EU-India STI Cooperation Days
8-9 November 2012, Hyderabad
www.euindiacoop.org/2012

UNIVERSITY of OULU
OULUN YLIOPISTO

UC UNIVERSIDAD DE CANTABRIA

The Application of Green Technologies for Sustainable Water Purification and Reuse *(GreenTech)*

New Indigo ERA-NET NPP2

Prof. I.Ortiz (PI)
University of Cantabria. Project Coordinator Group

Dr. V.K. Rathod
Institute of Chemical Technology. Indian Project Coordinator Group

This event is co-financed by the European Commission through the involvement of several projects.

A joint event organizated by:

Hosted by National Geophysical Research Institute (NGIR - CSIR).

RELEVANCE

Motivation

India suffers from a regional disproportion between natural sources and water demands

Cleaning of water from different sources and water re-use is of major importance to promote India as a self-sustained country and to alleviate poverty

Major contaminants in Indian ground-waters are arsenic and fluoride and a host of organic matter depending on location and source

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RELEVANCE

Global objectives

1. To analyse existing alternatives for cleaning water polluted with arsenic and fluoride reporting their sustainability as well as forefront technologies that need further research.

2. To develop novel hybrid processes to treat mining/industrial wastewaters with removal of pollutants and simultaneous recovery of valuable compounds. For this target, membrane units and other efficient technologies such as, photocatalysis and/or adsorption are selected.

3. To Evaluate alternative processes for wastewater reclamation and reuse making use of sustainability criteria.

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Project Partners

1

University of Cantabria (Santander, Spain)

European Project Coordinator

PI: Prof. Inmaculada Ortiz

SOSPROCAN unit

Dept. Chemical Engineering

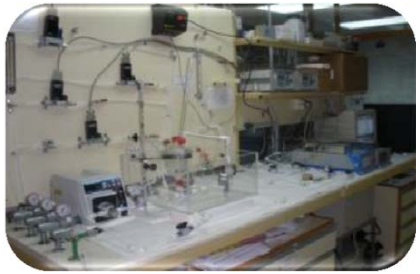
Unit for the Sustainability of the Production and Consumption at a regional level:

http://grupos.unican.es/pasep/

http://www.unican.es/Departamentos/ingquimica/Investigacion/20100208.htm

Research conducted:

1) Environment and natural resources protection. Membrane Technologies and integration with advanced oxidation processes
2) Food and Agriculture
3) Process Industries: Process optimisation, intensification and integration
4) Metrics for sustainability assessment



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Project Partners

2

University of Oulu (Oulu, Finland)

European Project Partner

PI: Prof. Riita Keiski

Mass and Heat Transfer Process Laboratory.

Dept. Process and Environmental Engineering http://www.oulu.fi/pyolam/

Research conducted:

1) Physical-chemical and biochemical phenomena in multiphase and multicomponent systems: a) Process development and design b) Sustainable products and processes

2) Treatment and utilization of industrial by-products and wastes. Sustainable products and processes

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Project Partners

3

Institute of Chemical Technology (Mumbai, India)

Indian Project Coordinator

PI: Prof. Ganapati D. Yadav

Chemical Engineering Dept.

http://www.ictmumbai.edu.in/DisplayPage.aspx?pageID=8&linkid=224

Research conducted:

1) Biotechnology & biomedicine
2) Nanotechnology and materials science
3) Energy science and engineering
4) Process systems engineering
5) Green chemistry and engineering
6) Environmental protection and Hazardous waste management
7) Product Engineering

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GreenTech Project

INDIGO-DST1-017

Scientific excellence groups and added value from the cooperation

University of Cantabria (UC)

Institute of Chemical Technology (ICT)

University of Oulu (UO)

OUTLINE

RELEVANCE

- Motivation
- Global objectives
- Project partners

ACTIVITIES

- WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (organic and emerging pollutants)
- WP2 (UO): Metals and nutrients in industrial waste waters
- WP3 (ICT): Pharmaceutical industry related waste waters
- WP4: Dissemination and training

OUTCOMES

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ACTIVITIES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

