NanoRem

NEWSLETTER

Nº1 Autumn 2013

Nanotechnology for Contaminated Land Remediation

Taking Nanotechnological Remediation Processes from Lab Scale to End User Applications for the Restoration of a Clean Environment

NanoRem (Taking **Nano**technological **Rem**ediation Processes from Lab Scale to End User Applications for the Restoration of a Clean Environment) is now under way. This research project, funded through the European Commission FP7, will focus on facilitating practical, safe, economic and exploitable nanotechnology for in situ remediation. This will be undertaken in parallel with developing a comprehensive understanding of the environmental risk-benefit for the use of nanoparticles (NPs), market demand, overall sustainability, and stakeholder perceptions.

The project is designed to unlock the potential of nanoremediation processes from laboratory scale to end user applications and so support both the appropriate use of nanotechnology in restoring land and water resources and the development of the knowledge-based economy at a world leading level for the benefit of a wide range of users in the EU environmental sector.

The NanoRem consortium is multidisciplinary, cross-sectoral and transnational. It includes 28 partners from 12 countries. The consortium includes 18 of the leading nanoremediation research groups in the EU, 10 industry and service providers (8 SMEs) and one organisation with policy and regulatory interest.

Objectives

The NanoRem's ambitious objectives are:

(1) Identify the most appropriate nanoremediation technological approaches to achieve a step change in remediation practice;

(2) Develop lower cost production techniques and production at commercial scales of nanoparticles;

(3) Determine the mobility and migration potential of nanoparticles in the subsurface, and relating these both to their potential usefulness and also their potential to cause harm;

(4) Develop a comprehensive set of tools to monitor practical nanoremediation performance and determine the fate of nanoparticles;

(5) Engage in dialogue with key stakeholder and interest groups to ensure that the work meets their needs, is most sustainable and appropriate whilst balancing benefits against risks

(6) Carry out a series of full scale applications in several European countries to provide realistic cost, performance, fate, and transport findings.

www.nanorem.eu

SEVENTH FRAMEWORK PROGRAMME

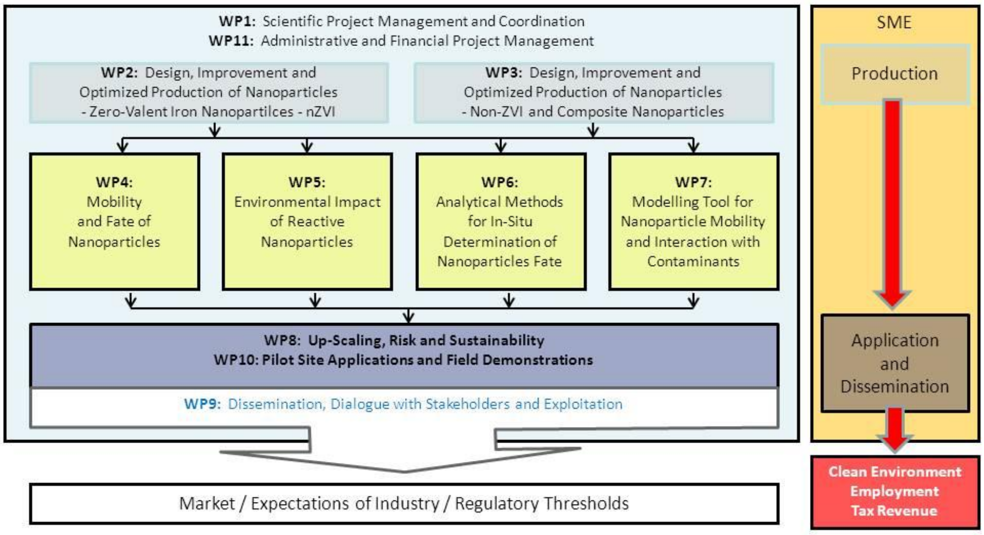

Figure 1: NanoRem's scientific and technical approach

WP1&11 Project Management and Coordination

NanoRem will be managed and coordinated by the coordinator. To facilitate maximum management efficiency, the tasks will be split based on their specific area of activity and responsibility: Work Package 1 (in future WP) WP1 (Scientific Management and Coordination) will be supported by WP11 (Administrative Project Management) in all matters concerning financial, legal and administrative issues. These two managers form, together with a Scientific Advisor and an Innovation and Information Manager the NanoRem Coordination Team. Jointly the two sub-WPs will:

- Guarantee communication within NanoRem. Financial controlling will be agreed upon and project workshops and conferences will be set-up and conducted.
- Ensure communication with external stakeholders in close collaboration with WP 9 (Dissemination, Dialogue with Stakeholder and Exploitation) to maintain close links to the scientific and regulatory advances, changes and expectations of the stakeholder community.
- Chair and support the Project Management Group and the Project Advisory Group recruited from within NanoRem and from outside experts. These groups will assist in making decisions regarding the goal oriented progress of NanoRem.
- Assure Quality Control and Timely Reporting via monitoring and enforcing NanoRem milestones and deliverables.
- Report to the European Commission.
- The project advisory group (PAG) consists of external experts. They have long-time experience in the field of nanoremediation. The aims of the PAG are:
- Provision of the viewpoint of end-users to provide assistance regarding the review and adjustment of project objectives and products.
- Make recommendations on the scientific and technological orientations of the project if needed in the course of the project when initial work has been performed and first results are available.
- Ongoing monitoring of progress / performance (through participation in annual meetings) to challenge the team on key issues, encourage additional collaboration between WPs and review the success and key results.
- Contribution to quality insurance & control of the research done.
- Contribution to transfer of information and product(s) to end-user communities (beyond project partners).
- Network with additional contacts beyond expertise of project partners, if needed.

