European Cooperation in the field of Scientific and Technical Research - COST -

Brussels, 14 November 2014

COST 116/14

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action TD1407: Network on technology-critical elements – from environmental processes to human health threats

Delegations will find attached the Memorandum of Understanding for COST Action TD1407 as approved by the COST Committee of Senior Officials (CSO) at its 191th meeting on 12-13 November 2014.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action TD1407
NETWORK ON TECHNOLOGY-CRITICAL ELEMENTS – FROM ENVIRONMENTAL PROCESSES TO HUMAN HEALTH THREATS

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 “COST Action Management” and document 4112/13 “Rules for Participation in and Implementation of COST Activities”, or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to create a network on trace elements critical for the development of new technologies, from an environmental perspective to potential human health threats, with the aim of defining the current state of knowledge and proposing priority research lines.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 64 million in 2014 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Section *2. Changes to a COST Action* in the document COST 4114/13.

GENERAL FEATURES

Initial Idea:

There are a number of trace elements that were considered just as laboratory curiosities but now, however, are key components for the development of new technologies. For most of these elements, the present understanding of their concentrations, transformation and transport in the different environmental compartments is scarce and/or contradictory. These elements, here defined as technology-critical elements (TCEs) – and include Nb, Ta, Ga, In, Ge, Tl, Te, the platinum group elements (PGE: Pt, Os, Ru, Rh, Pd and Ir), and most of the rare earth elements (REE: Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Yb, Lu) – are undergoing a significant change in their cycle at the Earth's surface due to their increase use in a variety of technological applications. Their impact on their biogeochemical cycles and potential biological and human health threats needs to be further explored. The holistic approach of the Action will cover research areas like: (i) Analytical challenges for quantitative and screening purposes; (ii) Environmental processes including biogeochemical cycles of the TCEs; (iii) Sustainable resource management; (iv) The exposure of humans to these elements and their compounds through air, water, and food.; (v) Potential ecological and human health threats (eco-toxicology).

The action will create a network of scientists working and interested on TCEs, from an environmental perspective to potential human health threats, with the aim of defining the current state of knowledge and gaps, proposing priority research lines/activities, and acting as a platform for new collaborations and joint research projects.

Keywords: Technology-critical elements, Analytical determination, Speciation, Environmental cycling, Sustainable resource management, Human exposure, Ecotoxicology, Toxicology

A. CHALLENGE

Approximately 99.7% of the upper continental crust is composed of a relatively small number of elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P) as their oxide forms, mainly SiO2 (66.6%), Al2O3 (15.4%), and FexOy (5.0%), whereas the vast majority of the naturally-occurring chemical elements – the so-called 'minor' or 'trace' elements –account only for the remaining 0.3% [Rudnick and Gao 2003]. The concentrations of these trace elements in the Earth span several orders of magnitude, from several hundreds of micrograms per gram down to tens of picograms per gram. Despite their low concentrations, the discovery and use of several trace elements by humans can be traced back several thousands of years – which is the case of gold (6000 BC), copper (4200 BC), silver (4000 BC) or lead (3500 BC), among others. The massive requirements of these trace elements for a variety of technological applications, especially after the industrial revolution in the late 18th century, led to their extensive extraction from the lithosphere and, as a consequence, caused the remobilization of these elements within the biosphere. The development of new analytical technologies during the past decades has made possible the determination of their concentrations in a range of environmental compartments and the study of their environmental cycling and fate [e.g. Salbu and Steinnes 1995; Duester and Vink 2008; Duester et al. 2011]. The deleterious effects of some of these elements to living organisms have been well documented [Fairbrother et al. 2007], and has underpinned the development of a range of environmental guidelines, policies and laws [e.g. EU Water Framework Directive; WHO Drinking Water Guidelines] being put into place to control the adverse effects of these elements (e.g. As, Cd, Cr, Cu, Hg, Pb) in their various chemical forms.

However, whilst considerable progress has been made in understanding the environmental behaviour and fate of elements listed above and appropriate standards developed, the use of a further range of trace elements (whose inherent properties are required for use in an ever expanding list of new technologies) is rapidly increasing [Karn 2011]. This group of elements, which includes Ga, Ge, In, Te, Nb, Ta, Tl, the platinum group elements (PGE: Pt, Pd, Rh, Os, Ir, Ru) and most of the rare earth elements (REE: Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Yb, Lu), are now essential components for a variety of applications including information and telecommunications technology, semiconductors, electronic displays, optic/photonic or energy technologies [Eggert 2011; Karn 2011; APS and MRS 2011]. Their current importance is such that several of these elements have been labeled as 'energy-critical elements' and initiatives at national levels are underway to secure their availability in the coming years [APS and MRS 2011].

Here we define these elements as 'technology critical elements' (TCEs).