TASK		ACTIVITIES		DELIVERABLES	
T1	Characterization of natural waters and municipal waste waters (ICT)	A1	Comparison of regulations in EU and India (UC, UO, ICT): August 2012	D1	Report based on literature survey
		A2	Natural and treated water database (UC, UO, ICT): August 2013	D2	Model for the sustainability assessment
				D3	Reports (guidelines for innovative processes) and publications
T2	Sustainability of reference processes (UC, UO, ICT)	A3	Listing the references processes (UC, UO, ICT): August 2012	D4	Proposal for new research project
		A4	Evaluation of the sustainability of the reference processes (UC, UO, ICT): 1st meeting, 2013		
T3	Sustainability of novel processes (UO, UC, ICT)	A5	Listing the novel processes (UC, UO, ICT): 1st meeting 2013		
		A6	Evaluation of the sustainability of the novel processes (UC, UO, ICT): 2nd meeting, 2013		
T4	Innovative technologies (UC, UO, ICT)				

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OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

Arsenic

Groundwater **arsenic contamination (Arsenicosis)** were discovered as early as **1976**

70.4 million people affected by As polluted groundwater

Sources	Previously used in pesticides (orchards) Improper waste disposal of product storage of glass or electronics, mining Rocks
Diagnostics	Weight loss, depression, lack of energy Nervous system toxicity Skin problems, kidney and lung cancer Reproductive disorder

Arsenicosis

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OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

A1. Comparison of regulations in EU and India (UC, UO, ICT)

Groundwater for drinking water

- World Health Organization (WHO)
- The Drinking Water Directive (DWD) 98/83)
- Decree 461/2000
- RD 140/2003. Calidad Aguas Consumo
- IS 10500 2004

Comparison of admissible limits for drinking water

	World Health Organization (WHO)	Europe Directive DWD 98/83	India IS 10500,2004	
			Desirable	Permissible
Arsenic (µg/l)	10	10	10	No relaxation
Fluorides (µg/l)	1500	1500	1000	1500

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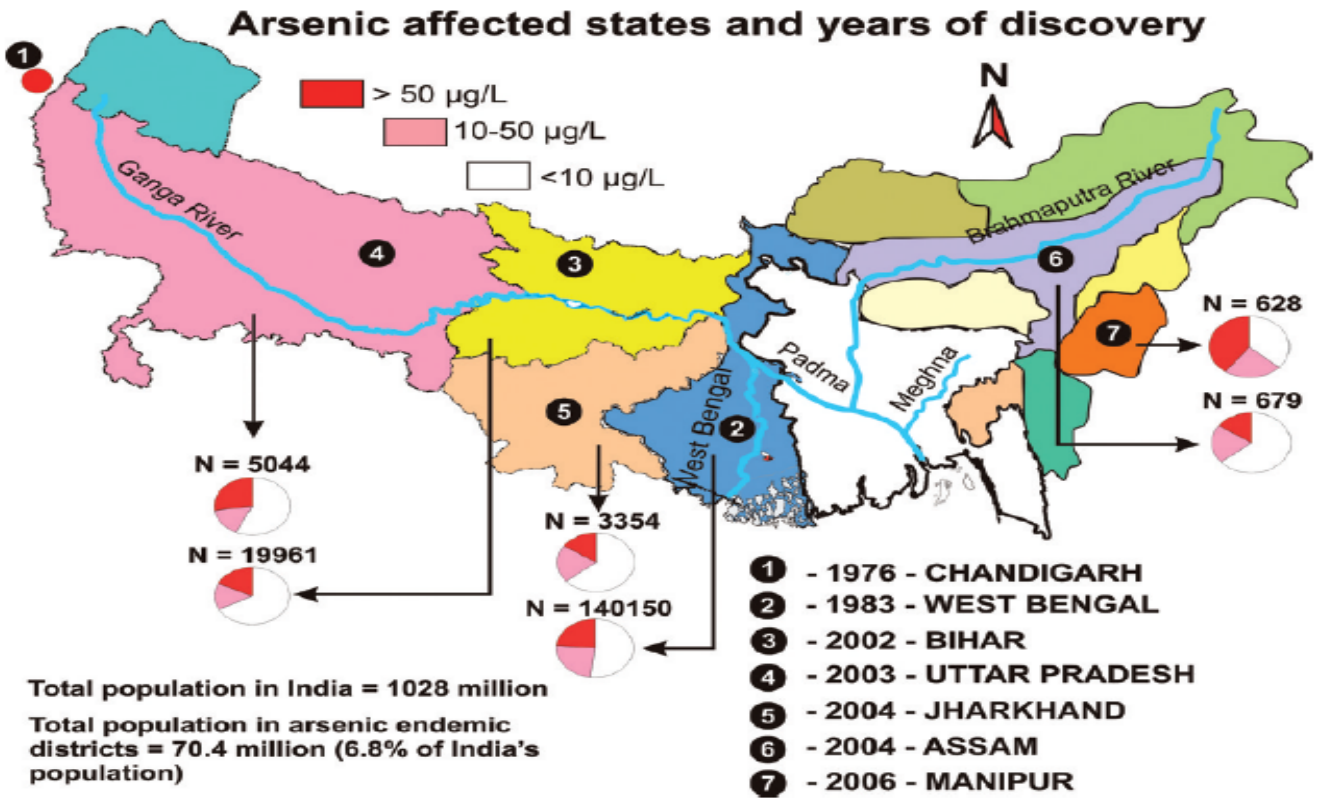
OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)



