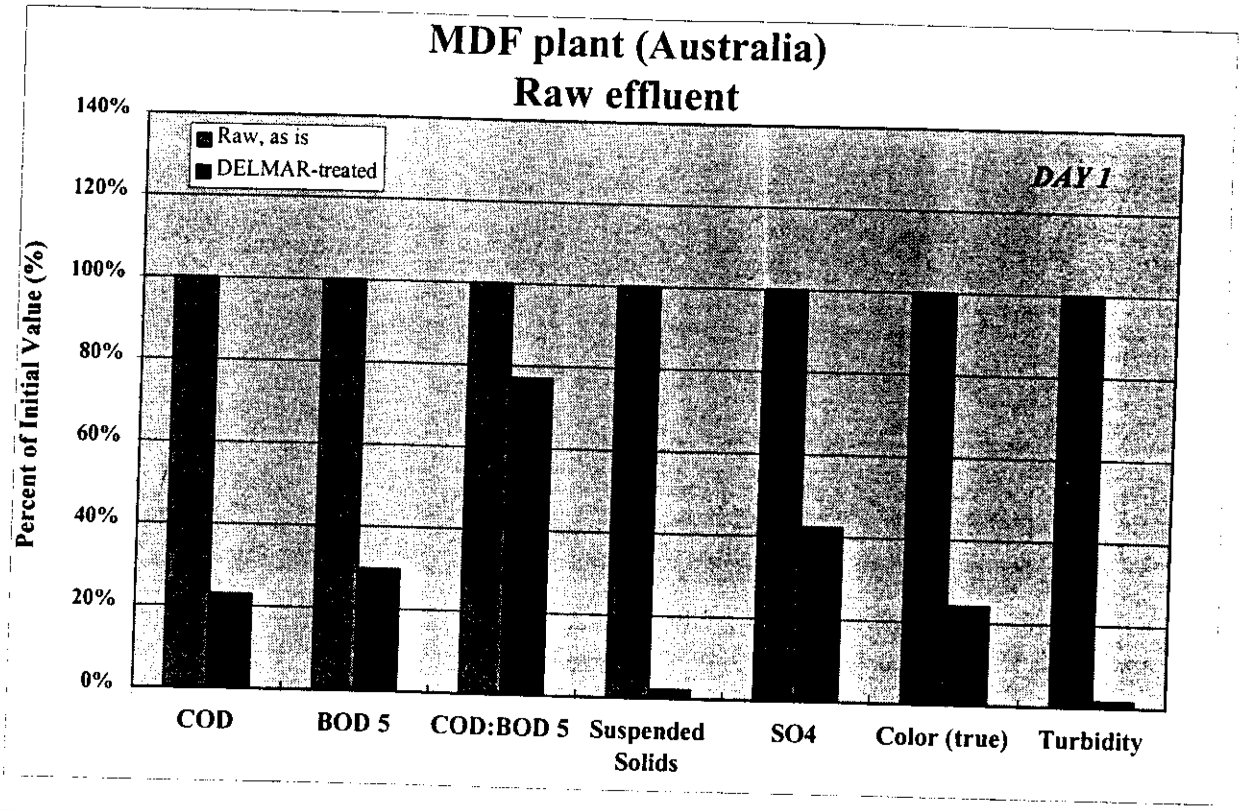

Figure 8: Efficiency of on-site pilot treatment of the raw effluent from an MDF plant in Australia.

The treatment removed on a continuous basis, approximately 70% of the COD, 60-80% of the BOD_5 and almost 100% of the suspended solids of the raw process water effluent from the mill. It also drastically decreased its true colour content and eliminated the turbidity. The results of the pilot trials suggest that the quality of the DELMAR-treated effluent is indeed better than that of the existing biological treatment and could be directly fed to membrane filtration and reverse osmosis, thus bypassing the biological treatment.

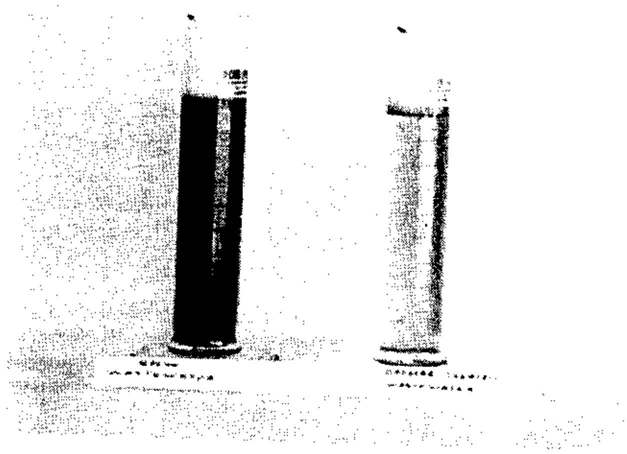

Figure 9: Typical inlet and outlet samples from the pilot trials on the raw process water effluent from an MDF mill in Australia.

CONCLUSIONS

The Delmar process is an effective and inexpensive chemical redox process for the treatment of industrial effluents. Its feasibility for the treatment of process water effluents from wood panel mills has been demonstrated in a large number of laboratory and on-site pilot trials. The process is capable of removing large fractions of COD, BOD and a number of pollutants that are specifically targeted by regulating authorities. Moreover, in all case studies presented herein it has been able to remove completely or almost completely particulate and colloidal matter and led to a dramatic improvement in the true colour and turbidity of the feed. Finally, it has been demonstrated that, by a combination of "softening" of complex molecules and removal of toxicity, the chemical treatment is capable of improving drastically the biodegradability of the typically non-readily biodegradable effluents from wood panel mills, thus, rendering them more amenable to on- or off-site biological treatment.

The DELMAR process may function equally well as a stand-alone treatment or as a pre-treatment to more elaborate treatment schemes. When applied as a stand-alone treatment, it may facilitate partial re-use of effluent and the reduction of costs associated with effluent discharge into sewers. When augmented by downstream on-site treatment towards recycling, it can improve the efficiency of downstream treatment and decrease the required capital expenditure and operating cost. In such cases, a fully recyclable effluent can, in some cases, be achieved even by the sole use of inexpensive biological treatment processes, thus bypassing the need for advanced and costly polishing processes. Finally, the process may also be retrofitted to existing under-performing facilities to help them meet the desired effluent quality requirements for discharging into a local municipal sewage treatment works and achieve increased operational stability.