The below examples provide a brief overview of the uses of several TCEs within a range of new technology applications:

- **Gallium (Ga):** This element, mainly in the form of gallium arsenide (GaAs), is used in semiconductor technologies and optoelectronic devices (i.e. LEDs, laser diodes, photodetectors, solar cells) [Jaskula 2013]. Gallium arsenide products account for approximately 95% of the annual global gallium consumption [Moskalyk 2003].

- **Germanium (Ge):** 70% of the worldwide production of germanium is utilised in applications such as fiber-optic systems (30%), infrared optics (25%), electronics (semiconductors) and solar panels (15%) [Guberman 2013].
- **Indium (In):** Most of the global indium mined is consumed in the form of indium tin oxide (ITO) [Tolcin 2013]. ITO is mainly used to make transparent conductive coatings for liquid crystal displays, flat panel displays, plasma displays, touch panels and electronic ink applications [Karn 2011].
- **Tellurium (Te):** The production of cadmium-tellurium-based solar cells [Karn 2011] represents the major end-use of this element [George 2013].
- **Niobium (Nb):** This element is currently used in emerging technologies such as the development of micro capacitors and superalloys, the latter representing 40% of total Nb consumption [Papp 2013].
- **Tantalum (Ta):** Tantalum capacitors are estimated to account for 60% of tantalum use. Major end uses of these Ta capacitors include automotive electronics, pagers, personal computers and portable telephones [Papp 2013].
- **Thallium (Tl):** Technological applications of thallium – in conjunction with other elements – include high-temperature semiconductors used in filters for wireless communications and in crystal filters for light diffraction in acousto-optical measuring devices [Guberman 2013].
- **Platinum Group Elements (PGEs: Platinum, Pt; Palladium, Pd; Rhodium, Rh; Ruthenium, Ru; Osmium, Os):** their outstanding catalytic properties underpins their widespread use in catalytic converters in motor vehicles, where this application currently represents the major end-use of total Pt (40%), Pd (70%), and Rh (80%) global demand [Johnson Matthey 2012]. Pt, Pd, and other PGEs are also used as catalysts in fuel cells, an application with increasing interest and market potential in the transportation sector [APS and MRS 2011]. Other uses of PGEs in new technologies include hard disk drives, liquid crystal displays (LCDs) or organic light-emitting diodes (OLEDs) [Johnson Matthey 2012].
- **Rare Earth Elements (REEs: Ytrium, Y; Lanthanum, La; Cerium, Ce; Praseodymium, Pr; Neodymium, Nd; Samarium, Sm; Europium, Eu; Gadolinium, Gd; Terbium, Tb; Dysprosium, Dy; Ytterbium, Yb; Lutetium, Lu):** as a function of their unusual magnetic and/or optical properties [APS and MRS 2011], these elements are increasingly used in a range of emerging technological applications, with particular key applications within the energy-related new technologies (e.g. renewable energy and energy efficient technologies) [Karn 2011]. The latter includes their use in electric vehicle batteries, magnets for motors of both

electric vehicles and wind turbines, and the production of energy-efficient lighting [Karn 2011].

Due to their high economic relevance and the Europe's dependency on imports (mainly from China), the EU has identified 14 critical materials (http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report_en.pdf) for which, at the moment, no mining zones with an acceptable short/mid-term profit exists within the EU borders. These critical 14 materials identified by the EU encompass most of the TCEs here defined, namely **Ga, Ge, In, Nb, Ta, the platinum group elements, and the rare earths.**

The current significant gaps in the knowledge on TCEs, from their environmental levels and fate to their potential (eco)toxicological impact, are mainly explained by two factors: (i) their typical ultra-trace concentrations, making their analytical determination extremely difficult and/or time-consuming, and (ii) the absence of any significant industrial role (apart some biomedical applications) prior to their massive use in the increasing demand of new technological applications, therefore discouraging scientists to assess the (eco)toxicological aspects of the TCEs.

However, this scenario is changing rapidly and substantially. The current use of TCEs in new technological products is resulting in significant changes in the processes associated with their natural environmental cycle at the Earth's surface due to increased mining activities, use in a variety of products, increased exposure of the biosphere, unknown biogeochemical or anthropogenic cycling and unknown potential toxicological endpoints and harmful effects. At all stages of their life cycle, these elements and their compounds can be released into the environment and come in contact with the biosphere. The wider impact of the increasing use of many TCEs within a range of environmental compartments is poorly understood; for several TCEs no field data is available.

As an example, anthropogenic disturbances in the geochemical cycles of the platinum group elements (PGEs) have recently been reported [Rauch et al. 2005; Rauch et al. 2010; Cobelo-García et al. 2013]; accordingly, elevated PGE concentrations have been found at urban sites in Western Europe [Gomez et al. 2002; Cobelo-García et al. 2011], the USA [Rauch et al. 2004] and an increasing number of countries worldwide [e.g. in Ghana: Kylander et al. 2003], as well as at remote sites [Rauch et al. 2010; Barbante et al. 2001]. Also, the disturbance of the natural environmental distributions of several rare earth elements (REE) has been recently reported in waters of the Rhine river, Germany [e.g. Kulaksiz and Bau 2011; 2013], and San Francisco Bay, USA [Hatje et al. 2014], indicating that human activities are already impacting the geochemical cycles of these elements. However, currently the database is insufficient to support even the calculation of mass balances, sources and/or sinks for TCEs in Europe or in the COST member countries. Of further concern is that, despite their widespread use, current knowledge does not support the application of robust risk assessment processes and, as a consequence they are not included in regulations (in contrast to other metals with a longer record of use).

