PROJECT FINAL REPORT

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1 FINAL PUBLISHABLE SUMMARY REPORT

1.1 EXECUTIVE SUMMARY

The project was defined by the partners and formulated in a report act as a guideline for partners in the consortium and summarizes the basic information needed for research and the challenges faced by the consortium. End-user applications are specified covering both indoors and outdoors. The 'AXIOMA' project focused at investigating fungal and algal growth on coating and plasters in both indoor as well as outdoor environment and growth of fungi on tiles and grout in two indoor environments: bathroom and kitchen. In indoor applications the highest risk of attack by such micro-organisms was shown to be the bathroom environment, which was concluded from extensive testing. Furthermore, cold cellars with thermal bridges were shown to form a risk. In the outdoor situation the focus was put on algal growth on coatings and plasters, since the main concern is algal growth, especially on north facing facades. The growth rate of micro-organisms is sensitive to relative humidity and temperature and depends on the organism. To be able to investigate the effect of environmental conditions, a specific data-set of weather conditions (relative humidity, temperature, days of rain, etc.) through Europe was created, with data covering the last 10 years. The micro-organisms present in each end-user application were identified. Enzymes secreted by these organisms were identified, except for algae in which no enzymes are excreted, however other organisms will grow in the biotope of this organism. The choice of biocides (especially zinc pyrithione) reflects considerations of cost, conformity to the relevant regulations and effectiveness against a broad spectrum of organisms (including bacteria).

For efficient protection biocides should be released at a rate reflecting the growth rate of the organisms. Thus any 'slow release' technology (controlled release by moisture) should be tuned to ensure that biocide release maps the growth of organisms in the substrate being protected. Ideally a switching mechanism would be most advantageous, since that would act only when needed. This strategy is called 'BioSwitch'. To achieve this BioSwitch biopolymers can be used that decompose on an action of the enzyme, freeing the active that prevents biological growth. To achieve this suitable biopolymers should be chosen that are compatible with coating and plaster formulations, and should be able to retain the biocide. Issues related to preparation and application, such as batch-sizes, maximum particles size of biocide containing additives, etc. For paints and plasters the behavior of the new materials in terms of rheology, gloss, setting-time etc. should differ little from that of conventional materials used in the building trades. For ceramic materials two approaches to achieving resistance against fungi were investigated. A suitable found working solution was submitted as a patent.

BioSwitch - Three bio-polymers were selected as BioSwitch materials, celluloses, proteins, and fats. After screening cellulose, they were not considered option in the formulations to be used. The biocide was inserted in the polymer to investigate the triggered effect. In both cases from capsules triggering was observed by addition of artificial enzymes, also confirmed by experiments on colored actives acting as model compounds for biocide. The particle size still needs to be further optimized. Also in coating and plaster formulations the BioSwitch materials were tested. However, unfortunately either too much retention or early leaching was observed, using the agar based medium tests. The high amount of nutrients may affect the testing. In all cases chemical analysis was difficult due to the low concentrations, and due to interference effects of other compounds. Fortunately, it was clear from the chemical analysis that the leaching and triggering can be observed, and may be optimized using a combination of biopolymers. Additionally, it was shown from a diffusion cell experiment that enzymes could pass the coatings used, allowing them to reach the biopolymers.

Nanoclay technology - Different nanoclays were produced with different surface modifiers. Different synthesis routes were investigated as well as different modifiers and clays. Discoloration effects were observed and subsequently solved. An improvement of a factor of 14 was observed in biological experiments, showing the potential of the nanoclay technology. However, the testing (performed by new test methods concerning artificial rain events and subsequent biological testing) conditions affects the release of the biocide. Differences in coating formulations also greatly influence the release rate. In most cases the nanoclay performed better (never less!) than the ordinary used biocide and/or zinc pyrithion. The latter has a very low solubility and showed already a slow release due to its chemical nature. Consequently, more in depth knowledge is required to optimize the technology.

Modelling - To understand the differences in coating formulation, environmental conditions, an empirical an deterministic model was built to describe the release of the biocide from the materials. The input parameters were determined from specially selected experiments, such as temperature, moisture transport, diffusion cell, wet cup and Magnetic Resonance Imaging (MRI) experiments. The resulting model calculations, verified by experimental tests, predicted a far slower release of biocides. We found that the humidity in the rain experiments is the reason, a high relative humidity after the rain event affects the release in fact it accelerates the release. Furthermore, the typical timescales of the process are identified and can be used for more targeted material development and release vehicles. Furthermore, a parameterized model was developed to describe the data obtained from the bathroom, cellar and kitchen. A specific software tool, based on experimental tests and empirical models, was designed and is available online through the AXIOMA website. It assists in the prediction of fungi and algae risk in both indoor and outdoor situations.