Chakraborty, 2011

OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

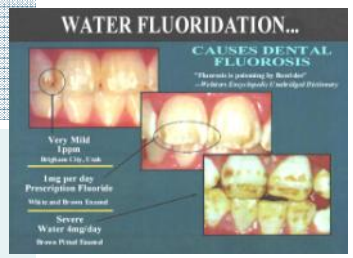
Fluorides

Chemical contaminants in India's groundwater had been identified as early as **1937 (fluorosis)**

20 of 28 Indian states have some degree of groundwater fluoride contamination (above GOI permissible level of 1500 µg/l), impacting **85-97% of districts in some states**

Sources	Industrial waste Geological
Effects	Brownish discoloration of teeth Bone damage

Flouridation



Chakraborty, 2011

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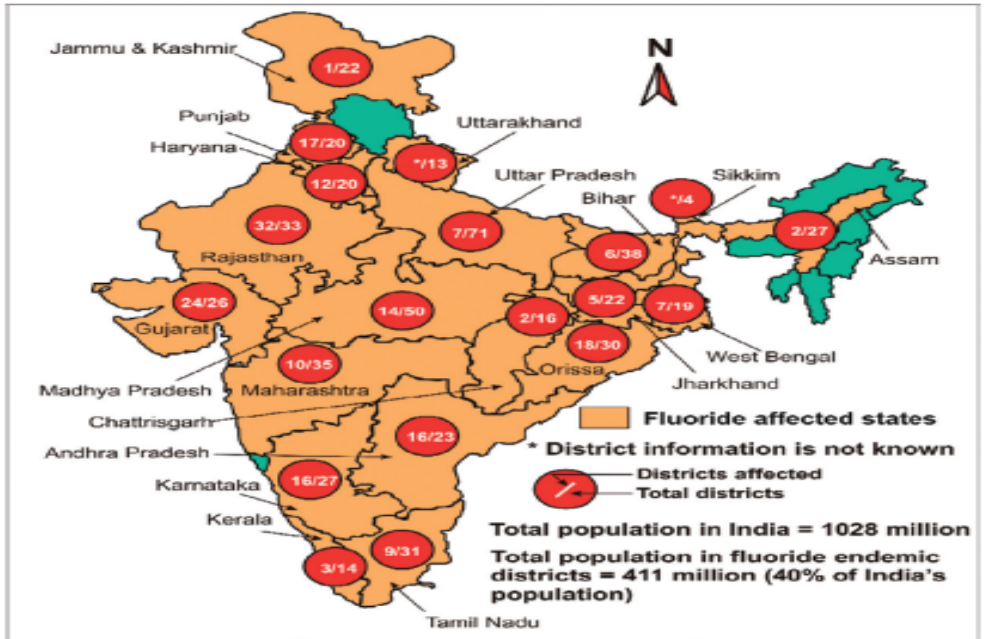
OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)



Fluoride-affected states and years of discovery

Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Punjab	1937 - 1950
Rajasthan, Gujarat, Haryana, Bihar, Jharkhand, Madhya Pradesh, Chattrishgarh, Orissa, Maharashtra, Karnataka	1950 - 1986
Kerala, Jammu & Kashmir	1986 - 1992
West Bengal	1997
Assam	1999
Uttarakhand, Sikkim	1999 to present

Chakraborty, 2011

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OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

A2. Listing the reference processes (UC, UO, ICT)

I) PRECIPITATION: a) As(V) by addition of **calcium**, **magnesium**, **manganese (II)** or **iron (III)** **and b) precipitation of As(III)** as **As(III) sulfide**

II) COAGULATION AND FILTRATION: coagulants $FeCl_3$, $FeSO_4$, $Al_2(SO_4)_3$ and lime; Filtration: 0.1 -1 μm filters.