It is within this context that it is considered timely and relevant that a coordinated scientific effort is pushed forward to improve our basic understanding of the behaviour of the TCEs, from the process underpinning their environmental behaviour, any potential human health threats and what is required in terms of monitoring, assessment and regulation, as well as raising public awareness and providing critical information to inform debate on the issues surrounding TCEs. The overall objective of this COST Action network is defined as:

The creation of a network of scientists and practitioners working on and utilizing trace elements critical for the development of new technologies, ranging from evaluating environmental processes to understanding potential human health threats, with the aim of defining the current state of knowledge and gaps, proposing priority research lines/activities, and acting as a platform for new collaborations and joint research projects.

Based on the issues that will be address by the network, the following objectives are stated:

Objective 1. Moving towards rapid, cost-effective and accurate analytical determination of the TCEs and their species in the environment.

Issue 1.1: Instrumental techniques. Since environmental concentrations of TCEs are usually at the trace and ultra-trace levels, their analytical determination is often expensive and time-consuming. Standard analytical procedures for many TCEs are not established.

Tasks: *The network will evaluate the most appropriate current available procedures and will propose directions for the development of new analytical strategies with the aim of decreasing the analysis time and costs to enable routine monitoring of these elements and support the development of standard analytical methodologies.*

Issue 1.2: Analytical protocols (from sampling to analysis), measurement uncertainty and validation. During the whole analytical process, from sampling to analysis, there are a number of critical steps

(e.g. type of sample container, preservation conditions, etc.) that may lead to inaccurate, erroneous or misinterpretation of results. Whereas these critical steps are well described and 'good practices' procedures are available for a number of 'common' trace elements, for most of the TCEs there is no such information and decision support. Also, certified reference materials
(CRMs) and inter-laboratory exercises, which are often used to check the accuracy of the analytical measurements, are not available for TCEs in one or more types of matrices (e.g. water, sediments and biota) which are needed in fate orientated studies.

Tasks: *Identify the critical analytical steps to take into account for the analysis of TCEs; promote research in those analytical steps where further information is needed; promote community-wide inter-laboratory exercises; interact with the Institute for Reference Materials and Measurements (IRMM; European Commission, Joint Research Center) for the development of appropriate CRMs for TCEs.*

Issue 1.3: Speciation analysis. The behavior of an element, including its reactivity and mobility in the environment and its bioaccumulation and potential toxicity, greatly depends on the physical and chemical forms in which it is present [e.g. Hirner 2006]. This is especially relevant for the TCEs since a major fraction of its use in new technological application is in the form of nanoparticles [Karn 2011].

Tasks: *Identify the target TCEs physico-chemical species based on their potential environmental and human risk. The suitability of the existing analytical techniques for such speciation measurements will be evaluated and the information on the need for new developments will be disseminated.*

Issue 1.4: Screening and environmental monitoring technologies. A critical issue on risk management of toxic chemicals in the environment is the availability of in-situ monitoring technologies (Frazzoli et al. 2007; Dragone et al. 2009) sensitive to the target compounds.

Tasks: *Evaluate the available screening methods and technologies, with particular reference to sensors and biosensors as well as biorecognition media (e.g. enzymes, cells) that can be further developed to be sensitive to target TCEs and/or their species.*

Objective 2. Environmental impact and cycling, and policy-oriented assessment

Issue 2.1: Modeling speciation in environmentally-relevant systems. One of the factors playing a major role in the environmental processes of trace elements is their speciation. Available models (www.speciation.net/Public/Links/DB/Links/topic_modelling.html?FILTER1) allow the calculation of species distribution in air, water, soils and sediments for a range of elements but require substantial updating to support their application in relation to TCE.

Tasks: *Create an updated thermodynamic database of TCEs to be used in environmental speciation modelling. Determine, based on theoretical speciation calculations, the most relevant species of TCEs in the different environmental compartments. Identify those elements for which necessary thermodynamic data is lacking to predict their speciation.*

Issue 2.2: Mapping the environmental concentrations of TCEs. There is a need to evaluate the impact of the use of new technologies on the TCEs concentrations in different environmental compartments, identify their sources and determine emission mechanisms and factors. This is especially critical for several TCEs, for which environmental concentrations are not yet fully known and, where data are available in the literature, are often contradictory [e.g. Filella 2010; Cobelo- García et al. 2013]. The COST Action will deliver data on concentrations from selected waste water treatment processes and plants, from surface water bodies, sediments, soils and biota. This data will be transferred to a map illustrating TCEs in the different environmental compartments, complementing and enhancing the current Geochemical Atlas of Europe (http://weppi.gtk.fi/publ/foregsatlas/), which will display the current state 2015 – 2018 and which will help to (i) search for anomalies either from geological or from anthropogenic causes, (ii) monitor at selected places mid and long term changes in concentration and (iii) fulfil recycling objectives where significant impacts from anthropogenic causes are visible. It will act as a crystallization core for subsequent activities.