LCA and risk assessment - LCA was carried out to compare the environmental footprint of AXIOMA paints, plasters and tiles. A comparative analysis of different scenarios were made by taking into account the release of the biocide, the lifespan of the product, as well as, the amount of paint used in intermittent repaints for the reference surface. The results of LCA on the base paints have been compared with similar studies that were performed in the past in other European countries as a benchmark for the base material. The LCA shows a clear impact and positive of the AXIOMA technology for the products investigated.

1.2 PROJECT OBJECTIVES

The acronym "*Axioma*" of this project is based on "***A**ctive e**X**ternally **I**nduced release in c**O**nstruction **MA**terials*", which is our "Axioma" for innovation of finishing materials for the sector of construction.

1.2.1 INTRODUCTION

Bio-resistancy of building and finishing materials usually requires addition of dedicated bioactive chemicals, so-called biocides. Two main reasons exist why biocides are added to materials for constructions. First of all, micro-organisms negatively affect the durability of material, i.e. induce biodegradation. Secondly, biocides are also used to prevent the growth of micro-organisms (algae, fungi and bacteria) that create unhealthy indoor environments or affect the esthetic value (Figure 1).

Figure 1: *Fungal growth in a living room, bathroom and algal growth on plaster.*

Traditionally, the action of biocides in materials, (e.g. coatings, plasters) is based on a *passive and uncontrolled* release principle, i.e. molecular dispersion of the active ingredients in the material matrix. As a consequence these bio-active agents have a high and inherent mobility in the matrix, which causes an initial boost in biocide activity and a steep decrease when time proceeds. Consequently, we are facing two challenges:

✓ ***Short bio-resistance of materials leads to early replacement***

Coatings in the built environment usually **exhibit biocidal functionality between 0.5 and 2 years**, whereas the desired service life in building practice is at least 10 years. Application of an increased biocide concentration only results in a minor prolongation of the material service-life. Besides the environmental impact of early replacement of such functional coatings, an inherent disadvantage of the inefficiency of the traditional release concept is the emission of a relatively large amount of biocide molecules into the environment. In addition, the limited bio-resistance of the material will allow the growth of micro-organisms, which negatively affect health, leading to hypersensitivity and allergic reactions such as rhinitis and asthma. This is a problem prevalent in homes and occupational buildings worldwide [1,[2]]. A total of 11% of the entire global burden of disease has been attributed to unhealthy buildings. A recent pan-European housing survey by WHO clearly indicates a link between present-day housing conditions and human health and well-being. Therefore, ***the performance of biocide containing materials needs to be improved.***

✓ ***Environmental legislation restricts use of biocides and chemicals***

[1] F. Wu, D. Jacobs, C. Mitchell, J.D. Miller, M. Karol, *Environmental Health Perspectives*, 115 (2007) 953-957;
[2] O.C.G. Adan, et al., *Environmental Health Perspectives*, 115 (2007) 983-988.

Growing ecological demands and international environmental legislation increases even more the pressure on the materials' performance. First, the application of active agents for materials' bio-resistance is regulated by the Biocidal Product Directive 98/08/EC, which sets strict conditions with respect to the use of bio-active agents [3]. In line with that, the European Commission launched mid 2004 the 6th Environmental Action Plan [4] in which the restriction of chemical emissions and consequent risks for human health have become a first priority. And second, the industrial trend towards eco-friendlier building products is often accompanied by an increase in the biodegradability, requiring even more biocides to compensate.

1.2.2 CONCEPT OF THE PROJECT

Our answer to the above challenges is:

To develop, adapt and apply smart release concepts of eco-acceptable biocides to extend service life of finishing materials substantially.