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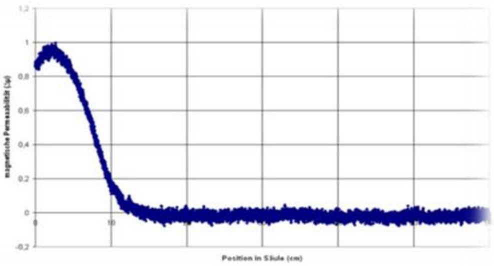
WP2 Design, Improvement and Optimized Production of Nanoparticles - Zero - Valent Iron Nanoparticles - nZVI

Nano zero-valent iron (nZVI) has the potential to become an important method for the treatment of water polluted by a large spectrum of contaminants. nZVI particles show an extremely high reactivity, being reflected in the effective transformation of more than 70 environmental contaminants like polychlorinated hydrocarbons, highly toxic substances such as As(III), As(V), Cu(II), Co(II), Cr(VI), nitrite, amoxicillin and ampicillin, TNT, chemical warfare agents and cyanobacteria. Aside from high remedial potential, there are three key obstacles to market entry: cost uncertainties, nanoparticle performance (is to be fully optimised), and validated large scale performance data for these optimisations are still pending. The currently used nanoparticles are not particularly stable and oxidise fairly rapidly, which affects particle storability, safety transport and reactivity. nZVI particles tend to agglomerate and adhere to solid surfaces resulting in a limited migration in groundwater.

- Production of new types of nZVI particles with a complex inorganic-organic surface stabilisation.
- Production and improvement of nZVI based on grinding/milling.
- Modification with environmentally friendly stabilisers.
- Expansion of the range of potential applications.

Objectives WP2



In order to prevent the nZVI particles from agglomeration and sorption to aquifer materials, and so improve migration distance, many surface modification methods have been tested. The basic intended step is to develop and establish a large-scale production of air-stable nZVI powder stabilised by a complex inorganic organic shell.

WP3 Design, Improvement and Optimized Production of Nanoparticles

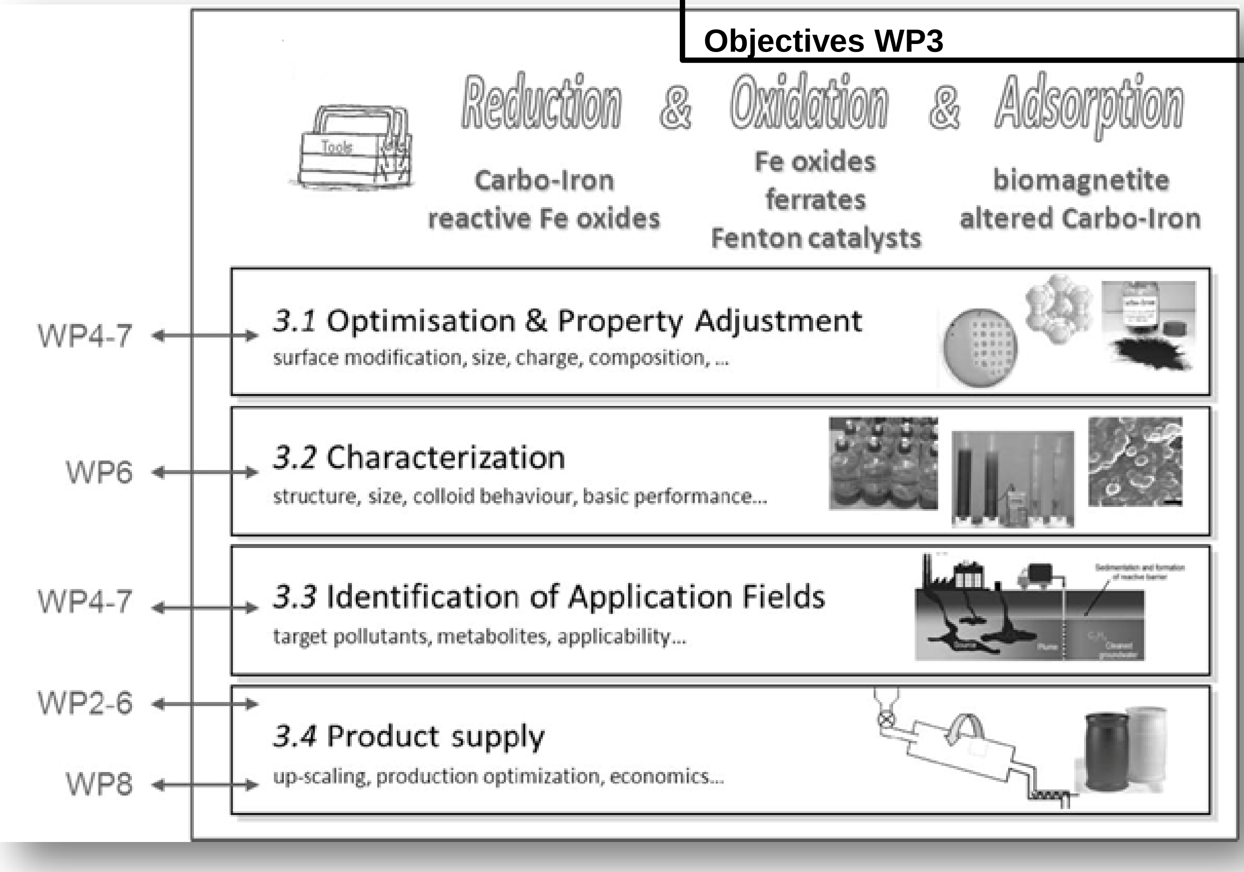
Until now, the focus of remediation activities connected to nanoparticles were redox reactions, where the particles reduce the contaminants, rendering them less harmful. WP3 extends the range of treatment approaches from reduction to include oxidation and sorption strategies, thus increasing the range of treatable contaminants in NanoRem. A new, iron-based colloidal composite "Carbo-Iron" combines surface properties of carbon (high mobility, low agglomeration and controllable deposition) with the reactivity of nZVI. Carbo-Iron is an air-stable, sorption-active reducing material where nano-iron clusters are placed within the pore structure of colloidal activated carbon particles. It shows great promise for both plume and source treatment.