Tasks: *Map current concentrations in the different environmental compartments across Europe. Provide baseline (background) concentrations in the different environmental compartments. Focus on facilities that have the potential to increase the environmental concentration of TCEs: (i) search, (ii) monitor and (iii) fulfil recycling objectives.*

Issue 2.3: Evaluate the environmental/biogeochemical cycling and fate of TCEs. The knowledge of factors such as the reactivity, mobility and bioavailability of any target compound is essential to predict its behavior in the environment (e.g. transfer between environmental compartments, biological uptake, etc.). The Action network will provide information on the current and future pathways that may cause adverse effects on ecosystems or human health. With regard to the urgently needed recycling of TCEs in Europe, the potential effects of these processes will be equally addressed.

Tasks: *Identify key environmental process studies that need to be addressed in order to understand the mobility and bioavailability of TCEs. Evaluate pathways with respect to future potentials to cause adverse effects.*

Issue 2.4: Environmental policies and guidelines. TCEs have been generally omitted from environmental policies [e.g. EU Water Framework Directive] and environmental quality guidelines [e.g. WHO Drinking water guidelines] due to the absence of a previous significant anthropogenic disturbance on their concentrations. However, the current changing scenario and the new data coming up pointing for a anthropogenic perturbation on TCEs environmental concentrations calls for an assessment on whether environmental quality guidelines for these elements are needed.

Tasks: *The improved knowledge on the environmental concentrations – both at pristine and impacted areas – of TCEs derived from the Action can support extending current and future policies for environmental protection. Here the Action will disseminate the appropriate information to the relevant bodies [e.g. European Commission, World Health Organization]*

Objective 3. Human exposure and toxicology

Issue 3.1: Evaluate the exposure of humans to TCEs through direct (air inhalation, dermal absorption, or soil ingestion) and indirect (water and food consumption) pathways. The human exposure to TCEs needs to be evaluated in order to calculate their daily intake, especially in the most sensitive population groups. In addition, the analysis of TCEs concentrations in different types of foods will allow the identification of sources of these elements and any potential bioaccumulation processes by vegetables and food producing animals. This will serve to assess potential health risks from exposure
Tasks: *Based on available literature, the Action will provide an evaluation of the human exposure through air, water and food for TCEs, and the groups of population that may be more sensitive to such exposure. This evaluation will also serve to identify those cases where no information is currently available and are more critical for public health, thus proposing appropriate research efforts.*

Issue 3.2: Food safety. Given the bioaccumulation potential of trace elements, a critical contamination of food chains occurs at the interface environment/food primary productions, e.g. water sources for animal watering and irrigation, and through fodder for animal feeding.

Tasks: *In order to control and manage the dietary exposure of TCEs, the Action will provide the assessment of key markers of TCEs contamination on the food production chain for regular monitoring by food safety agencies.*

Issue 3.3: Potential human health risks. Assessment of human health risks requires knowledge of effects, and therefore the availability of toxicological (in vitro, in vivo, human) studies and/or epidemiology and assessments from Agencies (if any).

Tasks: *The Action will evaluate the current toxicological data on TCEs and their compounds to identify the key substances of concern and data gaps. For these substances, markers of exposure and effect will be assessed.*

Issue 3.4: Eco-toxicological aspects of the TCEs and their compounds. An assessment of the current eco-toxicological data of TCEs and their compounds is necessary to determine the main substances of concern for living organisms (e.g. fish, oligochaetes, molluscs, crustaceans, insects, bioaccumulation in predatory animals, plants, algae).

Tasks: *The Action will evaluate the available eco-toxicological data and identify data gaps on TCEs and will assess whether existing information can be used in models (e.g. Biotic Ligand Model, BLM; Erickson 2013) to predict their bioavailability and toxicity in the environment.*

Issue 3.5: Mechanisms of action. The understanding of mechanisms of action plays an important role in the comprehension of toxicology and ecotoxicology as well as in the definition of markers of exposure and effect that are needed for monitoring the biological impact of TCEs.
Tasks: *Target substances will be grouped based on a common mode of action or additive mechanism of toxicity. A mechanism- based grouping will be applied to clusters of TCEs, thus allowing both detection and assessment.*