III) ADSORPTION: Granular **activated alumina**, granular **iron hydroxide**, granular **iron oxide**, commercial **titanium dioxide**, **cerium oxide** and **manganese oxide**.

IV) MEMBRANE PROCESSES: Nanofiltration, **reverse osmosis** and **electrodyalisis**.

V) ION EXCHANGE: Synthetic ionic exchange resins, generally of **polymeric matrix** (polystyrene cross-linked with divinylbenzene), linked to charged functional groups.

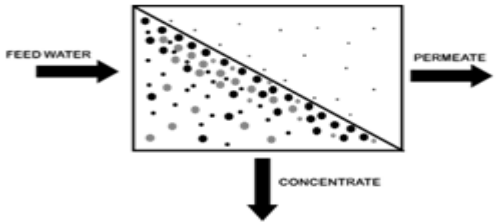
Litter et al. 2010

OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

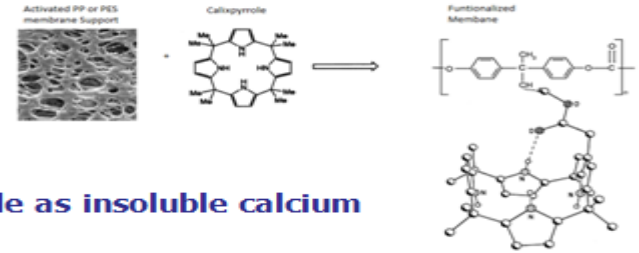
SEPARATION BY MEMBRANE TECHNOLOGIES

Basic reverse osmosis



Industrial system

Limitation: Disposal of the concentrated retentate
Low flux and high energy consumption.



Alternative: ***Functionalized Membranes***
Tunable flux and Selectivity in removal F^- and As (III)/As (V)

- **Addition of lime leads to precipitation of fluoride as insoluble calcium fluoride:**

$$Ca(OH)_2 + 2F^- \rightarrow CaF_2 + 2OH^-$$

- **Coagulant addition assists settling faster**

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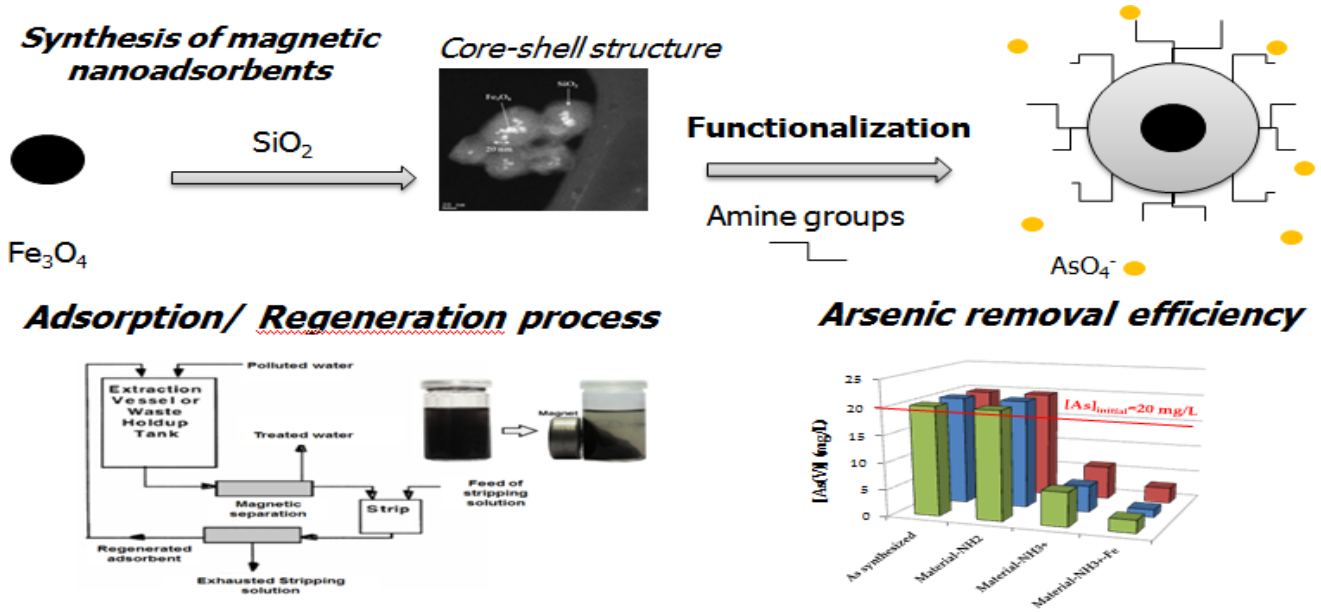
OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