Its utilisation may be extended to support microbial degradation of contaminants when present as aged iron-oxide/hydroxide-bearing activated carbon adsorber. In order to accelerate technology development for Carbo-Iron, optimisation of an up-scaled production process is included in this work package. Alternative metal nanoparticles (e.g. Al, Mg and their alloys) may expand the treatable contaminant spectrum.

Since these materials have not yet been considered for in-situ remediation, the research will focus on their stability, reactivity and selectivity towards various contaminant classes, especially as the lower density of Al and Mg compared to Fe may provide a means for improving mobility. Iron (II,III) oxide NPs also have versatile redox properties and potential applications in dehalogenation and reductive/sorptive processes for removal of metals/metalloids from water. NanoRem will investigate several iron-based particles, such as ferrates, which act as oxidants, catalyse oxidation reactions and support microbial oxidation.

- Optimisation and property adjustment of particles:
    - Carbo-Iron composite particles (for abiotic reduction, sorption enhanced),
    - Colloidal Fe-zeolites (as oxidation catalysts, sorption enhanced),
    - Iron(II,III) oxide particles (bioengineered and commercial for enhancement of microbial degradation),
    - Iron(VI) oxide particles (ferrates) (as oxidising agents),
    - non-ZVI metals and alloys (aluminium and magnesium, for abiotic reduction).
- Chemical and physical characterisation of particles
- Identification of particle application areas
- Particle supply and up-scaling of particle production for field application

Objectives WP3



WP4 Mobility and Fate of Nanoparticles

The effectiveness of in-situ groundwater remediation by nanoparticles depends to a great extent on their mobility in the subsurface. Nanoparticle mobility is limited to decimetres or at most a few metres,owing to their aggregation (due to particle-particle interactions) and their deposition onto the surface of the aquifer matrix (due to particle-collector interactions). Nanoparticle aggregation and deposition are influenced by both in-situ hydrochemical and hydrogeological factors as well as the physicochemical properties of particles. Nanoparticle- aquifer interactions are also influenced by the surface charge heterogeneities of the aquifer matrix. The influence of aquifer surface-charge heterogeneities are not addressed in almost all studies of mobility of nanoparticles used for remediation and this ought to be better understood and quantified in order to promote the use of nanoparticles.

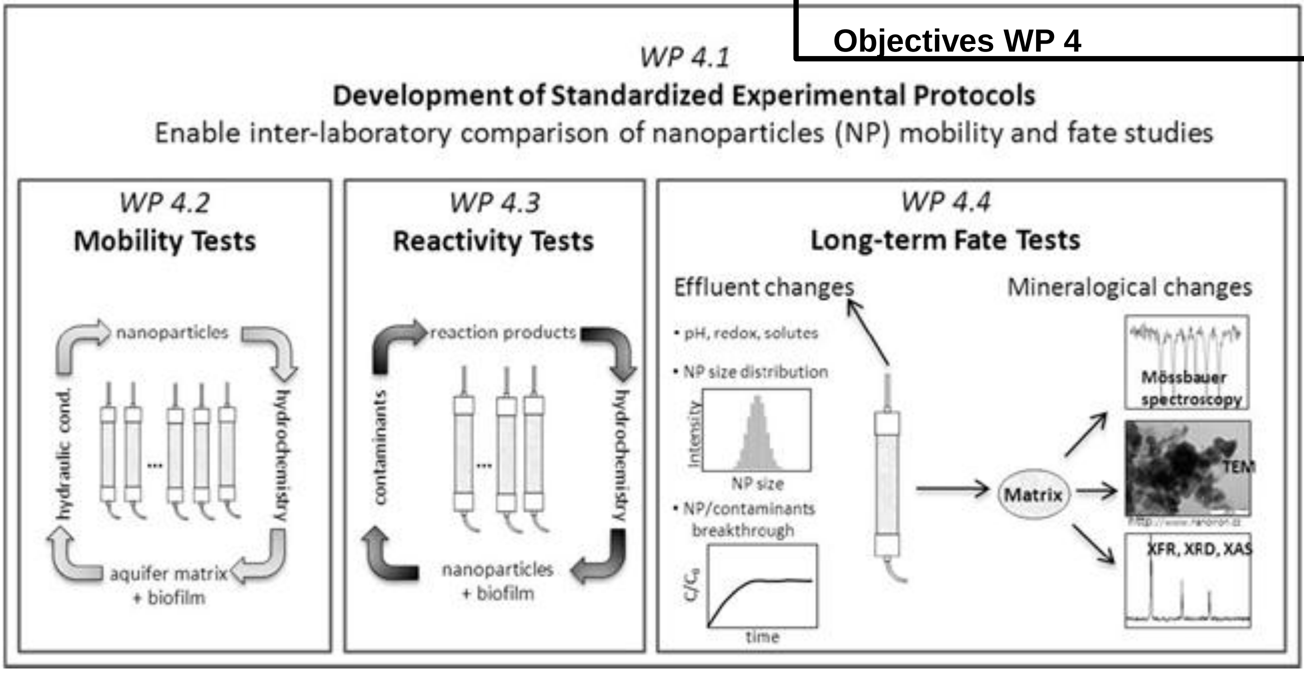
In NanoRem we will attempt to overcome these constraints by coating the aquifer matrix with a negatively-charged polymer prior to the injection of the nanoparticles as this will hinder the influence of the positive aquifer patches.

In parallel, we will assess the influence of this aquifer coating on indigenous microorganisms (in cooperation with WP5) and test for any negative effects. Groundwater composition, ionic strength, and pH also influence particle stability, mobility, and reactivity. Nanoparticle composition, density, size, and surface properties play a major role in the extent of both mobility and reactivity.