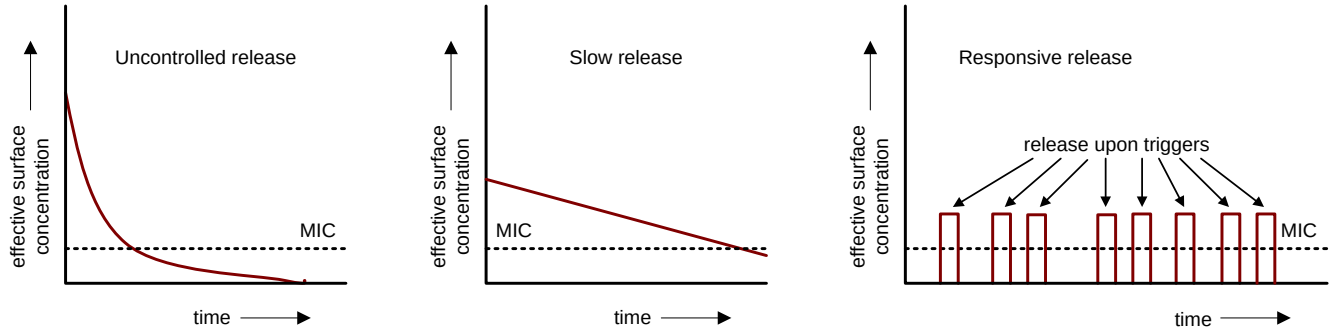

Figure 2: *Three release mechanism; uncontrolled release, slow release and responsive release. The minimum inhibition concentration (MIC) denotes the concentration necessary to inhibit biological growth.*

The smart release concepts will be based on induced or triggered release, giving **bio-inhibition only when needed**. This approach is **new** for materials **in the construction sector**, and requires considerable research effort to make the technologies applicable for finishing materials in the construction sector. Figure 2 shows three release principles. The left figure shows the uncontrolled release process which is the current situations for coatings and plasters in which biocides are added. The slow release mechanism is shown the middle, in that case a retarding step is used to release the biocides. However, the ultimate situation is the situation in which release is initiated in case of trigger.

In our case the responsive material will be able to react to variations in moisture level and presence of micro-organisms. We will focus on biocide release in response of secretion of enzymes by the micro-organisms (ultimate solution). To achieve this we will use a BioSwitch technology in combination with surface modified nano-clays. The BioSwitch matrix consists of a biopolymer which is destructed when in contact with enzymes secreted by micro-organisms. By combining this BioSwitch technology with surface modified nano-clays technology, a high loading of the BioSwitch material with biocides can be achieved. In addition the nano-clay technology itself can be used as a responsive release technology which reacts upon high moisture levels (can be considered a first step solution). We will focus on mainly on two finishing materials, plasters and coatings. In addition we investigate the possibility of applying a post-treatment (a coating) on ceramic materials.

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3 Biocidal Product Directive 98/8/EC issued on 16 February 1998 concerning the placing of biocidal products on the market.

4 6th EU Environmental Action Plan "Environment 2010: Our future, our choice" (2004)

1.2.3 SCIENTIFIC AND TECHNOLOGICAL OBJECTIVES

The scientific and technological objectives of this project are:

- To **extend the service-life of finishing materials by implementing a "smart" release mechanism consisting of an induced response on external stimuli in finishing materials.** The selected smart release mechanism is based on BioSwitch in combination with functionalized mineral (nano-clay) particles. With the selected release mechanisms we are aiming for **at least a factor 5 increase in life time with respect to bio-resistivity (>10 years)** to achieve the required impact. Simultaneously minimizing the concentration of active agents in the product formulation by a similar factor 5. Taking into account already a **two times increase** in service-life of only the 2.3 million ton architectural paints (100% replacement) of this would save **approximately 1 million ton (3.5 G$) of paint annually**, not even considering the plaster market.

- To **reduce the amount of biocides required considerably** (at least a factor of 5 compared to ordinary materials) and tune the release systems to "environmental friendlier" biocides. For example, "environmental friendlier" biocides can be used that decompose (e.g. as a consequence of UV radiation, or reaction with oxygen) after having performed their job. For example, this alone would lead to a reduction of 20 M$ annually in Europe if implemented on all film-fungicides in coatings in Europe.

- To **deliver a proof-of-principle of the smart release concepts in finishing materials.** This means that we focus on the application of *existing release concepts* in two host finishing materials by transferring proven release concepts from other application domains (food and pharmaceutical science) into the building and construction domain. We will focus at the BioSwitch technology in which we will use functionalized mineral particles. The proof of principles and up-scaling will target coatings, plasters, and a post-treatment (coating) on ceramic materials.

- To **develop new measurements techniques to assess the "smart release" of different products**. The new materials will require new measurement techniques and measurement procedures to asses the performance and the release in accelerated test methods. These accelerated test methods should resemble the conditions in the final application area.

