Project no. CT 2004-509188

Project acronym: EMCO

Project title: **Reduction of environmental risks, posed by Emerging Contaminants, through advanced treatment of municipal and industrial wastes**

Instrument: STREP

Thematic Priority: Integrating and Strengthening the European Research Area; Specific measures in support of international co-operation

Publishable final activity report

Period covered: from 01st July 2004 to 30th June 2007
Date of preparation: 20. July 2007

Start date of project: 1 July 2004 Duration: 36 months

1. Project execution

Co-ordinator:

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Contractors involved:

Participant 1 (Co-ordinator)	IIQAB-CSIC, Barcelona, Spain
Participant 2 (Contractor)	IRB, Zagreb, Croatia
Participant 3 (Contractor)	FKIT, Zagreb, Croatia
Participant 4 (Contractor)	PBF, Zagreb, Croatia
Participant 5 (Contractor)	TMF, Belgrade, Serbia and Montenegro
Participant 6 (Contractor)	EFF, Idstein, Germany
Participant 7 (Contractor)	AGBAR, Barcelona, Spain
Participant 8 (Contractor)	HEIS, Sarajevo, Bosnia and Herzegovina
Participant 9 (Contractor)	SLEnv, Nicosia, Cyprus

Project web site:

www.cid.csic.es/emco/home.htm

Project objectives

Project EMCO addresses the hot issue of so-called “emerging” or “new” contaminants (i.e. human and veterinary drugs, surfactants, textile dyes), whose emission has recently emerged as an environmental problem. It focused on their tracing in industrial and municipal effluents and removal by advanced water treatment technologies (membrane processes: MBR, RO/UF/NF and advanced sorbents). Emphasis was given on the application of small units for on-site treatment of industrial and municipal effluents with the objective to reduce environmental and health risks through an improvement of the quality of receiving surface waters.

Additionally, EMCO provided comprehensive data on the occurrence of emerging contaminants in effluents in the participating WB and EU countries and the extent to which these compounds can be removed by advanced treatment technology in order to allow their introduction on the list of relevant compounds to be monitored, and setting of new limits of emission and the development of avoidance strategies.

The specific objectives were as follows:

1. To improve the treatment of wastewaters by using novel membrane technology and to investigate its removal potential with respect to emerging contaminants from household and industry (pharmaceutical and textile)
2. To apply advanced sorption treatment using recycled materials as cost-effective sorbents for the treatment of textile effluents

3. To recommend a battery of treatment steps for the elimination of emerging contaminants from different types of wastewater prior to their discharge to municipal collection systems or receiving waters
4. To evaluate the ecotoxicological relevance of selected classes of emerging contaminants in relation with their biodegradability and elimination during treatment by existing and advanced wastewater and drinking water technologies
5. To provide the EU and the WBC with sufficient information about emerging contaminants on the basis of their degree of elimination during wastewater treatment

Methodology and approaches applied

Three main methodological elements are being integrated in the project workplan:

1. ***Stocktaking*** – compilation of existing data and collection of missing data on the occurrence of priority and emerging contaminants in the aquatic system of WBC. Data are used to evaluate the environmental risks posed by emerging contaminants from municipal and industrial sources and to identify the ecotoxicologically most critical contaminant groups in WBC wastewaters.
2. ***Development of analytical tools*** – development, optimization, validation of chemical and biological methods to be used for ecotoxicological study and risk assessment. Analyses included both parent compounds and possible degradation products, studying the behaviour or selected compounds in the environment and during waste and drinking water treatment.
3. ***Evaluation of treatment technologies*** – the stepwise adjustment of wastewater treatment technologies: (i) membrane bioreactors (MBR), (ii) reverse osmosis (RO) and nanofiltration (NF) and (iii) advanced sorbent materials from *laboratory scale* to *pilot plants.* Three pilot MBR were installed at locations in Croatia, Bosnia and Herzegovina and Spain, respectively. Pilot plant for RO/NF was installed in Croatia. Conventional physico-chemical and biological treatment are evaluated with respect to the elimination of select classes of emerging contaminants from water and drinking water. Data are used to recommend the best treatment strategy for each specific study site using criteria based on environmental impact and costs analysis.

Main results achieved:

Inventory

Inventory included identification and inter-comparison of the current state-of-the-art of wastewater treatment in the region and available expertise as well as the current status of legislation and standards related to wastewater treatment in WB countries

Inadequate waste management is a significant ecological problem in B&H, Croatia and SCG. The improved performance in environmental protection can be accomplished only through a well-defined legal framework accompanied by the application of the adequate policy and a wide public support. Current process of political, social and economic changes in the countries of the South-Eastern Europe, catalysed by accession process to the EU, is a promising basis for the introduction of systemic

measures in accordance with environmental acquis. Despite growing potential for private initiative in the environmental sector, priority measures and activities require an active participation of governmental institutions and close cooperation of relevant authorities as well as a strong involvement of internationally supported actions. The most important part of the approach are long-term systematic sanitary measures. However, due to the acute problems in waste management, some urgent preventive measures should be implemented to mitigate the consequences of pollution in the some critically polluted areas.