In case of nZVI, mobility is additionally reduced by magnetic interactions. Modifications of nanoparticle surfaces by coating them with polymers, polyelectrolytes, or surfactants (see WP2) are used to improve mobility of nanoparticles,but might at the same time reduce particle reactivity. Nanoparticle reactivity in real porous media has rarely been investigated, but is essential for designing field applications. Therefore, reactivity and fate of nanoparticles during their transport through real saturated porous media has to be clarified. NanoRem will investigate mobility, reactivity, and long-term fate of nanoparticles in standardised and real saturated porous media at the bench scale. The outcomes will provide:

- Develop standardised experimental protocols in order to facilitate inter-laboratory comparison of nanoparticles mobility and fate studies, enabling regulators and/or consultants to decide on the most suitable particles for a certain application and for certain field conditions.
- Optimise nanoparticle delivery based on the understanding of particle-particle, particle-aquifer, and particle-biofilm interactions, and deliver the effective nanoparticle transport parameters for computational modelling.
- Provide field-relevant information on nanoparticle reactivity and deliver reaction kinetic parameters for computational modelling.
- Provide field relevant information on chemical and size transformations, decomposition, performance, and long-term fate of nanoparticles.

Objectives WP 4



WP5 Environmental Impact of Reactive Nanoparticles

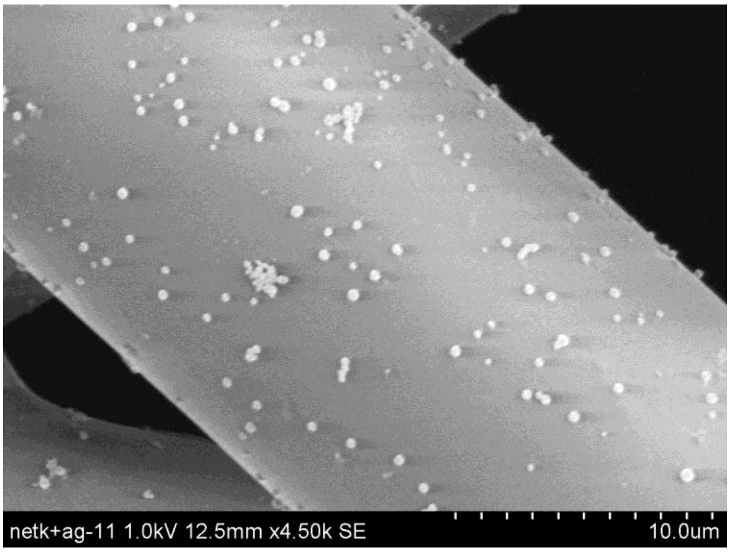
A major regulatory obstacle for widespread use of nanoparticles in-situ is uncertainty about unintended effects on the environment. Many stakeholders, including NGOs, regulatory authorities, and the general public, have expressed serious concern for the effects of unintended release of engineered nanoparticles into the environment. This scepticism is less pronounced when it comes to nZVI, as the transformation products are iron oxides, which are natural soil constituents. Yet, some uncertainties remain and new mobilising agents and new particle types (e.g. bi-metallic nanoparticles) need testing to verify or reject claims of possible adverse environmental effects. Two important characteristics determine environmental risks: mobility (transport of nanoparticles to deep layers of surface soil or to surface waters via erosion or recharge from groundwater) and toxicity (the capacity of reactive nanoparticles to cause harm).

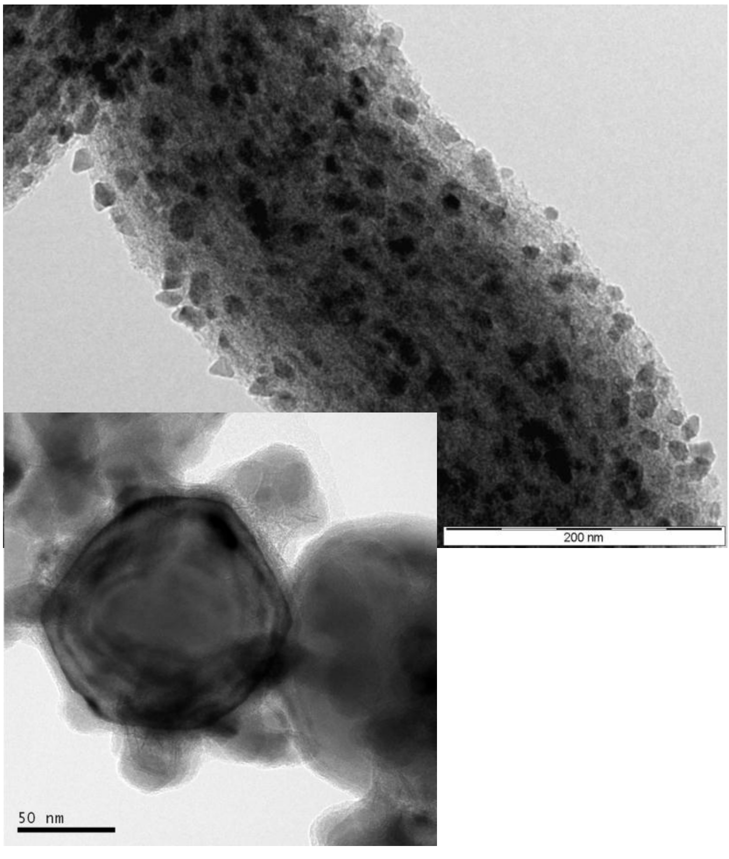
Ecotoxicity has been tested for a wide range of commercially used nanoparticles and in some cases low toxicity thresholds have been reported. Data on toxicity of nZVI and related materials are scarce, and more such data is needed. Bacteria are likely to be among the few organisms that will ever get in contact with reactive nanoparticles used for remediation, but for the completeness of NanoRem's environmental impact assessments, the provision of toxicity thresholds for other (standard) organisms is needed to cover the widest possible range of scenarios (accidental release, use in media like polluted water, sediments or surface soil). This will also provide a broad range of data that are useful in future risk assessments. The broad testing with standard methods (e.g. OECD standard tests) supplemented with test endpoints that provide mechanistic explanation will offer a solid foundation for arguing sustainability of nanoparticles that perform well in treating environmental pollutants and are truly inoffensive to the environment.