A2. Listing the novel processes (UC, UO, ICT)

USE OF NANOTECHNOLOGIES FOR As REMOVAL



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OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

A4. Evaluation of the sustainability of the reference processes (UC, UO, ICT)

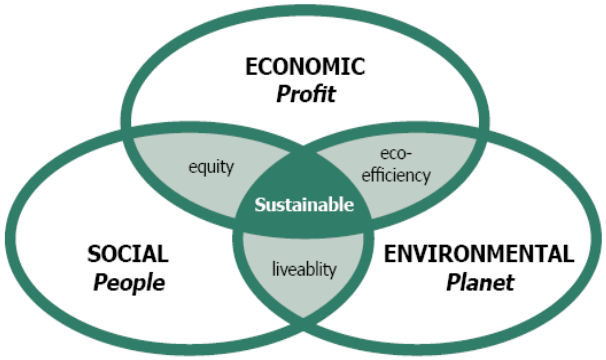
Products

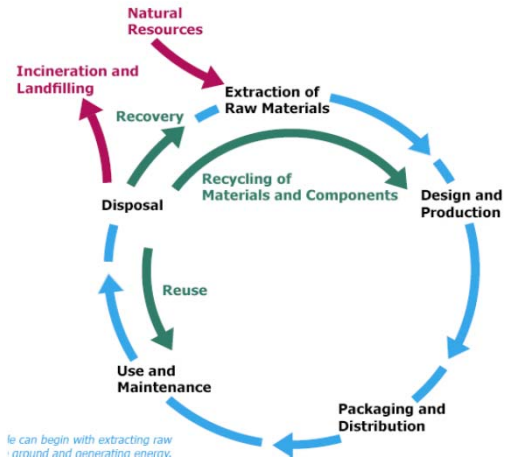
Clean and Sustainable Products
(Competitive advantage/Revenues)

Processes

Cleaner Production Processes
(Resources savings / Margins)

Environmental Management
(Continuous Improvements/Reputation)





Irabien A., 2010

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OUTCOMES

WP1 (UC): Natural waters (As and F) and reclaimed municipal waste water (org and emerging pollutants)

A2. Guidelines for the reuse of treated waters

Requirements for reuse of treated waters and creation of a database

SPANISH DATA BASE

TRAGUA DATA BASE:

http://www.consolider-tragua.com/guias.htm

PUBLICACIONES:

- **Base de datos de EDARs en España (Versión para Windows)**
  Access to a Data Base where is compiled the information about WWTP in Spain.

- **Servidor WEB de base de datos de EDARs en España:**
  A map of Spain with red points indicating the location of the WWTP. Clicking on them appear a table with info about the WWTP (the same info that in the Windows version).

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OUTCOMES

WP2 (UO): Metals and nutrients in industrial waste waters

A1. Evaluation of waste waters in mining and metallurgical industry in Finland (UO)

A2. List of technologies (UO)