These measures comprise a marked socio-economic and technological development and require engagement of significant financial resources. Financial resources, which, in the past, have often been an important obstacle in the realisation of adopted environmental protection policies, should include different sources such as budget funds, private funds, resource usage compensations etc. It is expected that the process of accession to the EU will result in a significant progress in the terms of strengthening regional cooperation on water protection.

New analytical methods

- A multiresidue method for trace level quantification of 29 pharmaceutical compounds in waste and environmental waters (target analysis using a HPLC-MS-MS (QqQ) with confirmation using an UPLC-Q-TOF)
- A multiresidue LC/MS/MS method for the analysis of 3 prominent classes of antibiotics, including sulfonamides, fluoroquinolones and macrolides, in wastewater
- HPLC/DAD/FL method for the analysis of veterinary antibiotics in process waste water.
- Analytical methods for polar organic acids (hyphenization of ion chromatography and Q-Tof-MS) as well as antibiotics (LC/MS and online LC-UV)): Barbiturates: Aprobarbital, Amobarbital, Butalbital, Hexobarbital, Pentobarbital, Secobarbital, Phenobarbital; Fungal skin infection agent: Clotrimazole; Pharmaceuticals: Carbamazepine, diclofenac,
- An automated SPE method for on-line measurement for the antibiotic chloramphenicol
- CLSA-GC-MS and SPE-GC-MS methods for musk compounds and fragrances in waters.
- A multi-residue analytical method has been developed to determine 80 multiple-class pharmaceuticals using liquid chromatography-quadrupole-linear ion trap tandem mass spectrometry.
- An analytical method to analyze eight β-blockers in wastewaters based on Molecular imprinted polymers (MIP) followed by liquid chromatography-quadrupole-linear ion trap tandem mass spectrometry.
- An LC-MS/MS method has been developed for the determination of drugs of abuse in wastewaters and surface waters.
- An analytical LC-MS/MS method for the persistent metabolite desphenyl-n-chloridazon and 70 further polar pollutants has been developed and applied to waste and surface water.

Bioanalytical tools for the assessment of ecotoxicological risks of emerging contaminants in the environment.

An overall evaluation of the different bioassays was performed. The selection of the bioassays was based on the following criteria:

- Easy standardization and cost effectiveness (low cost/fast application)

- Precision and accuracy
- Use of test organisms that belong to different trophic level in order to reflect effects on different organizational structures and sensitivities in the ecosystem,
- Each of them must be selective to a number of different compounds or groups
- The selected tests should clearly show co-linearity but not complete equivalence with each other and provide complementary information

A battery of bioassays is selected based on tests already available at the labs of the participants. A battery of tests covers a wide range of ecotoxicologically relevant end-points in a reasonable cost-effective way, allowing relatively simple and high-throughput characterization of wastewater samples and identification of relevant contaminants in complex environmental mixtures. In addition, the tests applied are based on a variety of test organisms belonging to different trophic levels, reflecting different aspects of the ecosystem, provide complementary information.

- Microtox test
- Determination of CYP1A induction potential of environmental samples – EROD activity in primary culture of rainbow trout (*Oncorhynchus mykiss*) hepatocytes
- Chronic toxicity test protocol - growth inhibition test with unicellular algae (*Selenastrum capricornutum*) – microplate method
- Yeast estrogen screen (YES-assay) for the detection of ER-active compounds
- Detection of MXR-inhibiting properties of chemicals and environmental samples – "Pgp-inhibition assay"

Occurrence of emerging contaminants in wastewater from Wester Balkan region

Two comprehensive sampling campaigns were performed in Croatia (16 locations), one in Bosnia and Herzegovina (6 locations) and Serbia (7 locations) (Fig. 1). The majority of samples from Bosnia and Serbia were untreated municipal and industrial wastewaters, while in Croatia, effluents from the existing wastewater treatment plants (WWTPs) were also collected, which allowed the assessment of the removal efficiencies for the most prominent classes of emerging contaminants.

Fig. 1 Map of the region with indicated sampling locations for wastewater monitoring campaigns in Bosnia and Herzegovina, Croatia and Serbia; Legend: municipal wastewaters (circles); industrial wastewaters (squares).

The results obtained confirmed a widespread occurrence of the emerging contaminants in municipal wastewaters of the WB region. Regarding raw wastewaters, the situation is similar to that in the Western Europe and USA. However, due to the rather poor wastewater management practices in WB countries, there is a significant difference with respect to the increased percentage of wastewater contaminants that ultimately reach the ambient waters in WB countries. Futhermore, this study confirms that the removal rates for some of the emerging contaminants, including numerous pharmaceuticals, in WWTPs using conventional activated sludge treatment are very low, which indicates that more advanced treatment methods might be necessary to cope with the increasing inputs of such contaminants.