An additional concern for use of reductive nanoparticles in the subsurface is that they may, at least temporarily, remove biologically available electron acceptors (e.g. SO_4 denitrification that removes NO_3 possibility of restitution (likely to be high) will be conducted.

- Assess ecotoxicity of NPs, NP transformation products and pollutant metabolites under lab and field conditions, taking into account matrix effects on exposure.
- Describe time-course of ecotoxicity and quantify the potential for toxicity alleviation after migration, oxidation and ageing of NPs in contact with soil.
- Describe NP-microbial interactions during and after remediation with NPs.

Objectives WP5





WP6 Analytical Methods for In-situ Determination of Nanoparticles Fate

A major challenge in assessing the performance of engineered nanoparticles is the detection of those nanoparticles in environmental media, and in particular their isolation from natural nanoparticles and colloidal material. This represents a particular hurdle for the use of Fe-based nanoparticles in remediation, owing to high levels of naturally occurring iron. Many techniques are routinely applied to characterise nanoparticles under controlled laboratory conditions. A number of these could be applied to samples collected under field testing conditions, but the techniques require further method development and validation, and methods also need to be developed for new remediation nanoparticles (e.g. Fe-zeolites and Carbo-Iron). As one of the main ambitions of the project is to move from the realm of laboratory tests on nanoremediation to field and in-situ testing of the particles, the development and application of suitable analytical techniques forms a central role in demonstrating the viability of nanoremediation.

An analytical toolbox will be available which refers to all methods to support laboratory and field studies on the reactivity, fate and bioavailability of the nanoparticles of interest. According to where they can be applied, these can be divided into three main types of methods: i) techniques for laboratory use (e.g. for particle characterisation and stability); ii) techniques with a capability for on-site use in the field (i.e. requiring some sampling and infrastructure but providing immediate data); and iii) techniques that can be used in situ (i.e. providing data with a high resolution in space and time).

On site and in-situ methods include techniques that monitor within the aquifer and those that rely on site sampling (e.g. ultrafiltration for size distribution) followed by laboratory analysis. The methods have different detection limits in terms of particle concentration, particle size distribution and most importantly their ability to detect above background colloids. In-situ techniques can be used to directly monitor levels of nanoparticles in-situ, using for example their magnetic properties or chemical reactivity through measurement of redox or hydrogen production, but these rely on relatively high concentrations of nanoparticles. Tracing methods (e.g. isotope or rare earth element analysis) can be applied to follow the movement of particles and reaction products out of the aquifer. Isotope labelling techniques allow sensitive and specific location of nanoparticles and their products in laboratory studies - where the ease of detection makes radiolabelling useful for high throughput experiments – and field studies where stable or short-lived isotopes can be used. Dual labelling, including with rare earth metals and stable isotopes, can be applied to study particle dissolution and reaction products.

Since nanopoarticle stability is a key performance issue, reaction products are an important focus. Rapid freezing Mössbauer spectroscopy can distinguish and quantify various Fe-bearing phases, and can be applied for ex-situ identification of transformation products of a variety of Fe-based nanoparticles. In the case of ferrate nanoparticles, it is possible to discern and quantify various oxidation states. NanoRem will adapt and develop these techniques for a controlled study of iron-based nanoparticles.

- Monitoring and tracing tools based on measurement of the ferro-magnetic properties (susceptibility) of iron as well as chemical reactivity of nanoparticles (redox, hydrogen production) will be optimised to follow iron reactivity in the field.
- On-site measurements and in-situ characterisation of natural and engineered nanoparticles will be carried out through the development of method protocols and the application of modern high performance site-specific analytics (e.g. Time of Transition measurement, in-situ turbidity and fluorescent measurements). Methods for detection of Fe-zeolites in aquifers will be developed. A range of different techniques will be tested, including indirect methods that can potentially be applied cheaply and continuously in the field (e.g. redox measurement).
- Field and laboratory tests of the methods developed will be conducted, providing documentation of “fit for purpose”, detection limits and costs, and assessments of the potential for routine application (e.g. wastewater) in a wider context of product safety and monitoring. Their applicability for other applications will be assessed. Field measurement data necessary for the assessment of the efficiency of the nanoremediation will be provided, together with application of analytical and sampling methodologies in field site studies (WP10).

The overall goal is the development and application of analytical methods and protocols for in-situ measurement, detection and studies of the fate of nanoparticles. This will be achieved by research activities covering three main areas:

- Optimisation of monitoring and tracing tools for laboratory and field use.
- Application of modern high performance analytics for on-site measurements and in-situ characterization of natural and engineered nanoparticles, and development of protocols. Methods for detection of Carbo-Iron and Fe-zeolites in sediment matrices will be developed.
- Laboratory and field tests of the methods developed will be conducted, providing documentation of “fit for purpose”, detection limits and costs, and assessments of the potential for routine application in a wider context of product safety and monitoring.