- To **define and obtain the technical requirements** of a production process that is needed **to up-scale** the new smart release concept. Of course finally the technology should be produced in large quantities. The materials will be demonstrated in a demonstration room in Spain and in the Netherlands to show the performance of the materials in their application area.

The results of the project will be innovative building materials (coatings, plasters and post-treated ceramic materials) with high added value, which provide cost-effective solutions for the building and construction sector and a strong reduction of the environmental impact and health related problems. Various demonstrators (e.g. walls with coatings, plasters and post-treated ceramic materials) will be available. Furthermore, more know-how will be available, including methods (models) and setups to test products for their bio-effectiveness.

1.2.4 S&T RESULTS

The project has focused on developing the BioSwitch technology, which is a triggered release of biopolymers and slow release 'nano-clay', which can be combined with the biopolymer BioSwitch technology. In addition, the AXIOMA project has focused at developing specific measurement methods, models, and a software tool for evaluating the fungal and algal growth risk in the different application areas. Furthermore, life cycle analysis has been used to assess the impact of the technologies. To evaluate the products the materials were tested in demonstration setups.

- ✓ To investigate the BioSwitch technology the AXIOMA project has focused on testing different biopolymers. We have shown that cellulose based biopolymer could not be used because of the incompatibility with the coating matrix. Clearly, the combined approach of research on fundamental and application level proved to be an advantage. Proteins and fat based biopolymers showed to be more suitable biopolymers. It was shown in lab experiments that triggering of biocides could be achieved when triggered with enzymes. Furthermore, we have shown several methods and strategies to "tune" the release within these biopolymers, by addition of several compounds to influence the network structure and increase binding with the biopolymer. Different methods of preparation were investigated, including spray drying. The most challenging was to obtain particles sizes below 40 µm, needed for paint applications. For application in plasters this was not a restriction. Experiments have also shown that the enzymes can permeate the commercial coatings used.

- ✓ In case of the nanoclay technology we have shown a potential protection of the nano-clays up to a factor of 14, using a rain setup (developed within the framework of the AXIOMA project) reflecting more realistic and practical leaching conditions. In the demonstrator we have shown that nano-clay containing materials were always amongst the best performing.

- ✓ New experimental test methods have been developed. A large data set of indoor (bathroom and kitchen) and outdoor temperature, rain and relative humidity conditions have been collected. Furthermore, the experiments showed that the test method greatly influences the release behavior of the material. Slow release technology based samples outperforming others, showed equal performance with other samples in other tests. In those cases, these were standard testmethods, having an extreme regime, and as such those methods currently in use in the biocide industry, cannot be used to assess the performance of triggered release. Agar based test have an excess of spores and nutrients, and as such the timescale of growth is much shorter than in the application. In case of leaching tests, 24h dipping tests showed that this is a very aggressive tests. Consequently, it was concluded that this has shown to greatly affect the results of the tests. This indicates the timescales of the processes are very important, and a more deep insight in the fundamental processes is needed. Also the coating formulation has a major impact on the release, e.g. binder content, porosity, will influence the behavior. Furthermore, we concluded that even accelerated tests took a relatively long time, extending the time needed for a feed-back loop essential in development to several months for each step taken.

- ✓ We have demonstrated the concept materials in demonstrators, since it is necessary to demonstrate the effectiveness of the proposed new products in comparison with existing practice. However, unexpected difficulties were encountered in attempting to establish the growth of microorganisms on the surfaces to be examined in the demonstrator. Controlling the climate proved to be difficult, several months were needed setting up, running and improving various test rigs and the protocols for using them. However, it was found that:
    - The materials containing the nano-clays were always best performing, and outperformed the standard biocide used.
    - The ceramic tiles protect the grouts, which directly relates to the experiments performed in the laboratory.

- ✓ To develop a suitable release system, models are needed to determine the typical timescales and obtain the corresponding parameters which can be used for the design of the release technology. The model built, within the framework of AXIOMA and TNO internal programs, can be used to predict the biocide release, based on determined parameters. As a result of the model we have obtained more

insight in the working process and timescales thereof. The model has also provided considerable insight in the processes and timescales involved.