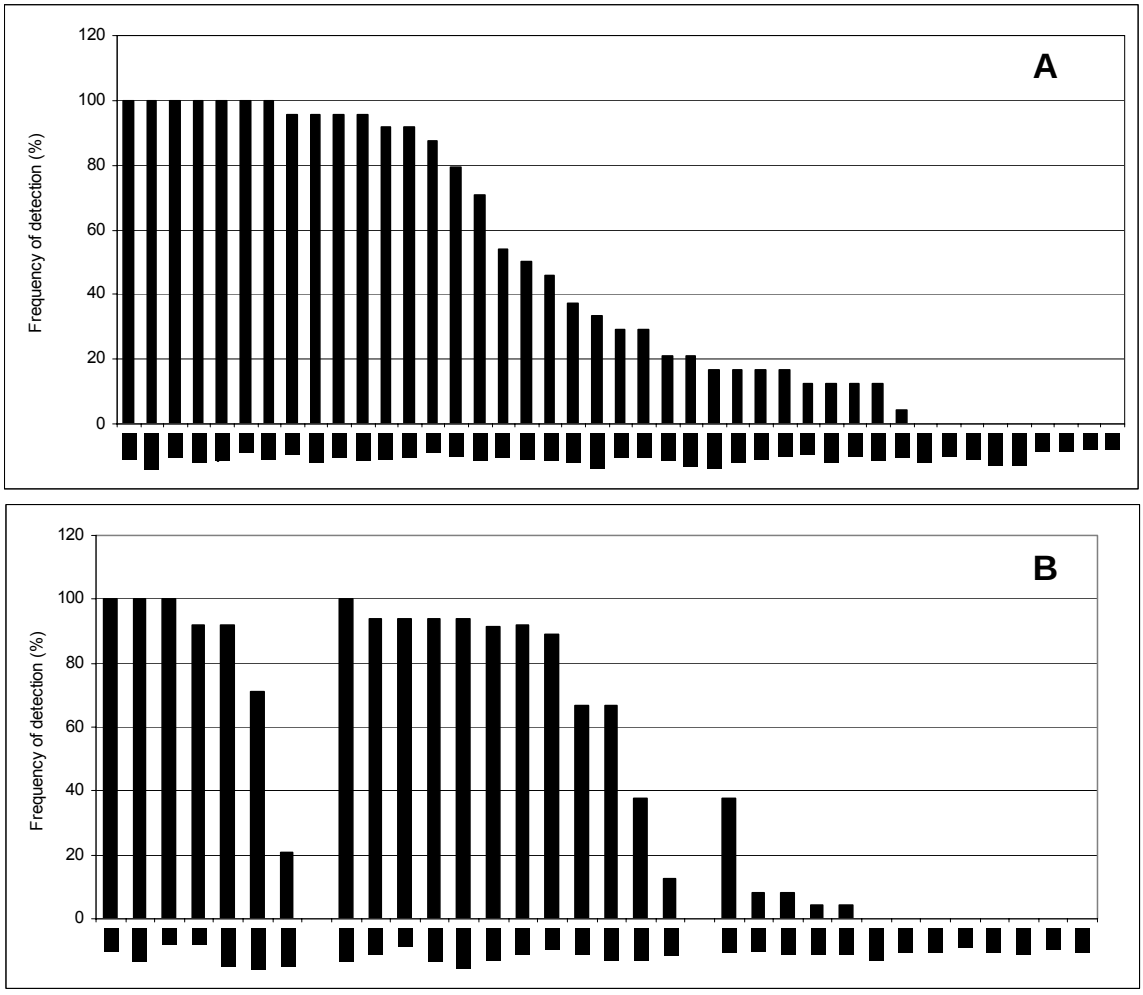

Fig. 2 Frequency of detection for individual emerging contaminants (%). A) Pharmacueticals; B) Surfactants, fragrances, flame retardants, insect repellents and pesticides

Treatment of emerging contaminants in WW using membrane bioreactors (MBR)

Four MBR laboratory and pilot scale plants were used duringthe course of the project:

- MBR Zenon was situated at the Municipal wastewater treatment plant (WWTP) of City of Čakovec in northern Croatia (P4 and P2)
- A submerged MBR purchased from Kubota (Osaka, Japan) installed in a municipal WWTP in Rubí (Barcelona, Spain). (P1)

- A pilot plant MBR consisting of submerged hollow fiber and flat membranes, respectively, installed at WWTP Terrasa (Spain) (P1)
- Laboratory-scale MBR installed at pharmaceutical industry Bosnaliek, Sarajevo, Bosnia and Herzegovina (P8)

The behavior of several pharmaceuticals belonging to different therapeutic categories (analgesics and anti-inflammatory drugs, lipid regulators, antibiotics, etc.) was monitored during treatment of wastewater in a laboratory-scale membrane bioreactor (MBR). The results were compared with their removal in a conventional activated sludge (CAS) process in an existing wastewater treatment facility. In general pharmaceuticals were removed to a higher extent in the MBR integrated system than during CAS process. For most of the investigated compounds MBR treatment had better performance (removal rates>80%) and steadier effluent concentrations than the conventional system (e.g. diclofenac, ketoprofen, ranitidine, gemfibrozil, bezafibrate, pravastatin, ofloxacin). In some cases the removal efficiencies were very similar and high for both treatments (e.g. ibuprofen, naproxen, acetaminophen, paroxetine, hydrochlorothiazide). The antiepileptic drug carbamazepine turned out to be the most persistent pharmaceutical as it passed both through MBR and CAS system untransformed. Since there was no washout of biomass from the reactor, high- quality effluent in terms of chemical oxygen demand (COD), ammonium content ($N\text{-}NH_4$), total suspended solids (TSS) and total organic carbon (TOC) was obtained.