Wastewater composition of mining industry

Metals

Cr, Cu, Pb, Mo, Ni, Zn, V, U, Fe, Al

Metalloids

As, Sb

Anions

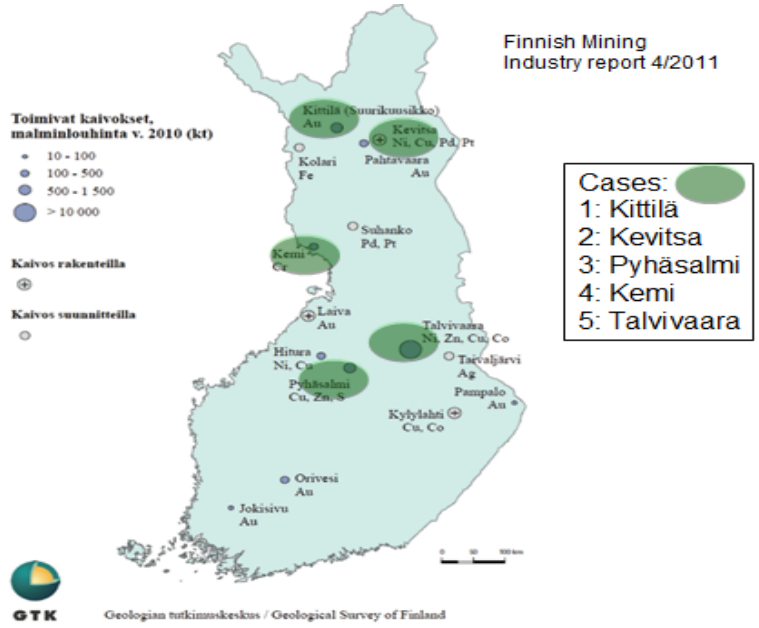
Sulphate, chloride, cyanydes

Nutrients

Nitrates

Organic compounds

Mineral oils



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OUTCOMES

WP2 (UO): Metals and nutrients in industrial waste waters pollutants

Wastewater composition, discharge limits and problematic points in the studied cases

	Case1	Case2	Case3	Case4	Case5
	Agnico-Eagle Finland Oy (Kittilä)	FQM Kevitsa Mining Oy (Sodankylä)	Pyhäsalmi Mine Oy (Pyhäjärvi)	Outokumpu Chrome Oy (Keminmaa)	Talvivaara Sotkamo Oy (Sotkamo)
	Limits (EP)	Limits (EP)	Limits (EP)	Limits (EP))	Limits (EP)
Aluminium (Al)	x				
Cadmium (Cd)			x		
Chromium (Cr)				x	
Copper (Cu)		0,3 mg/l	0,2 mg/l		0,5 mg/l
Iron (Fe)	x		x	x	
Gold (Au)					
Lead (Pb)			x		
Mercury (Hg)					0,5 mg/l
Manganese (Mn)	x		x		X
Nickel (Ni)	0,5 mg/l	0,5 mg/l			X
Platinum (Pt)					
Silver (Ag)					
Uranium (U)					
Zinc (Zn)			1,0 mg/l		1,5 mg/l
Arsenic (As)	1,0 mg/l				
Antimony (Sb)	0,5 mg/l				
Sulphate (SO_4)	x	x	x		X
Cyanide (total CN)	0,4 mg/l				
Calcium (Ca)			x	x	
Solid	20 mg/l	10 mg/l	10 mg/l	10 mg/l	10 mg/l
Nitrogen (N)	x	x	x	x	
Phosphorus (P)				x	
pH	**6-10**	**6-9,5**	**5,5-9,5**		**6-9,5**

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WP2 (UO): Metals and nutrients in industrial waste waters pollutants

Drainage treatment technologies used in the studied cases

	Case1	Case2	Case3	Case4	Case5
Drainage Treatment Technology Categories	**Agnico-Eagle Finland Oy (Kittilä)**	**FQM Kevitsa Mining Oy (Sodankylä)**	**Pyhäsalmi Mine Oy (Pyhäjärvi)**	**Outokumpu Chrome Oy (Keminmaa)**	**Talvivaara Sotkamo Oy (Sotkamo)**
Neutralization					
Lime/Limestone Process	X (CaO)	X ($Ca(OH)_2$)	X (CaO)		X
Metal removal					
Precipitation/Hydroxide	X	X	X		X
Other Technologies	X				
Specific target pollutant treatment					
Cyanide removal -chemical oxidation -biological oxidation -complexation	x (chemical oxidation)				
Arsenic removal -oxidation/reduction -precipitation -adsorption	x (precipitation)				
Removal of suspended solids					
Clarification by adding flocculants	X	X		X	X
Wetland	X	X			