Objectives WP6

WP7 Modelling Tool for Nanoparticle Mobility and Interaction with Contaminants

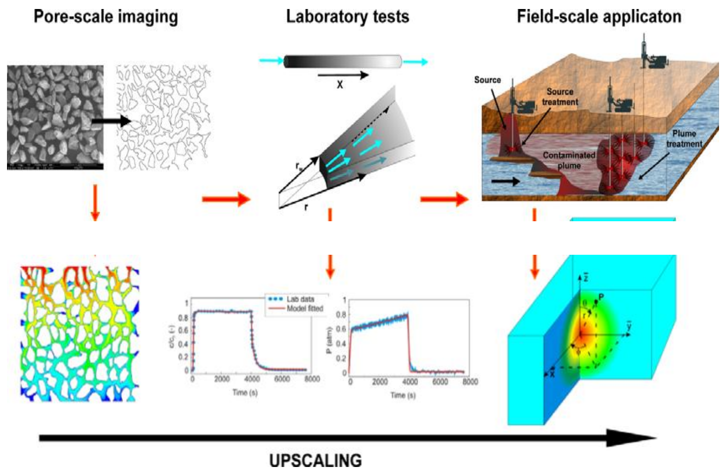
A key issue for field emplacement of reactive nanoparticles is assessing the mechanisms which control their mobility in the subsurface. Whilst transport of dissolved contaminants is thoroughly understood and many numerical models are commercially available to assist the design of a remediation intervention, fundamental factors that control the transport of nanoparticles in porous media are still largely unknown.

Predicting the mobility of nanoparticles in the subsurface underpins practical field applications. Whilst extensive literature is available on modelling approaches for colloid and virus transport in groundwater systems, models are commonly based on a modified advection-dispersion equation, with a term accounting for the exchange with the solid phase. The exchange terms are usually modelled with rudimentary empirical equations, which include particles deposition onto the solid matrix and their release.

Early stages of particles deposition are mainly controlled by particle-porous medium interactions, while in a second stage particle-particle interactions prevail, especially repulsion or attraction of the particles. The influence of pore water chemistry on physico-chemical interactions, and consequently on deposition and release kinetics, is well known, and usually modelled with relationships empirically derived from laboratory data. The deposition of a relevant mass of particles may also affect the hydrodynamic properties of the porous medium, decreasing porosity and permeability, thus resulting in clogging phenomena.

The coupling of the aforementioned phenomena was studied by Tosco and Sethi for viscous suspensions of iron colloids, and resulted in a numerical model for colloid transport simulation in 1D geometry (MNM1D). However, this modelling approach is based on an empirical description of transport mechanisms, and not necessarily in line with the fundamental phenomena occurring at the micro-scale. Indeed, finding relationships derived from physico-chemical fundamental principles, verified and validated at the pore-scale, would represent a great step forward in the modelling approach.

Experimental studies are reported in the literature for micro-scale imaging of colloid retention in porous media, as well as numerical transport simulations which include pore-scale processes, but few studies are available which use the micro-scale results to provide a rigorous justification of the macroscopic deposition/release relationships. Moreover, modelling approaches which incorporate transport parameters obtained via averaging of pore-scale simulation results are lacking, as well as any systematic analysis on the effects of porous medium properties (porosity, tortuosity), particles properties (composition, size and concentration) and pore water chemistry (pH, ionic strength) on nanoparticle transport.



Physico-chemically based models that describe these phenomena are currently missing. By means of a multi-scale approach, NanoRem is intended to fill this gap, providing a numerical tool for large-scale simulation of nanoparticles transport based on physico-chemical fundamental principles.

Numerical techniques developed in NanoRem will be used to determine the parameters most relevant for transport and so advance up-scaling from the lab to field application:

- Fundamental understanding of nanoparticle transport in porous media. A pore-scale network model will be developed, validated and used to describe movement of nanoparticles and their interactions at the pore-scale. A wide range of properties (e.g. size, type, concentration, surface properties, salinity, pH, ionic strength) will be incorporated. Gravitational, hydrodynamic, electrostatic forces will also be included.
- Development of numerical design tool. The developed relationships will be built into shared software for transport simulation in porous media, through user-defined sub-routines. The resulting numerical package will provide a new tool for predicting the fate and reactivity of nanoparticles in the subsurface.
- Design of field applications. After demonstration of predictive capability, the software will be used for the design of pilot remediation schemes (WP8, WP10) and subsequent evaluation of their performance.

Objectives WP7

- Developing a user-friendly simulation tool (RT3D module) for the design and interpretation of laboratory tests and for predicting the fate and transport of nanoparticles and their effectiveness at the field scale.
- The simulation tool will make use of up-scaled relationships, to be developed from fundamental physicochemical principles and modelling, for describing mass transfer processes affecting the mobility of nanoparticlesand their deposition onto and release from the porousmedium, as well as interaction with dissolved substances.

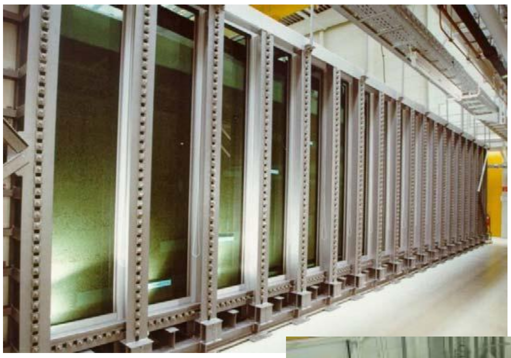
WP8 Up-scaling, Risk and Sustainability

The step from (small) laboratory experiments to a field size application is an extremely challenging task. NanoRem will bridge the gap between laboratory and field application via large scale experiments. Such experiments must be contained to allow for the use of noxious model contaminants and to sustain an exact mass balance. While these experiments are similar in size to the field application and their artificial aquifers show realistic heterogeneities, their instrumentation is much denser and sampling intervals are much smaller than anticipated in the field. Furthermore, instrumentation tested in these experiments may be extrapolated to field applications.

Data derived from these experiments will not only yield a profound understanding of the "real" field situation, they will also allow to design a cost effective sampling and monitoring strategy for NanoRem pilot and demonstration projects. Furthermore, all aspects relevant for the application of nanoparticles can be investigated, i.e. the transport behaviour of the particles, the reactivity of the particles with the contaminants as well as (unwanted) side reactions and, finally, the ultimate fate of the particles.