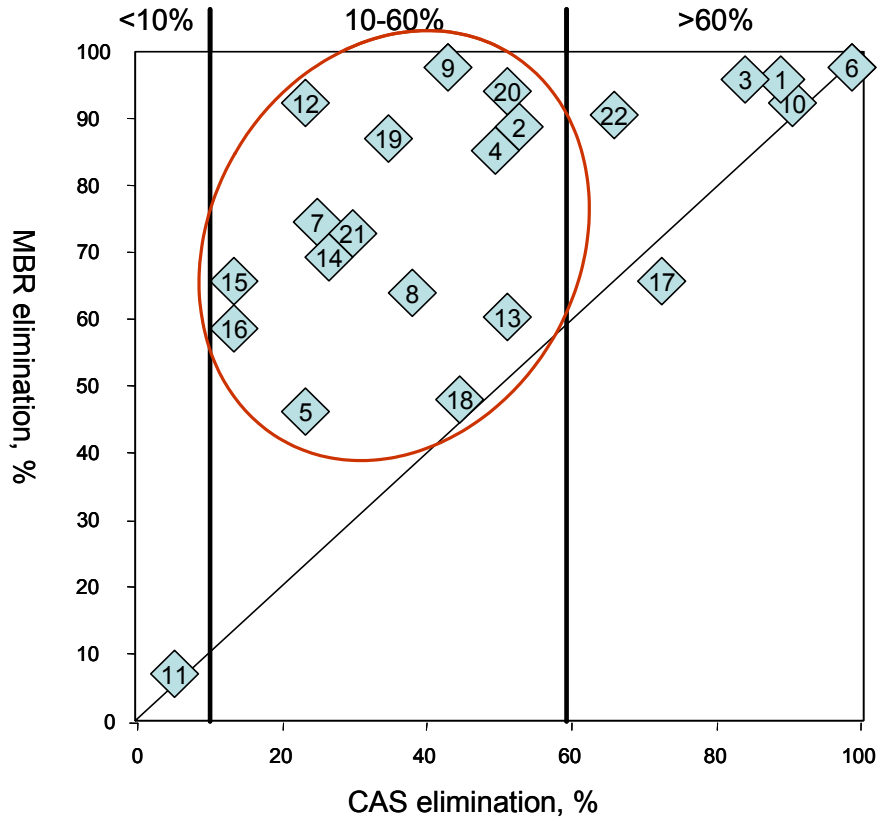

Fig. 3 Enhanced removal of pharmaceutical residues in MBR compared to CAS; 1-naproxen, 2-ketoprofen, 3-ibuprofen, 4-diclofenac, 5-indomethacin, 6-acetaminophen, 7-mefenamic acid, 8-propyphenazone, 9-ranitidine, 10-paroxetine, 11-carbamazepine, 12-ofloxacin, 13-sulfamethoxazole, 14-erythromycin, 15-atenolol, 16-metoprolol, 17-hydrochlorothiazide, 18-glibenclamide, 19-gemfibrozil, 20-bezafibrate, 21-clofibric acid, 22-pravastatin

Treatment of emerging contaminants in WW using reverse osmosis/nanofiltration (RO/NF)

A pilot-plant unit (Fig. 4) containing two 5 μm cartridge filters and three spiral wound membrane elements [L = 1000 mm (40”), D = 64 mm (2.5”) and active area = 2.6 m^2] was installed at Veterina, Kalinovica (Croatia). The performance results show the complete removal of all the antibiotics by the RO membrane and by the tight nanofiltration membrane NF90. Only the loose nanofiltration membrane element HL incompletely removed the smaller sulfonamide antibiotics. All these findings confirm again the size exclusion as the decisive antibiotics removal mechanism, which was explained earlier by the membranes pore size distribution curves.

Figure 4. Pilot-plant RO/NF unit

Treatment of emerging contaminants in WW using advanced sorbent material

As a major achievement, the experimental unit specifically designed for treatment of real textile wastewater from “SIMPO-Dekor” (Vranje, Serbia) was constructed. The results obtained indicate that RWNM can be used as a good sorbent for lead, copper, zinc and cobalt cations. On the other hand, insufficient sorption of direct dyes occurred whether in the case of untreated RWNM or RWNM treated with biopolymer chitosan or hydrogen peroxide. It was shown that sorption of these dyes was significantly affected by initial dye concentration, pH and temperature. COD_{Mn} and TOC values of dye solutions decreased after the sorption.

The possibility of using the RWNM for purification of real effluents from textile industry was investigated in the experimental unit especially constructed for this project. In accordance with results obtained in laboratory conditions, hydrogen peroxide treated RWNM was selected as a sorbent for the study of real effluents. Twelve different effluents released from dyehouse of “SIMPO Decor” (Vranje, Serbia), containing different types of dyes were collected and analysed. The results demonstrated that decrease in COD_{Mn} of each investigated sample was obtained after 3 h of sorption. Sorption on RWNM also provided decolourisation of effluent that was more or less evident, depending on the dye type present in the effluent. The results showed that pH

adjustment of the effluent can provide sufficient degree of decolourisation, particularly when the metal complex dyes were present in the effluent.