B. ADDED VALUE OF NETWORKING

The current socio-economic and environmental challenges that European countries are facing clearly need common- defined strategies at an European level to inform and support our transition to a sustainable economy. The relevance of the identified technology-critical elements (TCEs) in emerging key technologies in Europe – including renewable energy, energy efficiency, electronics or the aerospace industry – is such that policy-oriented recommendations to secure access to these raw materials have been given by the Enterprise and Industry department of the European Commission [European Commission, Enterprise and Industry 2010; http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report_en.pdf]. Similar initiatives in the US [APS and MRS 2011] state the existence of a global issue in this matter. On the other hand, the impact on environmental processes and potential (eco)toxicological threats is not restricted to a national level but most likely to a global scale; thus, trans-national scientific coordinated activities – here at a European level – appears as the optimum strategy to tackle the objectives indicated, through:

(i) **Identification of and collaboration with all the relevant actors** in Europe (and World-wide) which are interested in all aspects of the technology-critical elements, from their environmental processes, (eco)toxicological issues, and resource management. This includes research groups, funding bodies, stakeholders and policy-makers. For example, the EU, through the Directorate-General for Enterprise and Industry has recently launched a European Innovation Partnership (EIP) on raw materials (http://ec.europa.eu/enterprise/policies/raw-materials/innovation-partnership/index_en.htm) – which includes the here defined technology-critical elements (TCEs), with the aim of helping increase the supply of raw materials (e.g. new mining methods, recycling, retrieving of materials from waste), substitution of materials, and finding new ways to make better use of what we already have. This COST Action on TCEs will foster cooperation with this EIP on raw materials; accordingly, achievement of several EIP targets will benefit from the COST Action network, especially those related to (a) the creation of a network of research, education and training centres on sustainable raw materials management (http://www.criticalrawmaterials.eu/portfolio/knowledge- and-innovation-community-kic-for-raw-materials/), and (b) enhanced efficiency in material use and in waste prevention, re-use and recycling, with a specific focus on flows that are common to many product life-cycles and have potentially negative impact on the environment (http://europa.eu/rapid/press-release_MEMO-13-92_en.htm).

(ii) **Optimization of human and material resources in order to achieve the objectives in a shorter time frame.** The different research groups and the national-level research agendas vary so that research projects are generally focused on a small number of trace elements. Also, it is not uncommon that similar research objectives and projects are carried out by independent groups of different COST countries. In order to optimize the human and material resources, the network will promote the coordination of research efforts through collaboration between groups. This will ensure that a full suite of TCEs are considered in the maximum number of research projects and areas. Also, it will help avoiding duplicity of research therefore aiming for cost-effective scientific funding.

(iii) **Training of researchers and capacity building.** Transfer of analytical or (eco)toxicological procedures from labs that pioneer them to other labs is often slow. Publication of protocols may help, but there is no substitute for talking to those that make measurements and experiments and, ideally, seeing and making the work oneself. The network established in this COST Action will permit the training of researchers in new techniques and approaches through laboratory visits (STSM) and through training schools. These activities will involve researchers at all levels: those with many years of experience and those who are starting new methodologies. This will ensure that best experimental practices are spread amongst the COST nations.

(iv) **Improving the quality and comparability of results through standardized procedures**. Many TCEs measurements are challenging and have not been well standardized. It is often not clear that measurements of TCEs in one lab can be compared with those made by another lab and for many environmental matrices adequate reference materials and round robin tests are missing. This limits the understanding that can be derived from and the validity of global datasets and future fate-orientated models. To overcome this, the network will promote the establishment of standard procedures from sample collection, sample treatment and analysis and the exchange of samples between labs so that the full range of collection and measurement techniques can be inter-calibrated.

(v) **Establishing key research priorities on TCEs, increasing the level of scale and scope of the research activities**, funded at a national or international level. The network, formed by experts on the different research areas of TCEs indicated in the Challenge section, will evaluate and establish the research priorities – based on the current state of knowledge and future trends – and make this information available to the international scientific community. This will foster the implementation of common and complementary research strategies in the different research groups that increase the level and scale of their activities.

(vi) **Promote multidisciplinary research and interactions between scientific fields.** One of the major benefits of the Action is the creation of a multidisciplinary network around the study of TCEs, from analytical and geo-chemists to environmental scientists, toxicologists and engineers. This will allow a close interaction and exchange of ideas and current knowledge that one field of research may need/offer from/to the others. For example, this will help addressing whether appropriate analytical tools are available to determine the potentially toxic TCEs compounds or if the toxicity of a certain environmentally-impacted TCEs has already been tested.

C. MILESTONES AND DELIVERABLES: CONTENTS AND TIME FRAMES

STRATEGY

Objective 1 (A.1) - Development of a common understanding/definition of the subject matter

1. Science and Technology Event or Meeting, Action Workshop.
2. Internal and External Communication, Website.
3. Action Science and Technology Meeting, Working Group.
4. Joint peer-reviewed publication , open access.
5. Handbook, Guidelines, Best Practices, for S&T purposes.