- ✓ LCA has shown that release technologies have a considerable reduction in the environmental impact. Moldy conditions have a major impact on the indoor unprotected environment, due to airborne emissions and can increase the human health impact up to 89%. Conventional antimicrobial materials have significant higher impact compared to products using encapsulated technologies in all scenarios studied. Conventional antimicrobial materials have a higher impact on human health compared to products using encapsulated technologies, when assessed in view of ecosystem quality.

- ✓ During the course of the project the landscape with respect to biocides in Europe has changed considerably, with the biocidal product directive[5] and the biocidal product regulation (BPR)[6]. The number of biocides that can be used in products have reduced considerably. Additionally, labelling regulations will also lower the threshold for pot labelling. The focus of the AXIOMA has been on several biocides, but especially zinc pyrithione. At an early stage in the project it was decided to concentrate on zinc pyrithion for practical reasons: one of the beneficiaries is a supplier of the material, the product is known to be effective against a broad spectrum of micro-organisms and is widely used in toiletries such as anti-dandruff shampoo. Furthermore, it was likely to be acceptable in the context of building products. Zinc pyrithion has some advantages: Its low solubility in water makes it an inherently slow-release biocide. However, this makes the task of demonstrating the benefits of slow and triggered release compared to 'normal' release more difficult. It must be stressed that the AXIOMA concepts are 'generic' and potentially applicable to any permitted biocide compound.

- ✓ In addition, some fast and relatively low-cost assay techniques were difficult to apply to low concentrations owing to spectral masking by other materials. In all it was difficult to determine the low concentration of biocides, especially in case of more practical release circumstances. The rain test method developed has the disadvantage that although it is more realistic, more spreading in the results exists. Consequently, duplicates for the chemical and biological tests are needed. A good relation has been observed between chemical and biological tests.

- ✓ Making products acceptable to manufacturers of surface coatings at a price attractive to buyers in view of improved performance: the choice of materials and processes for AXIOMA is closely circumscribed, notably in terms of particle size, stability, viscosity, colour, ageing, temperature sensitivity, fire, health and environmental hazard, compatibility with a host of ingredients used in product formulation and finally cost. Finding a route through such a maze without a map & compass proved frustratingly slow and almost brought the project to a halt around mid-term. It then became necessary to shift resources from new product development to screening processes and materials towards techniques for modelling biocide and enzyme transport mathematically.

    - The mathematical model and prediction tool will facilitate resumption of work after the project's end in different combinations and permutations of parties, target product, release system and choice of biocide (or combinations thereof). In case of the ceramic products, the technology applied can be used as an active trigger to protect the grout. A patent was written. Furthermore, it was shown that a route towards the market is realizable, not only based on the technical results, but also based on costs and gains.
    - Furthermore, for the nanoclays it was shown that it can be an economically feasible route, when taking certain commercial attractive clays and modifiers.
    - Some biopolymers needed for the BioSwitch materials are costly, however, some particular based bioswitches seem to be the most commercial attractive material.

[5] Biocidal Product Directive, BPD, 98/8/EC: 1998 – 31/08/2013
[6] Biocidal Product Regulation, BPR, (EU) No. 528/2012: 01/09/2013

1.2.5 POTENTIAL IMPACT

A complication has since arisen with the arrival of the Biocide Directive and Biocide Regulations now coming into force. This will have a major impact on the building industry:

1) the high *cost* of compliance will further restrict the choice of biocide available for product formulation; and
2) the *need* for compliance will shift concern from the present overriding pre-occupation with carbon emission and energy to bio-protection and safeguarding health and environment.

In the distant past building design concerned aesthetics, structural integrity and durability, today's regulations force attention on energy efficiency and sustainability, but from now on the Biocide Directive will force attention onto concerns with environment, health and safety. In this milieu it is not structural integrity and comfort that plays the key role but chemistry – a subject about which the building industry (comprising the regulators, architects, contractors and building managers) knows next to nothing while facing a lamentable lack of reliable data.

Past experience with the ozone layer and global warming shows that it takes at least a couple of decades to pass from a regulatory *crisis* to established *practice*. In due course, the emerging crisis in bio-protection will provide fertile ground for new scientific services, R&D, innovation and new product development but in the meantime there is the problem of how to operate in this nascent environment, affecting particularly those parties in the value chain, e.g. like partners in AXIOMA, who possess only modest means.

Best placed will be AXIOMA partners offering scientific/technical services – they can already promote themselves unhindered by publishing papers, appearing at conferences, lobbying regulators and cultivating those who control funds (something they do in any case). This should put them into a prime position for creating and subsequently exploiting the new opportunities emerging in the wake of the Biocide Directive.