The overall results indicated that RWNM can be efficiently used for removal of different pollutants from textile effluents. Its application in combination with other treatment to achieve maximum purification of effluent is recommended.

Fate of emerging contaminants in conventional wastewater treatment

- Fate of drugs of abuse during CAS treatment was studied in Spain and Germany. Cocaine and its metabolite (benzoylecgonine) were detected at concentrations up to 225 ng/l and 2307 ng/l, respectively in Spanish wastewater influents and up to 47 ng/l (cocaine) and 928 ng/l (benzoylecgonine) in wastewater effluents. For German samples, these values were 99 ng/l and 892 ng/l, respectively for influents and <LOD and 339 ng/l in effluents. Amphetamines such as MDMA (ecstasy) were also identified with maximum values of 91 ng/l and 14 ng/l in wastewater influents from Spain and Germany, respectively. The concentrations in wastewater effluents reached up to 67 ng/l in Spain and <LOQ in Germany.

  Biodegradation studies

  To investigate the microbial degradation of selected pharmaceutically active compounds, batch reactors were freshly loaded with 1L of sewage sludge taken from the aeration basin of wastewater treatment plant (WWTP) Rubí, Barcelona, Spain. Potential sorption of pharmaceuticals was monitored in batch reactors with formaldehyde added to sludge, which excludes any biotic degradation and assures that possible attenuation in the concentration of a compound is consequence of its adsorption to sludge particles. Selected compounds were gemfibrozil, hydrochlorothiazide, ranitidine and glibenclamide.

  During batch experiments, gemfibrozil was degraded up to 80% in the first 12 days, whereas the acclimation period of sludge was relatively short (6-7 days). In the experiments with added formaldehyde into batch reactors, no abiotic removal was recorded.

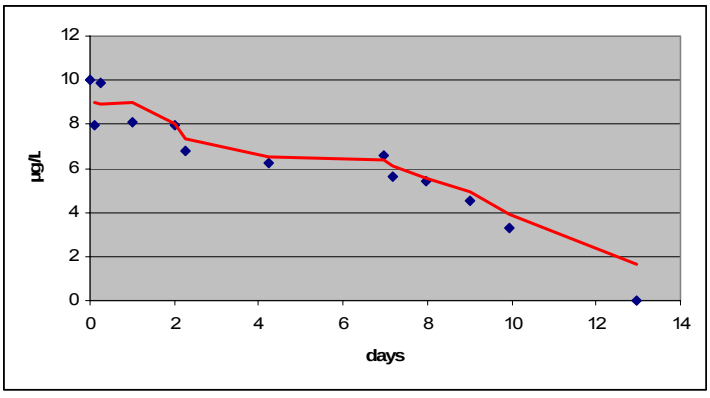

Fig 5. Aerobic biodegradation of gemfibrozil in a batch reactor spiked to 10 µg/L.

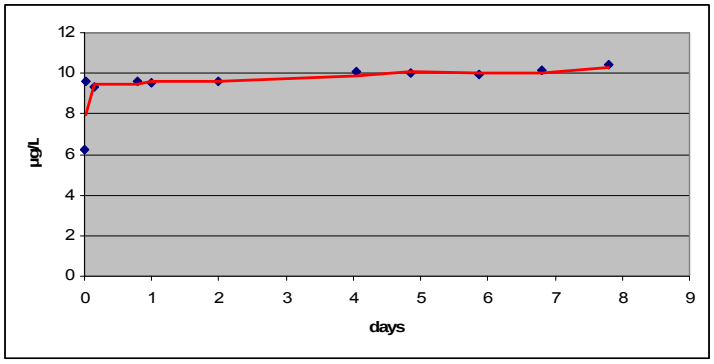

Fig 6. Abiotic elimination of gemfibrozil in a batch reactor with added formaldehyde and spiked to 10 µg/L.

Contrary, ranitidine was very rapidly eliminated within the first three days. However, attenuation of its initial concentration is probably a consequence of adsorption to sewage sludge particles in both batch reactors (with and without added formaldehyde). This could explain its better elimination in MBR than in CAS, since MBR sludge has higher sorption potential, because of the smaller floc size and higher content of organic matter.

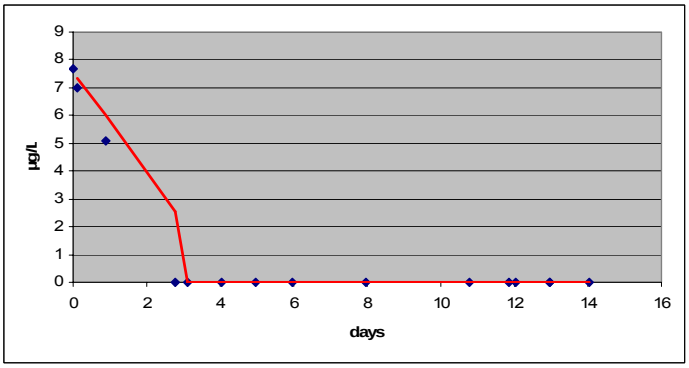

Fig 7. Aerobic biodegradation of ranitidine in a batch reactor spiked to 10 µg/L.