Objective 2 (A.7) - Input to stakeholders (e.g. standardization body, policy-makers, regulators, users)

1. Contacts with Stakeholders, Input for the Formulation of Framework Programme Calls.
2. Stakeholders Outreach, including Unwritten Inputs and Dissemination, to end users/practitioners.
3. Documents to be Used as Input to Stakeholders, to the government sector.
4. Database , Open access.
5. Input to Other Science and Technology Funding Scheme for the Formulation of Calls for Proposals, written - international.

Objective 3 (B.11) - Around a topic of scientific and/or socio-economic relevance, allowing for knowledge exchange and the development of a joint research agenda beyond objectives 1 to 10.

1. Achievement of Specific Network Features in terms of WG Composition, expertise.
2. Science and Technology Event or Meeting, Action Conference.
3. Science and Technology Coordination, Short-Term Scientific Missions (STSM).
4. Science and Technology Event or Meeting, Training School.
5. Science and Technology Coordination, Application for Framework Programme Funding.

MILESTONES AND DELIVERABLES: CONTENTS AND TIME FRAMES

Management Committee (MC) and Working Group (WG) meetings:

A critical early milestone of the MC is to establish membership of WGs. Also, the MC will supervise and approve the activities of the WGs. Other milestones of the MC are the Action conference, the creation and managing of the Action website, the preparation of documents to be used as inputs to stakeholders, the liaison with other research programs, and ensure that gender balance and involvement of early-stage researchers is respected. Milestones of the WGs are the training and capacity building activities, organization of two workshops, production of a cookbook with tested and validated protocols for the analytical determination of TCEs, and preparation of publications. These milestones are detailed below.

Training and capacity building

Short term scientific missions (STSMs): STSMs will allow young researchers to spend 3-8 weeks at a research centre specializing in any particular area covered by the Action objectives: analytical determination of TCEs, environmental cycling and modelling, exposure and (eco)toxicology, to ensure that this knowledge is disseminated to where such expertise is lacking (e.g., authorities, industry or science). It is expected that 20-30 STSMs are completed during the life of the Action.

Training schools (TS): Training schools will feature lectures from leaders in the field and practical experience supervised by active practitioners. The audience of the TS will be graduate students and new post-doctoral workers with the aim of introducing them in the latest advances. Two TS will be held and, provisionally, the focus of the first TS will be on analytical protocols (from sampling to analysis) for TCEs, measurement uncertainty and data validation, and the second will concentrate on methods for impact assessment including environmental cycling, exposure and (eco)toxicology. First TS will be held on the second year of the Action (18 months), and the second on the third year (30 months).

Workshops:

Workshops will bring together scientists and stakeholders to discuss the current state of knowledge and plan future research. They will be open for participation of scientists from non-COST countries. Two workshops will be held, and the provisional foci are:

Environmental concentrations, cycling and modelling of TCEs. This workshop will be held on the second year of the Action (14 months). Here the current state of knowledge on the environmental concentrations and cycling of TCEs will be provided by the relevant research groups. The workshop will address the following questions: (i) How well do we know the cycles of TCEs? (ii) Which of these cycles are dominated (or may be in the future) by human activity? (iii) What are the implications on the elemental cycling from this anthropogenic perturbation? (iv) Does the current knowledge allow for a policy-oriented assessment (environmental guidelines, waste management, etc.)?

Human exposure and toxicology of TCEs. Will take place during the third year of the Action (26 months). The workshop will concentrate on current data of the human exposure to TCEs and their compounds from foods, water and air, and all aspects relevant to the potential biological effects of these substances. Based on a risk assessment perspective, the workshop will aim for identifying which TCEs and compounds are (or may be in the future) of concern for health organizations based on the combined factors of their amount of exposure, bioaccumulation and their degree of toxicity.

Conference:
In the final year of the Action a large high-profile conference will be organized and widely advertised. It will attract a diverse audience, including analytical and environmental chemists, environmental modellers, resource managers, toxicologists, food safety organizations, NGOs, industry, and the media and will be a flagship for TCEs research across Europe. The book of abstracts will be accessible at the Action website and/or at a specific website created for the conference. Also, a conference report will be produce and disseminated (i.e. conference website, conference proceedings will form the basis for a special issue in an international peer-reviewed journal, etc.).

Dissemination:
The MC will oversee dissemination activities and organize reviewing and approval of publications and reports through a Dissemination and Editorial Board composed of MC and WGs members as well as external experts (e.g. individuals from non-COST country institutions).
Action Specific Website: An Action specific website will be set up and regularly updated. It will contain overview material about the Action, and act as a portal from which to enter information about all aspects of the Action. It will contain reports of the MC and WG meeting and all relevant information on STSMs, TS, workshops and conference. Links to dissemination material (cookbooks, publications, workshops and conference reports, etc.) will be prominently given in the Action website.