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OUTCOMES

WP2 (UO): Metals and nutrients in industrial waste waters pollutants

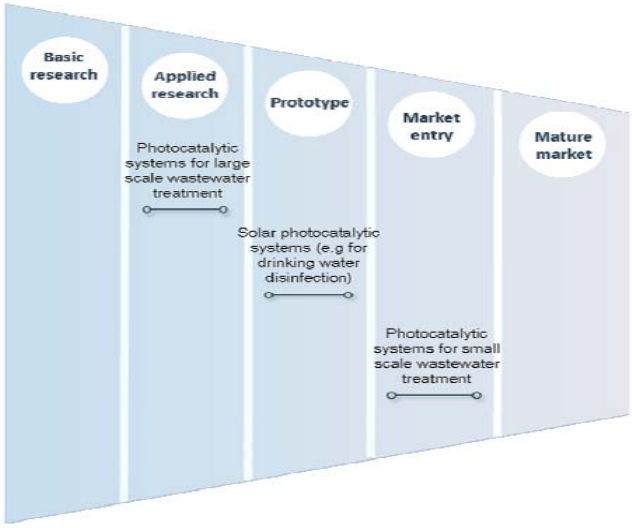
Use of membrane technology, photocatalysis and adsorption in Finnish mining industry

Adsorption

Activated carbon is mostly used as the adsorbent material
Used in the Kittila mine
Other adsorption materials such as zeolites are also under research

Photocatalysis

It is studied in research projects but it is not yet used in the mining industry



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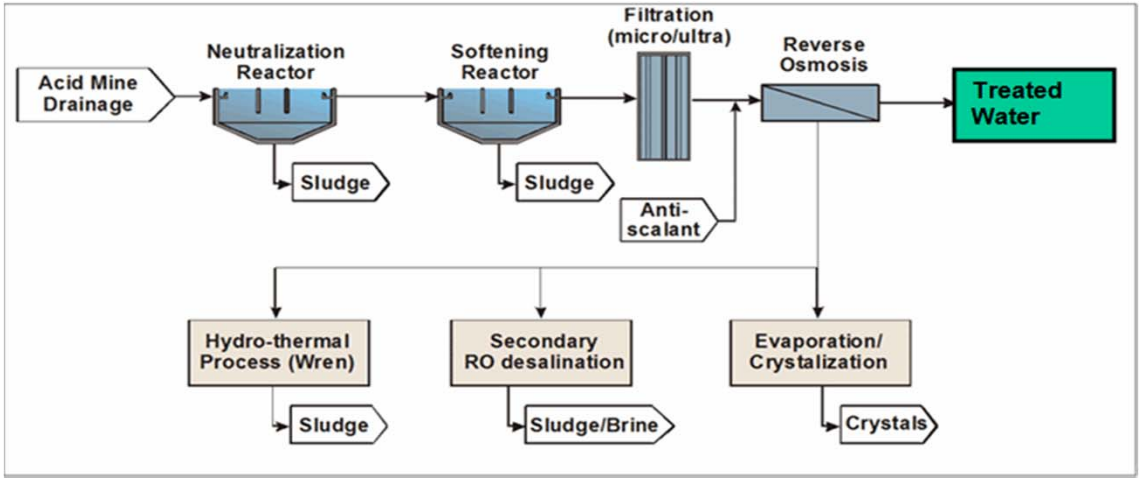
OUTCOMES

WP2 (UO): Metals and nutrients in industrial waste waters pollutants

Membrane technology

Reverse osmosis/nanofiltration for the removal of sulphates
Finnish mining company Talvivaara will start in November 2012 using membrane technology

A possible wastewater treatment process for the removal of sulphates using membrane technology



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OUTCOMES

WP3 (ICT): Pharmaceutical industry related waste waters

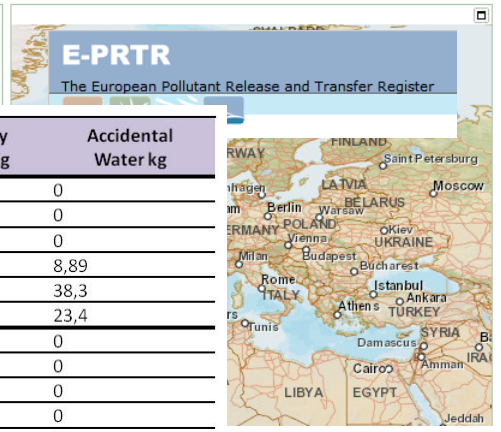
T1. Evaluation of waste waters from pharmaceutical industry

Development of an inventory of emissions to water / main pollutants of wastewater from the pharmaceutical industry in Europe

Facility level

rted releases and transfers of a specific facility. You can also search for a facility by using the map search