In this context attention to the Simplified Active Substances scheme of the Biocides Regulation 528/2012 might be helpful: it offers both opportunities for lobbying (as 'discretionary powers' to modify Annex 1 are implied) and the pursuit of new ideas and innovations meeting the requirements of the Simplified Active Substances regime. Much more difficult will be the position of those offering, or planning to offer, biocidal products. Again, there are several routes to exploitation that merit further consideration:

- As zinc pyrithion is already widely used in toiletries, there is an opportunity to lobby for its inclusion under the Simplified Active Substances scheme, though this will no doubt take time and much effort to bear fruit.
- In the meantime it may be possible to incorporate zinc pyrithion in formulations without making any biocidal claims for it. This could be particularly promising if the smart release technologies developed under AXIOMA allowed the use of very low levels of biocide in producing effective and long lasting formulations. Promoting such products to justify the extra cost will require an imaginative approach and considerable care.
- Finally, the situation should stimulate a search for other solutions to the problems addressed by AXIOMA that more readily fall into the simplified active substance category. Guidance Notes on the subject being drafted by the Commission will cover, among others, substances such as *'food additives, pheromones and other substances considered to have low toxicity such as weak acids, alcohols and vegetable oils used in cosmetics and food'*. The wording, seems to invite creative interpretation.

The coming years it is clear that the biocide producers will move from getting their products legislated through the complex regulatory system towards new product development, in a next step to keep or increase their market share via innovations. Steps towards stabilizing and decrease the biocide release from products is to be expected. As indicate the challenges related to measurement and long cyclic testing, requires new approaches.

It seems that the modelling aspect is a great opportunity to aid the market by focusing their product innovation.

1.2.6 DISSEMINATION ACTIVITIES AND EXPLOITATION

In the table a list of the scientific publications is given, which the partners have published during the course of the project, updated in accordance to the indication of partners. They are briefly listed here:

- ✓ TNO: Decreased bio-inhibition of building materials due to transport of biocides
- ✓ TNO: “Ontwikkeling van release technologieën voor verlengde bescherming van coatings tegen micro-organismes”, VVVF Meeting
- ✓ TNO: AXIOMA Promotion video
- ✓ TNO: “Better biocide release for better buildings”
- ✓ ITC: "A project steps forward to increase the useful life of construction products"
- ✓ ITC: "An R+D project is about how to avoid the damage on construction materials due to the growth of micro-organisms"
- ✓ ITC: "ITC takes part in a project which aims to prevent the growth of micro-organisms on ceramic tiles"
- ✓ DAP / NEA: "From textile to construction, Nearchimica Experience"
- ✓ DAP: “Communication of AXIOMA activities and brief resume of achievements”
- ✓ NTUA: “Environmental performance of antimicrobial paints enhanced with biocide smart release technologies”
- ✓ NTUA: “Environmental performance of antimicrobial ceramic tiles enhanced with biocide smart release technologies”