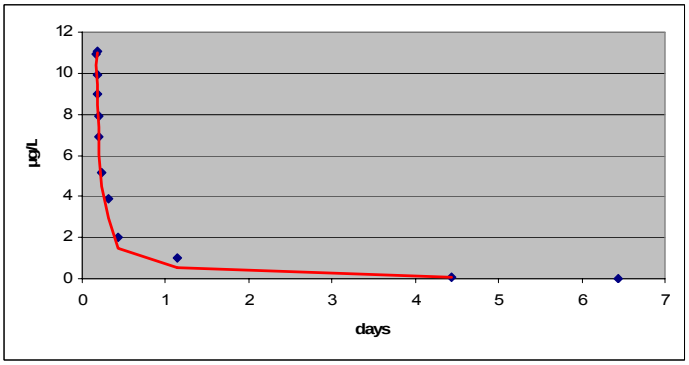

Fig 8. Abiotic elimination of ranitidine in a batch reactor with added formaldehyde and spiked to 10 µg/L.

Behavior and removal of selected compounds during drinking water treatment using RO/NF

Feed, permeate, concentrate and treated water samples from an RO/NF DWTP Besos (Barcelona) were monitored for musks and fragrance compounds; triazines and metabolites; chlorinated solvents and dioxanes and dioxolanes in order to study their occurrence and removal. All compounds are efficiently removed except Galaxolide lactone (metabolite of Galaxolide) which is poorly eliminated using NF but can be improved using RO. Other musk compounds such as Galaxolide, Tonalide and musk present intermediate percentages of elimination in NF and RO processes. An incomplete elimination of common chlorinated solvents such as trichloroethylene and perchloroethylene, in NF and RO processes is achieved. On the other hand, the effciency of both treatments for odorous pollutants at ultratrace level (ng/L) such as dioxanes and dioxolanes is proved with a complete elimination.

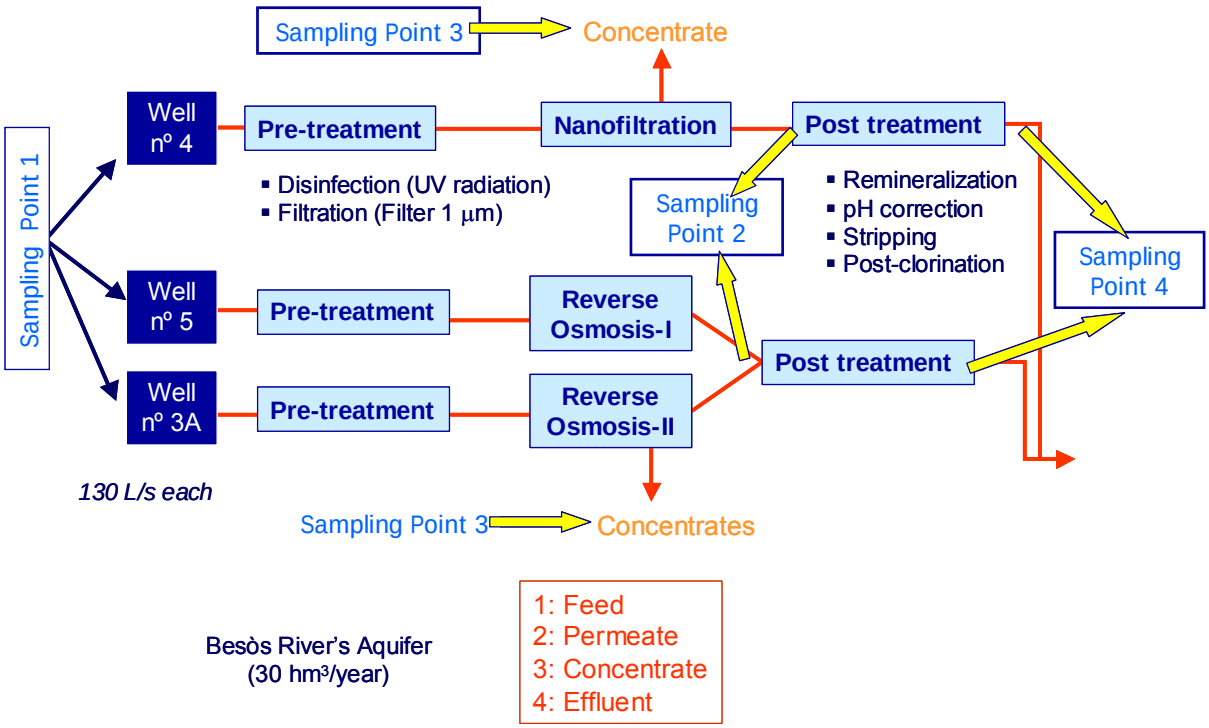

Fig. 9. Scheme of the Besós RO/NF drinking water treatment plant.