Year 2010



		Nºfacilities	Quantity Water Kg	Accidental Water kg
CHLORINATED ORGANIC SUBSTANCES	Halogenated organic compounds (as AOX)	3	8610	0
	Dichloromethane (DCM)	12	3135,5	0
	Trichloromethane	3	903,3	0
	1,2-dichloroethane (DCE)	4	378,6	8,89
	Tetrachloroethylene (PER)	1	51,5	38,3
	PCDD + PCDF (dioxins + furans) (as Teq)	1	0,01	23,4
HEAVY METALS	Zinc and compounds (as Zn)	7	3428	0
	Nickel and compounds (as Ni)	7	879,9	0
	Chromium and compounds (as Cr)	1	157	0
	Copper and compounds (as Cu)	2	124	0
	Lead and compounds (as Pb)	2	117,5	0
	Arsenic and compounds (as As)	4	79	0
	Cadmium and compounds (as Cd)	1	5,8	0
	Mercury and compounds (as Hg)	3	5,77	0
INORGANIC SUBSTANCES	Chlorides (as total Cl)	7	29097650	0
	Total phosphorus	9	9409440	0
	Total nitrogen	7	1680800	0
	Fluorides (as total F)	4	46130	0
	Cyanides (as total CN)	2	73,99	0
OTHER ORGANIC SUBSTANCES	Total organic carbon (TOC) (as total C or COD/3)	18	2583700	0
	Phenols (as total C)	8	1541,8	0

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OUTCOMES

WP4: Dissemination and training

T1. Research visits; T2. Meetings; T3. Conducting lectures and training

Visiting the laboratories

Prof.Yadav's presentation on Advanced separation processes course.

Lectures and meetings

Meeting in UO, Oulu
3-5 April, 2012

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OUTCOMES

WP4: Dissemination and training

T1. Research visits; T2. Meetings; T3. Conductings lectures and training

Meetings

Visiting the laboratories

Meeting in ICT, Mumbai
20-25 August, 2012

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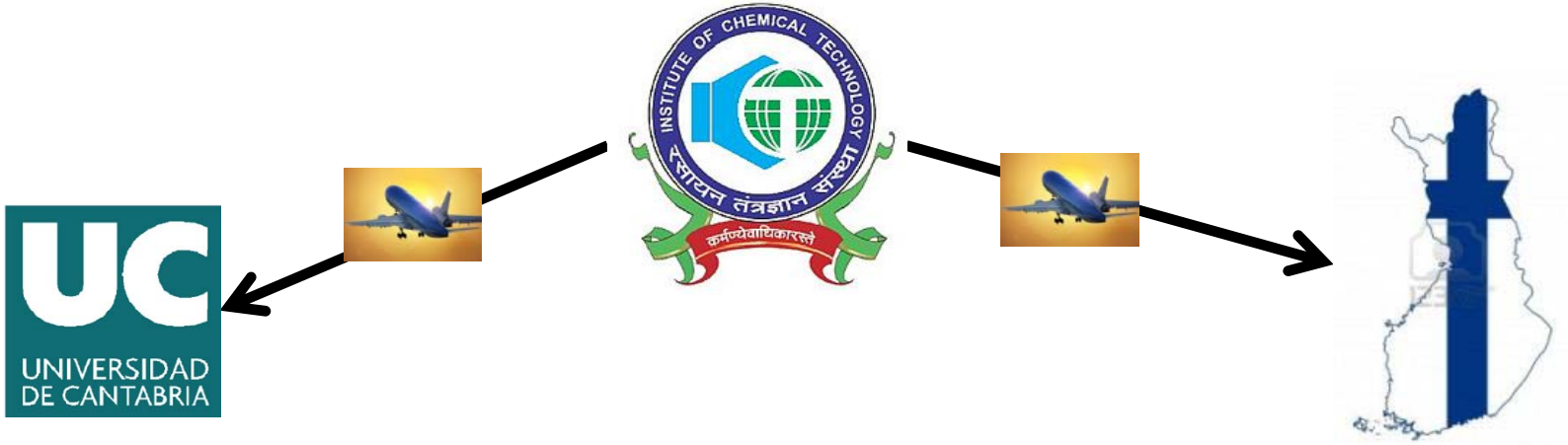
OUTCOMES

WP4: Dissemination and training

T1. Research visits; T2. Meetings; T3. Conductings lectures and training

Visit of three research scholars from ICT Mumbai to University of Cantabria and University of Oulu for two months



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EU-India STI Cooperation Days

THANK YOU VERY MUCH

Science brings Europe and India closer

NEW INDIGO

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