	Title of the paper	Journal/Oral	Authors	Published
ALL	AXIOMA Promotion video	www.axioma-project.eu	VWV/TNO/STR	December 2013
ALL	Impact of biocide and release technologies in the built environment	SYMPOSIUM	All partners	11th December 2013
TNO	Decreased bio-inhibition of building materials due to transport of biocides	Heron	S.J.F. Erich, S.M. Mendoza, W. Floor, S.P.M. Hermanns, W.J. Homan, O.C.G. Adan	2011
TNO	Development and evaluation of a biocide release system for prolonged antifungal activity in finishing materials	Progress in Organic Coatings	J. Eversdijk, S.J.F. Erich, S.P.M. Hermanns, O.C.G. Adan, M. De Bolle, K. de Meyer, D. Bylemans, M. Bekker, A.T. ten Cate	2011
TNO	Ontwikkeling van release technologiën voor verlengde bescherming van coatings tegen micr-organismes "Development of release technologies for prolonged protection of coatings against micro-organisms	VVVF/NVVT Coating Innovation Day		April 2013
TNO	Better biocide release for better buildings	International Innovation	TNO/UNR	January 2014
TNO	Auswaschungen aus beregneten Fassaden	Technische Akademie Esslingen	S.J.F. Erich	21-22 February 2011
TNO	Novel biocide technology V Berlin, Germany	Vincentz Network, Berlin	S.J.F. Erich	12-13 April 2011
TNO	Conference "Leaching of Biocides from Façade Coatings "University of Applied Sciences, Switzerland	HSR University of Applied Sciences, Rapperswil, Switzerland	S.J.F. Erich	24-25 May 2011
TNO	Modelling biocide release based on coating properties to predict anti-microbial protection	Progress in Organic Coatings	S.J.F. Erich, V.V. Baukh	Deadline: 31 july
TNO	Towards new testing methodologies for materials having new smart technologies for release of biocides (OUTLINE)	To be determined	TNO	2014
TNO	Enzymatically triggered release of model compounds from zeine particles (DRAFT)	To be determined	M. Nieuwland, N. E. Papen-Botterhuis, W. C. Drost, T. M. Slaghek, B.S.J.F. Erich	2014
UPM	Measurement protocols for temperature and relative humidity assessment in indoor living environments	Journal of metrology	UPM	March 2014
NTUA	Environmental performance of antimicrobial paints enhanced with biocide smart release technologies	Poster session	NTUA, M. Taxiarchou, A. Peppas, M. Krokida, K. Kyriakopoulou.	June 2013
NTUA	Potential environmental impact of Nanotechnology based antimicrobial coating for construction applications	Integrated Environmental Assessment and Management (IEAM)	NTUA	March 2014
NTUA	Predicting smart biocide protection in building materials.	Measurement, Science & Technologies	DAPP, TNO, UPM	After the project end
NTUA	A novel approach to biocide modeling and micro-organism growth for providing effective information on building material's lifetime	Building Materials, (…)	DAPP, TNO, UPM, NTUA	After the project end
KER	Ceramic product with controlled release of a compound with biocidal activity	PATENT	KER, JAN, TNO, ITC, UJI	Dec 2013

1.2.7 PROJECT WEBSITE AND KEY CONTACTS

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1.2.8 THE PARTNERS

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1.2.9 PROMOTION WORK MATERIAL

Furthermore, project logo, diagrams or photographs illustrating and promoting the work of the project (including videos, etc.), as well as the list of all beneficiaries with the corresponding contact names can be submitted without any restriction.

2 USE AND DISSEMINATION OF FOREGROUND

2.1 SECTION A (PUBLIC)

The list below describes all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

	Activity	Medium	Authors	Published
ITC	News article *"ITC participa en un estudio para eliminar las bacterias de las baldosas cerámicas"* "ITC takes part in a project which aims to prevent the growth of micro-organisms on ceramic tiles"	Local newspaper Levante	ITC	January 2010
ITC	Presentation of AXIOMA " An R+D project about how to avoid the damage on construction materials due to the growth of micro-organisms " This material was addressed to scientific community, media and public in general	Servicio de Información y Noticias Científicas del Ministerio de Ciencia e Innovación	ITC	March 2010
ITC	Presentation of AXIOMA "An R+D project about how to avoid the damage on construction materials due to the growth of micro organisms" This dissemination material aims to show the project to Spanish construction sector in the beginning	Centro Informativo de la Construcción-CIC	ITC	April 2010
UNR	Project Website	www.axioma-project.eu	All	April 2010
DAP / NEA	Publication *"Dal tessile alle costruzioni L'esperienza di Nearchimica"* "From textile to construction Nearchimica Experience" to promote Nearchimica business activities and its collaboration in the Axioma project with an highlight of the outcomes from the research activities developed along this research framework promote	Innovare	DAP / NEA	November 2010
DAPP	Flyer and Poster	www.axioma-project.eu	All	February 2011
DAPP	3 Newsletters	www.axioma-project.eu	All	February 2011, November 2011, April 2012
TNO	Presentation "Auswaschungen aus beregneten Fassaden"	Technische Akademie Esslingen	S.J.F. Erich	21-22 February 2011
TNO	Participation to sectoral event, speech and contact with potential stakeholders at Novel biocide technology V Berlin, Germany	Conference via Vincentz Network, Berlin	S.J.F. Erich	12-13 April 2011
TNO	Participation to sectoral event, speech and contact with potential stakeholders at Conference "Leaching of Biocides from Façade Coatings" at University of Applied Sciences, Switzerland	HSR University of Applied Sciences, Rapperswil, Switzerland	S.J.F. Erich	24-25 May 2011
TNO	Decreased bio-inhibition of building materials due to transport of biocides	Heron	S.J.F. Erich, S.M. Mendoza, W. Floor, S.P.M. Hermanns, W.J. Homan, O.C.G. Adan	2011
TNO	Development and evaluation of a biocide release system for prolonged antifungal activity in finishing materials	Progress in Organic Coatings	J. Eversdijk, S.J.F. Erich, S.P.M. Hermanns, O.C.G. Adan, M. De Bolle, K. de Meyer, D. Bylemans, M. Bekker, A.T. ten Cate	2011
ACC	Stand with AXIOMA flyers	Genera International	ACC	February