Prospective analysis of the most suitable treatments for selected study sites in WB countries

All treatment technologies applied at study site demonstrated to be suitable to improve the removal of selected emerging contaminants. MBR has shown to be a ready available technology that is nowadays increasing its market share. This technology achieved a full scale implementation in the pharmaceutical industry Bosnalijek, Sarajevo, Bosnia and Herzegovina, for the treatment of their process wastewater.

Although the advanced stage of development many researches needs to focused on understanding, optimization of the process and discovery of new application. Removal of emerging contaminants is not complete but generally improved if compared with conventional technology. The use of tertiary treatment after MBR to further reduce the emrging contaminants load is also facilitated by the better quality of the secondary effluent.

Application of reverse osmosis and nanofiltration processes achieved the best results in terms of emerging contaminants reduction in the effluent however identification of proper solution to handling the concentrate/rejected stream should be further investigated. Additional researches on membrane selection and process optimization are of high importance to further decrease the investment and operational cost of this technology.

Advanced sorbent material is a technology initially specifically tailored for the textile industry that shown to have potential also in other application (reduction of heavy metals and oils). The most suitable treatment for the selected study site appears as a combination of biological and physico-chemical treatments with the final treatment with low-cost sorbent manufactured from recycled wool-based nonwoven material.

Treatment technology	**Invest./ Operat. costs**	**Emerging contaminants removal efficiency**	**Notes**
Conventional Activated Sludge	- / -	+	
Membrane Bioreactor (MBR)	-/ --	++	
Micro – Ultra filtration	-/ --	+	
Nano filtration – Reverse Osmosis	--- / ---	+++	Require high feed water quality
Activated carbon adsorption	-- / ---	+++	Require high feed water quality
Advanced sorbent adsorption	- / -	++	Suitable for specific applications (i.e. textile industry)
AOPs	--- / ---	+++	Require high feed water quality

2. Dissemination and use

Main dissemination activities

1st EMCO workshop entitled: **Analysis and removal of contaminants from wastewaters for the implementation of the Water Framework Directive (WFD**) was organized in Dubrovnik, Croatia on 20 - 21 October 2005 in collaboration with the EU project SWIFT-WFD (*Screening methods for Water data InFormaTion in support of the implementation of the Water Framework Directive*), Faculty of Chemical Eningeering and Technology of the University of Zagreb (Croatia), Consejo Superior de Investigaciones Cientificas (CSIC, Barcelona) and Agilient Technologies. The workshop took place at the International Center of Croatian Universities.
In the course of the workshop, 28 lectures and 20 posters were presented, being the principal topics legislation and policy in the field of wastewater treatment, analysis of contaminants in wastewaters, wastewater treatment technologies, risk assessment with special emphasis on the use and validation of the yeast assays for estrogenicity and the special session devoted to report the results of the fist year of the EMCO project.

Executive summary is published in TrAC Trends in Analytical Chemistry, Volume 25, Issue 3, March 2006, Pages 191-193
Damià Barceló and Mira Petrovic, Reducing the environmental risk from emerging pollutants: Report on the 1st EMCO Workshop "Analysis and removal of contaminants from wastewaters for the implementation of the Water Framework Directive (WFD)", Dubrovnik, Croatia, 20–21 October 2005

2nd EMCO workshop entitled **Emerging contaminants in wastewaters: Monitoring tools and treatment technologies** was organized in Belgrade, Serbia on 26-27 April 2007 in collaboration with the Faculty of Technology and Metallurgy, Belgrade (Serbia) and Consejo Superior de Investigaciones Cientificas (CSIC), Barcelona (Spain).
It was attended by 71 participants, from Bosnia and Herzegovina, Croatia and Serbia and 10 European countries, being therefore a platform for communication and exchange of information among scientists from the Western Balkan region and the rest of the Europe. In the course of the workshop, 24 lectures and 24 posters were presented, with principal topics:

- analysis of emerging contaminants in wastewaters, including toxicity issues,
- occurrence of emerging contaminants in wastewaters
- wastewater treatment technologies.

Executive summary will be published in TrAC Trends in Analytical Chemistry, In Press, Corrected Proof, Available online 6 June 2007
Damià Barceló and Mira Petrovic,Under the analytical spotlight, contaminants emerge: Report on the 2nd EMCO Workshop "Emerging Contaminants in Wastewaters: Monitoring Tools and Treatment Technologies" held in Belgrade, Serbia, 26 and 27 April 2007

The full papers presented at the workshop will be published in a **special issues Trend in Analytical Chemistry** (Elsevier).