NanoRem will use various large scale tanks of the VEGAS facility to provide:

- Representative scale testing of emerging nanoparticle applications in contained facilities. The VEGAS facility is unique in Europe in allowing in-situ testing under controlled boundary conditions in large contained tanks (approx. 250 m³). This provides three major benefits: precise mass balance, capacity for comprehensive instrumentation not possible in the field, and also – if necessary – assurance of no potential for release of nanoparticles into the wider environment.
- Optimisation of nanoparticles and tools (WPs 2-7) via feedback from large scale performance testing. Injection in the laboratory (VEGAS facility) will be early in the project time to allow for a timely feedback to improve nanoparticle design (WP2, WP3), understanding of transport (WP4) and monitoring equipment (WP6).
- Knowledge on degradation products under field relevant conditions. Nanoparticle transformation products and contaminant degradation products will be monitored to ensure efficiency of degradation, and the potential of microbiological enhancement will be assessed (WP5).
- Testing appropriate injection technologies for varying hydrogeology including gravitational porous media flow, high pressure injection etc.
- Developing an understanding of nanoparticle deployment risks for in-situ remediation. WP8 will integrate NanoRem's technical and field project findings, with an initial opinion based on stakeholder and expert views gathered in WP9, to provide a more substantial basis for assessing and (if necessary) managing risks from nanoparticle deployment for remediation .
- Assessing the sustainability of nanoremediation compared with alternate (remediation) strategies. Contemporary tools for understanding sustainability in remediation will be applied to the field tests (not only the large scale laboratory tanks) in NanoRem to provide case study based comparative sustainability assessments and considering a range of stakeholder opinions where possible. Sustainability will be considered across a system boundary and a life-cycle relevant for the remediation work being undertaken.
- A thorough validation and verification of the numerical tool (WP7) will be possible based on these large scale experiments.



- Up-scaling and testing at representative scale of emerging nanoparticle applications in contained facilities.
- Optimisation of nanoparticles and tools (WPs 2-7) via feedback from large scale performance testing.
- Knowledge on degradation products under controlled large scale conditions.
- Testing appropriate injection technologies for varying subsurface conditions.
- Risk model, sustainability appraisal and life-cycle assessment (LCA) consideration for nanoparticle applications.

Objectives WP8

WP9 Dissemination, Dialogue with Stakeholders and Exploitation

Communication is the key for exploitation of the results of NanoRem. Dissemination of NanoRem findings will take place via several channels, including: conventional routes such as scientific publications and web sites, via social networking and also via the major international stakeholder networks involved in contaminated land management across Europe (COMMON FORUM and NICOLE). Dialogue with stakeholders (industry, service providers and regulators) will collect information via structured workshops, online consultation and dialogue with the key stakeholder network. The information collected will be related to policy and regulation, risk management and risk perception and ethical concerns, sustainability assessment and market evaluations and any other key stakeholder concerns. The goals of this effort are, (a) to ensure that the WPs 2 to 7 are informed of considerations that might have a bearing on the choices they make during research within the project, (b) to provide an informed basis for exploitation, and (c) to provide an informed interim view of nanoparticle deployment risks from previous field trials to support the design of field-scale applications in WP 10. Opportunities for exploitation will be investigated in the context of a risk-benefit appraisal, based on dialogue with key practitioner and stakeholder interests from across the EU and market assessment activities. Contemporary opinions of market niches in the short, medium and long term; risks; and sustainability (including life cycle considerations) will inform the exploitation strategy developed. WP 9 begins with the recently published opinions of the risks vs. benefits of nanoparticle use in remediation from several Member States; and will develop these, as NanoRem technical findings become available, in consultation and dialogue with external stakeholders to provide a substantive opinion on risk-benefit appraisal and nanoremediation exploitation at a European level.

- Dissemination across the project will follow an overarching communication plan, and will be co-ordinated and supported by WP 9. Key tasks are i) Dissemination management; ii) Dissemination support services, iii) Central project publicity and content management services; iv) Project web site; v) Leveraging dissemination opportunities (i.e. identification of and linkage with existing “high value but low cost” dissemination and dialogue opportunities); and vi) Training recommendations.
- Dialogue: Two elicitation workshops will be held to provide a project orientated workshop that also delivers specific usable information for risk assessment policy, market analysis, legal/ethical aspects, and societal acceptance. Furthermore, in order to disseminate the harmonisation efforts and to align standards within the project and existing ones outside the project, an exchange will be initiated between CEN and NanoRem.
- Exploitation includes two tasks: i) benefits assessment and exploitation strategy; and ii) risk-benefit appraisal and developing a market consensus.
- Successful exploitation of nanoremediation technology will only happen if there is a broad market consensus (across site managers, users, regulators and other stakeholders) that the benefits of nanoparticle use in remediation far outweigh their risks. The second task seeks to develop a European consensus on nanoremediation risks and benefits with the COMMON FORUM, NICOLE and other interested stakeholders.

- Facilitate dissemination, dialogue and exploitation, transmitting the results of NanoRem widely amongst user communities.
- Support dialogue to collect “soft” information from a broad range of stakeholders internationally.
- Provide a risk-benefit based identification of key exploitation opportunities.