		Fair of Energy and Environment		2013
TNO	Ontwikkeling van release technologiën voor verlengde bescherming van coatings tegen micro-organismes "Development of release technologies for prolonged protection of coatings against micro-organisms	VVVF/NVVT Coating Innovation Day		April 2013
NTUA	LCA fact sheets	www.axioma-project.eu	NTUA	April 2013
ACC	Visit to EuroNanoforum 2013	Flyers	ACC	June 2013
NTUA	Presentation "Environmental performance of antimicrobial paints enhanced with biocide smart release technologies"	Poster session	NTUA, M. Taxiarchou, A. Peppas, M. Krokida, K. Kyriakopoulou.	July 2013
NTUA	AXIOMA presentation of LCA results, networking of the project ideas at the 3rd International Exergy, Life Cyles Assessmnet and Sustainability Workshop & Symposium (ELCAS-3)	Workshop and Symposium	NTUA	July 2013
NTUA	Presentation of environmental performances of AXIOMA results at 19th SETAC Europe LCA Case Study Symposium	Symposium	NTUA	November 2013
DAP	Communication of AXIOMA activities and brief results of achievements, published on the ECTP Construction Technology Platform. Giving visibility to the final Workshop	ECTP Platform	DAP / ECTP	November 2013
NTUA	Article "Environmental performance of antimicrobial ceramic tiles enhanced with biocide smart release technologies" by M. Taxiarchou, A. Peppas, M. Krokida, K. Kyriakopoulou.	19th SETAC Europe LCA Case Study Symposium acta	NTUA/KER	November 2013
KER	Ceramic product with controlled release of a compound with biocidal activity	PATENT	KER, JAN, TNO, ITC, UJI	December 2013
ALL	AXIOMA Promotion video	www.axioma-project.eu	VWV/TNO/STR	December 2013
ALL	Symposium "Impact of biocide and release technologies in the built environment"	SYMPOSIUM	All partners	11th December 2013
TNO	Article "Better biocide release for better buildings"	International Innovation	TNO/UNR	January 2014
TNO	Modelling biocide release based on coating properties to predict anti-microbial protection	Progress in Organic Coatings	S.J.F. Erich, V.V. Baukh	2014
TNO	Article "Towards new testing methodologies for materials having new smart technologies for release of biocides "	To be determined	TNO	2014
TNO	Article "Enzymatically triggered release of model compounds from zeine particles"	To be determined	M. Nieuwland, N. E. Papen-Botterhuis, W. C. Drost, T. M. Slaghek, B.S.J.F. Erich	2014
UPM	Article "Measurement protocols for temperature and relative humidity assessment in indoor living environments"	Journal of metrology	UPM	March 2014
NTUA	Article "Potential environmental impact of Nanotechnology based antimicrobial coating for construction applications"	Integrated Environmental Assessment and Management (IEAM)	NTUA	March 2014
NTUA	Article "Predicting smart biocide protection in building materials: a correlation between models and real scale testing for the performances of active, slow and triggered release, biocide materials in the building sector.	Journal of Environmental Technologies	DAPP, TNO, UPM	2014
NTUA	A novel approach to biocide modeling and micro-organism growth for providing effective information on building material's lifetime	Building Materials, (…)	DAPP, TNO, UPM, NTUA	2014
UPM/TNO/JAN/ DAP/NTUA	WP4 final complete publication	To be decided	UPM/TNO/JAN/ DAP/NTUA	Expected date June 2014

2.2 SECTION B (CONFIDENTIAL[7] OR PUBLIC: CONFIDENTIAL INFORMATION TO BE MARKED CLEARLY)

This section is fully confidential. Any applications for patents, trademarks, registered designs, etc. are confidential.

Exploitable Foreground and how to exploit this foreground has been discussed in the project and is described in the Plan for Use and Dissemination of Knowledge (deliverable D6.4) but is at this time confidential.

[7] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.