Cookbook: The production of a cookbook with details of suggested protocols for the accurate determination of TCEs and their species in the different environmental matrices will be organized by WG1. This will be a unique resource for future scientist interested in the determination of TCEs as these measurements become increasingly routine in coming years.
It is expected that scientist from non-COST countries collaborate in the production of the cookbook in those cases where their expertise is relevant. A version of this cookbook will be available free to download on the Action website. The cookbook is expected to be available online (Action website) before the end of the Action (year 4).

Open-access peer-reviewed publications: One of the objectives of WGs 1, 2 and 3 is to provide a clear picture of the current state of knowledge of their subject areas and propose research priorities.

In order to make these conclusions widely disseminated among the scientific community, open-access peer-reviewed publications in the form of a forefront/trend will be produced, covering the analytical aspects of TCEs (WG1), their environmental concentrations and cycling (WG2), and their exposure and (eco)toxicology (WG3); these publications will be advertised on the Action website, and are expected to be available before the end of the Action (year 4).

Workshop reports: Workshop reports will be produced outlining the discussion and findings of the two scheduled workshops. These will act as a summary of the workshops and will serve as a starting point for further discussion, as well as for communication of the workshop findings to a wider audience. These reports will be provided online on the Action website as pdf documents. Reports will be available within 2 months after the workshops.

Conference reports: The book of abstracts will be accessible at the Action website and/or at a specific website created for the conference. A conference report will be produced – within two months – outlining the discussion and findings of the conference and it will be accessible on the Action and conference website. The presentations given in the conference will form the basis of a special volume in an international peer-reviewed scientific journal, and should be expected around one year after the conference.

Inputs to policy makers, stakeholders, governmental authorities: The Action will engage with relevant stakeholders from the start and meet periodically at the MC and WGs meetings to show results and get feedback. A document compiling the most relevant information, findings and conclusions derived from the activities of the Action will be produced and will serve as an input to stakeholders. It will be circulated to public health departments, environmental protection agencies and industry departments both at a national and European level, as well as other organizations interested in TCEs like industrial consortiums or NGOs. The document will be available on the fourth year of the Action.

Liaison and interaction with international research programs, funding bodies and industry: This Action will provide a mechanism for interaction between national research programs within the EU Member States and associated COST countries as wells as providing a forum for liaison with TCEs focused research programs in other countries (e.g. NSF in USA). The Action will seek interaction and cooperation with international research programs (e.g. www.geotraces.org) and networks (e.g. EuroGeoSurverys, International Waters Association, Society of Environmental Toxicology and Chemistry, etc.) which may benefit from the activities carried out and outputs delivered during the Action. The Action will foster cooperation with the European Innovation Partnership (EIP) on raw materials (http://ec.europa.eu/enterprise/policies/raw-materials/innovation-partnership/index_en.htm) – which includes the here defined technology-critical elements (TCEs); accordingly, achievement of several EIP targets may benefit from the COST Action network, especially those related to (a) the creation of a network of research, education and training centres on sustainable raw materials management, and (b) enhanced efficiency in material use and in waste prevention, re-use and recycling, with a specific focus on flows that are common to many product life-cycles and have potentially negative impact on the environment. The activities of the Action will also serve for those industries working on the mining, supply and recycling of TCEs in Europe, increasing the impact of the Action significantly.

Gender balance and involvement of early-stage researchers:
This Action will respect an appropriate gender balance and will involve early-stage researchers in all its activities and levels, and the MC will place this as a standard on all its MC agendas.

Overview of the Scientific and Societal Impacts of the Action:
The activities aimed in the Action and the foreseen milestones and deliverables detailed above are designed based on the urgent need in Europe (and globally) to have a Europe-wide integrated response in order to gain environmental and toxicological data on these technology-critical elements, enabling Europe to lead the way in tackling this priority issue on a global stage. That is, to improve our basic understanding of their behavior and what is required in terms of monitoring, assessment and regulation as well as raising public awareness and providing critical information to inform debate on the issues surrounding TCEs.

This COST Action will last for four years, which is the time required to achieve the specific goals outlined in this COST Action. Actions goals of each of the four years of its duration include:

Year 1:
1.1 Convene Management Committee (MC)
1.2 1st MC meeting
1.3 Action website launched
1.4 At least one meeting of all four WGs
1.5 Second MC meeting to solve any early teething problems and review early work of WGs. Establish Dissemination and Editorial Board
1.6 5 Short Term Scientific Meetings (STSM) conducted

Year 2:

2.1 One/Two annual MC meetings to review progress and planning for the future

2.2 WG meetings

2.3 Website update

2.4 First Action workshop – 'Environmental concentrations, cycling and modelling of TCEs'

2.5 First Training School – 'Analytical protocols, uncertainty measurement and data validation'

2.6 5-10 STSM conducted

Year 3:

3.1 One/Two annual MC meetings to review progress and prepare dissemination activities (publications)

3.2 WG meetings

3.3 Second Action workshop – 'Human exposure and toxicology of TCEs'

3.4 Second Training School – 'Methods for impact assessment'

3.5 5-10 STSMs conducted

Year 4:

4.1 One/Two annual MC meetings to review progress and prepare dissemination activities

4.2 WG meetings

4.3 Final Action conference

4.4 5-10 STSMs conducted

4.5 Publications, input to stakeholders

D. ACTION STRUCTURE AND PARTICIPATION – WORKING GROUPS, MANAGEMENT, INTERNAL PROCEDURES

Management Committee

The management committee (MC), led by the Chair and Vice-Chair, will contain at least one member from all COST participating Countries. It will meet once or twice per year depending on workload and budgetary constraints. A critical early milestone of the MC is to establish membership and chairs of WGs (Month 1). It will supervise the activities of working groups (WGs), oversee all WGs tasks and receive reports from them. The MC will be responsible for the administration of financial arrangements within the COST Action. The MC will oversee outreach (including the website) and organize reviewing and approval of publications and reports through a Dissemination and Editorial

Board composed of MC and WGs members as well as external experts (e.g. individuals from non-COST country institutions). Accordingly, the MC with the aid of the Dissemination and Editorial Board will be responsible for the dissemination of the results and conclusions delivered by the WGs, making this information available to the international scientific community, stakeholders and public bodies (preferably using open access systems). These publications will have a forefront/trend/view format in order to show the current state of knowledge and propose research priorities to tackle the scientific challenges. The MC will also oversee organization of Workshops and the Conference. Additionally, the MC will have a proactive strategy with the aim of boosting the creation of consortia for the preparation of project proposals both at a national and international (e.g. EU programmes) level.

Working Groups (WGs)

Membership of WGs may be subject to change according to the needs of particular expertise. However, some permanent members staying in the WGs are needed to ensure the transfer of knowledge. Therefore, composition of Working Group will be adapted as the different key issues are being considered. Where applicable, and in certain cases, individuals from non-COST country institutions will be involved as WG members if their expertise is beneficial to attain the Action objectives.

Four WGs will deliver the Action objectives:

Working Group 1. Analysis and Inter-calibration

This WG will evaluate the most appropriate current available procedures for the determination of TCEs and their species, especially those with known or suspected deleterious effects, in environmental samples. It will also propose directions for the development of new analytical strategies with the aim of decreasing the analysis time and costs allowing routine monitoring. It will promote community-wide inter-laboratory exercises to ensure analytical accuracy and will seek interaction with the Institute for Reference Materials and Measurements (IRMM; European Commission, Joint Research Center) for the development of appropriate certified reference materials for TCEs. An expected product of WG1 is to prepare an analytical “cookbook” providing details and best practice advice on suggested protocols for accurate measurement procedures for TCEs.

Working Group 2. Environmental Impact and Cycling

The WG will address different dimensions of the environmental fate of TCEs: (i) It will condense the available information on environmental TCEs concentrations from national and international databases across Europe (e.g., www.weppi.gtk.fi/publ/foregsatlas), (ii) complement the existing data by own measurements and incubation experiments, to create more complete pictures on the human impact on the TCE cycles and (iii) interact with and complement existing efforts on TCEs sustainable exploration, extraction, processing and recycling (e.g. KIC on raw materials: http://eit.europa.eu/kics/2014-call-for-kics/) in order to name sectors in which recycling and waste management strategies may be improved. The overall goal is to deliver new insights on the anthropogenic impacted biogeochemical TCEs cycle in Europe. WG2 will organize the workshop 'Environmental concentrations, cycling and modelling TCEs'.

Working Group 3. Human exposure and (eco)toxicology

This WG will critically collate the available data on human exposure, potential human health risks, mechanisms of action and (eco)toxicology, identifying the existing gaps that need to be addressed. Where existing data allows it, estimations of the human exposure for TCEs will be provided, indicating the most sensitive groups of population (e.g., children or aged people) and the food groups with a higher contribution on the intake of TCEs. Based on toxicological data, main TCEs and their compounds of concern will be identified; for these, the WG will evaluate suitable markers of exposure and effect. Also, this WG will foster the use of the Biotic Ligand Model (BLM) to predict the toxicity of TCEs in aquatic bodies; given that this requires the knowledge of the element speciation under the different environmental conditions, WG3 will seek collaboration in this task with WG2 (regarding environmental cycling) and WG1 (regarding speciation). WG3 will organize the workshop 'Human exposure and toxicology of TCEs'.

Working Group 4. Training and Capacity Building

This WG will organize and supervise training and capacity building events. It will meet less frequently, generally adjacent to a MC meeting to reduce costs. Its remit will be to ensure that young researchers are adequately trained and that information about TCEs analytical determination, sustainable environmental resource management, and exposure as well as (eco)toxicology is disseminated to where such expertise is lacking (e.g., authorities, industry or sciences). This WG will organize, together with the respective managers, the short-term scientific missions (STSMs), and two training schools (TS).