Scientific publications:

Book: 1 (in press)
Book chapters: 3 + 7 (submitted)

Papers (SCI) 28 + 11 (submitted)

Presentations at international and national symposiums
Oral: 47
Poster 42

Publishable results

Main project results

No.	Self-descriptive title of the result
1	***Analytical methods*** Various analytical methods have been developed for the determination of different classes of pharmaceuticals and adjusted to the complex matrix wastewater (WW). Methods permitting detection of pharmaceuticals at low levels in complex matrices are prerequisite for proper risk assessment. Application of these methods in monitoring of European waste, surface and drinking water resulted on a broad database of these class of pollutants. More detailed information can be obtained by reading the various papers published and cited under scientific results. M.José Gómez, M. Petrovic, A.R. Fernández-Alba, D. Barceló, Determination of pharmaceuticals of various therapeutic classes by SPE-LC-MS/MS in hospital effluent wastewaters, J. Chromatog. A 1114 (2) (2006) 224-233 M. Gros, M. Petrovic and D. Barceló, Development of a multi-residue method for the analysis of pharmaceuticals based on solid phase extraction and LC-tandem mass spectrometry in surface and wastewaters. Talanta 70 (2006) 678-690 Mira Petrovic, Merixell Gros, Damia Barcelo, Multi-Residue Analysis of Pharmaceuticals In Wastewater By Ultra Performance Liquid Chromatography – Quadrupole – Time of Flight Mass Spectrometry (UPLC-Q-TOF-MS), J. Chromatogr. A 1124 (2006) 68-81 S. Babić, D. Ašperger, D. Mutavdžić, A.J.M. Horvat and M. Kaštelan-Macan, Solid phase extraction and HPLC determination of veterinary pharmaceuticals in wastewater, Talanta 70(2006)732-738. Peschka, M., Eubeler, J.P., Knepper, T.P.; Occurrence and Fate of Barbiturates in the Aquatic Environment. Environ. Sci. Technol. 40(23) (2006) 7200 – 7206 Senka Terzić and Marijan Ahel, Organic contaminants in Croatian municipal wastewaters, Archives of Industrial Hygiene and Toxicology (Arhiv za higijenu rada i toksikologiju), 57 (2006) 297-306.

2	Book **Emerging Contaminants from Industrial and Municipal Wastewaters** (Editors: D. Barcelo and M. Petrovic). The Handbook of Environmental Chemistry" (series edited by Prof. Hutzinger) The consortium has prepared a book for Springer-Verlag series "The Handbook of Environmental Chemistry" (series edited by Prof. Hutzinger) titled **Emerging Contaminants from Industrial and Municipal Wastewaters** (Editors: D. Barcelo and M. Petrovic). The publication is planned for spring 2008. The book gives a comprehensive overview of the current state of the art of the analysis of emerging contaminants in wastewaters, sources and occurrence data, as well as an overview of different treatment options. **The Handbook of Environmental Chemistry** (series editor Prof. Hutzinger) **Emerging Contaminants from Industrial and Municipal Waste** Editors: D. Barcelo and M. Petrovic Chapter 01: Emerging Contaminants in Waste Waters. Occurrence, Sources and Levels. ***M. Ahel, S. Terzic (IRB), M. Petrovic, D. Barcelo (CSIC)*** Chapter 02. Chemical analysis of emerging contaminants in wastewaters, ***M. Gros, M. Petrovic, D. Barcelo (CSIC)*** Chapter 03: Removal of Emerging Contaminants in Wastewater Treatment. 3.1. Conventional Activated Sludge Treatment. ***T. Knepper, (EFF)*** 3.2. Removal by MBR, ***J. Radjenovic, M. Petrovic (CSIC), M. Matosic, I. Mijatovic (PBF)*** 3.3. Removal by NF and RO, ***B. Kunst, K. Kosutic (FKIT)*** 3.4. Removal by Ozonation and other oxidative processes (AOP) *(A. Fernandez-Alba, University of Almeria)* 3.5. Removal by Photocatalytic Processes. (*S. Malato, CIEMAT)* 3.6. Wetlands for the treatment of wastewaters V. Matamoros, J.M. Bayona CSIC) 3.7. Artificial recharge of wastewaters for the removal of emerging contaminants, **S. Diaz-Cruz, D. Barcelo (CSIC)** 3.8. Advanced sorbent materials for the treatment of wastewaters, ***P. Jovancic, M. Radetic (TMF)*** Chapter 04: Acute and Chronic Effects of emerging contaminants in wastewaters, **T. Smital, (IRB), S. Canna Michaelidou (SGLEnv)** Chapter 05. Treacability of emerging contaminants form wastewater to drinking water, ***F. Ventura (AGBAR)*** Chapter 06: Impact of Emerging Contaminants in the Environment. Environmental Risk Assessment. *(J. Blasco, CSIC)* Chapter 07: Current and future legislation in Europe and USA, ***D. Barcelo (CSIC)*** *** in bold letters – participants of EMCO**

3	Membrane bioreactor (MBR) - data regarding elimination of pharmaceuticals and other emerging contaminants A Membrane Bio Reactor pilot plant has been constructed using three A4 unit of Kubota submerged membranes (Type 203) with a total surface of 0.33m2. Biological basin equipped with an automatic level control has an adjustable volume settable between 20Land 30L. This low cost Membrane bioreactor has been successfully tested in the laboratory and at field. Data regarding elimination of multi-class pharmaceuticals are obtained and based on the results obtained the management of the EMCO industrial partner (pharmaceutical industry Bosnalijek, Sarajevo, Bosnia and Herzegovina) decided the construction of a full scale plant (30 m3/d with future possible expansion to 60m3/d). Main findings are published in: J. Radjenovic, M Petrovic and D Barceló, Analysis and removal of pharmaceuticals in wastewater using a membrane bioreactor, Anal. Bioanal. Chem. (387 (2007) 1365-1377