Objectives WP9

WP10 Pilot Site Application and Field Demostrations

For a successful transfer to the end user, nanoremediation technology performance and applicability has to be shown convincingly at realistic scales, including considerations of cost and wider impacts. The demonstration of the performance of nanoremediation in the field complements the demonstration in the VEGAS facility towards a better public acceptance. Although less controlled than laboratory experiments, successful field demonstrations will be much more convincing for stakeholders such as regulators, problem owners or consultants. On the other hand, aspects as the test of different injection methods for difficult geological conditions (low permeable aquifers), the influence of climatic conditions or the conditioning of aquifers with certain hydrochemical situations and indigenous microbial communities cannot be investigated in laboratory systems without restrictions. This means that tests are needed under both highly controlled, yet field similar conditions as well as tests in real field situations

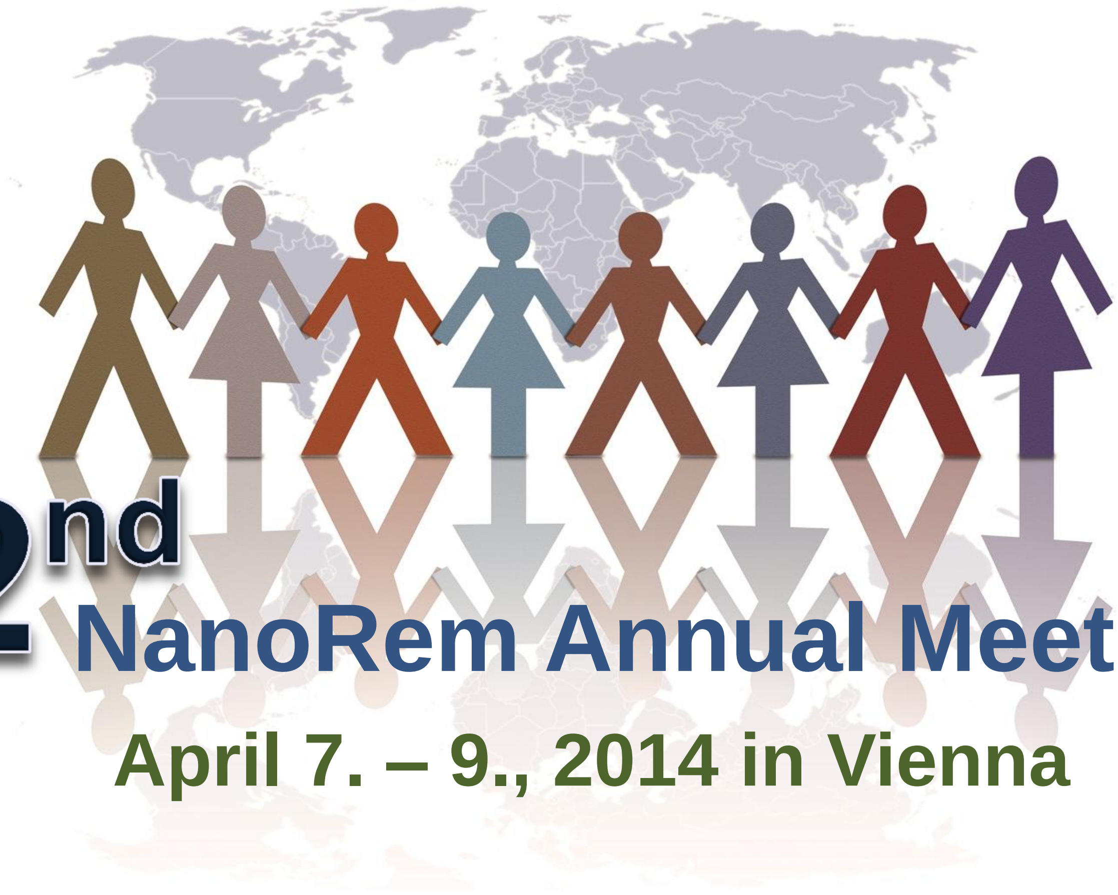
Selected nanoparticles developed in NanoRem (WP2, WP3) are tested in different hydrogeological, hydrochemical and climatic environments and also against different contaminant distributions and target contaminants. Demonstrating effective performance will depend on showing that nanoparticles can be transported to the required treatment zone (and not substantially further – WP 4) and that their longevity will guarantee an economical application (but not a hazardous long term persistence in the environment – WP 5). Longevity has strong implications with respect to source vs. plume remediation. Effective analytical monitoring methods (WP 6) and reliable numerical design tools (WP 7) developed in NanoRem will be verified against these large scale trials.

NanoRem uses demonstration and pilot sites at representative scales to provide:

- Representative scale testing of emerging nanoparticle applications on field sites. Different sites were chosen based on preliminary site investigation, geohydrology, target contaminant, communication with local regulators and willingness of the owners to participate in pilot and demonstration applications.
- Verification of particles, tools and methods developed in WPs 2-8. Proof of concept and feedback will be provided from the application in real field situations for the efficiency of the particles, the investigation methods as well as for the numerical simulations .
- Assessment of reactivity and degradation products under real field conditions. The efficiency to degrade contaminants will be verified at real field conditions. The formation of degradation products and metabolites will be monitored to ensure efficiency of degradation and to test for microbiological enhancement.
- Application of appropriate injection technologies for varying hydrogeology including gravitational porous media flow, high pressure injection and, if necessary, hydraulic fracturing.
- Answering the current lack of validated field scale performance data for end users and regulators. Detailed practical scale test reports will be produced including technical descriptions, design parameters, operating windows and limitations of the technology. All experiences and insights achieved during the course of the project will be merged into general guidelines which will be made widely available via WP 9 to support a more positive public awareness and better acceptance of nanoremediation and hence market building within the EU. This will help producers of particles to better assess the market potential of products, consultants to better decide on the suitability of an application of nanoparticles at specific site conditions and authorities to better judge chances but also potential risks.

- Testing of emerging nanoparticle applications on pilot field sites.
- Optimisation of nanoparticles and tools (WPs 2-7) via feedback from pilot sites and field demonstrations.
- Determination of degradation products at field conditions.
- Application of appropriate injection technologies for varying hydrogeology.
- Alleviating the current lack of validated field scale performance data for end-users and regulators.

Objectives WP10



2nd NanoRem Annual Meeting

April 7. – 9., 2014 in Vienna

You can find our full list of partners on our project website (www.nanorem.eu). If you would like any further information please contact Hans-Peter Koschitzky at koschitzky@iws.uni-stuttgart.de.

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