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Bionic development of textile materials for harvesting water from fog

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The provision of drinking water turns out to be one of the great challenges of the future. Currently, about one billion people have no access to the essential wet – a problem that mainly is evident in the developing countries.
Here central water supply systems normally cannot technically and logistically be realized or the connection of remote settlements on islands, in isolated bays or higher regions is uneconomic.
For thousands of years nature has been managing on its own as regards the safeguarding of the survival of plants and animals in dry regions – by the procurement of water from the humidity of the air. In extreme desert areas especially often amazing complementary mechanisms are active in order to wrest the essential elixir. They are useful models for a corresponding technical implementation.
The development of functional products for the procurement of drinking water from fog without energy supply is the aim of a current project at the Institute of Textile Technology and Process Engineering (ITV) Denkendorf. Details about the bionic implementation are comprehensively given in the following – from the research and construction of suitable textile fabrics to lab trials regarding material analysis up to the first field trials.

- **Aims of development**

The aim of the research project at ITV Denkendorf is to analyse the biological mechanism of the separation of droplets of water from the air to design corresponding bionic implementations. Fiber-based materials for the procurement of water from morning dew and fog shall be designed and developed in that case. The textile humidity absorbers subsequently are to be used for the production of complete systems for the procurement of water and to be tested for this application. The main focus of the investigations is on the efficiency of water separation, mechanical stability, self-cleaning behavior, and on the collection, storage and eventual treatment to drinking water. According to the plan, larger settlement units such as multiple dwellings, schools and villages in the future will be able to independently meet their own need of water and/or to take over filtration tasks by means of the differently dimensioned fog collector systems.
For the purpose of the implementation of this plan, at first, fiber polymers and geometries have to be analyzed and – based on the findings – fibers to be produced showing a favorable behavior regarding water absorption and release.
The surface energies and spectral properties of the fiber materials, in addition, shall be optimized by a specific surface coating. The further works deal with supporting measures for the collection and leading off of the separated water – a task that can be fulfilled by functional micro and nano structures. By using the findings of filtration on coalescence, finally a spatial textile fabric has to be designed that offers with its third dimension a favorably high air permeability and an efficient aerosol separation at the same time.

- **Biological models**

Two biological systems acted as the model for the development works at ITV: the marram grass Stipagrostis subulicola and the Namib Desert beetle Onymacris unguicularis – both being natural survivalists in the Namib Desert. In the extremely dry zone at the west coast of Africa hardly any rain falls, but in certain seasons in the night there often and regularly occurs fog.
The Stipagrostis subulicola plant uses the water droplets, that are dispersed in the air, by means of a sophisticated interaction of its roots and leaves. The roots of the marram grass are in a maximum depth of 20 cm; they, however spreading over a length of 20 m forming a carpet that absorbs the water dripping from the leaves – before completely seeping away in the ground. A spatial construction of a horizontally oriented 2D-network in the ground and a vertically ramified green on the surface thus form the basis of the combing out process of the fog.
As for the grass leaf, the REM, in addition, reveals surface structures, that possibly are in conjunction with the separation efficiency. The specific interrelations are investigated at the Institute for Geoscience, University of Tübingen, under the supervision of Dr. Anita Roth-Nebelsick. Concerning the way how to handle water, the desert beetle Onymacris unguicularis developed another possibility of best practice during evolution. In the morning dew the beetle known as fog drinker exposes itself with his backside on the top of the dune and thus in the wind. The fog condenses on the shell of the beetle and flows through the grooves of the back directly into the mouth.

- **Demands to textile fabrics**

Textile-based fog separators (Fig. 1) must fulfill basic requirements regarding material properties, separation efficiency for air-transported water aerosols and profitability in the overall system.
In practice, the textiles to be developed must show favorable tear strength and air permeability so that they can reliably fulfill their function even at bad weather such as storm. The textile fabric, moreover, should have self-cleaning properties to be protected against dirt, dust and blockades of the fabric itself. In addition, maximum weathering and ultraviolet resistance is required because of extreme insolation.
As for the investments, the production and maintenance costs for the textile fabric and overall system should be as low as possible. Simple design and easy handling are the essential conditions for the use of the water separator in barren landscapes.
Last but not least, all material surfaces, that get into contact with water, must be compatible with food as the separated water is used as drinking water.

- **Trials performed in the lab**

A suitable test stand for the analysis of the efficiency of water separation of the textile materials has been designed in the lab of ITV. During the comparative investigations the test items were exposed to a shower of aerosols by a cold fog equipment with a droplet diameter from 10-100 µm. Smoke screen and inflow were realized on the basis of a reliable processing technology in order to get reproducible results.

- **Results**

In the course of a screening phase the project team of ITV conducted tests on a multitude of textile fabrics. The influence of textile-physical parameters such as polymer material, filament and fiber diameter, design, and surface energy or air permeability on separation efficiency was determined. The analyzed test items also included the Raschel meshed fabrics made of polyethylene. Based on the findings new textile constructions were developed and patented meanwhile. The favorite fog separators consist of polyester with 3D-design and – as regards conducting away water – are optimized within their spatial structure. In this way, 3D-textiles reach separation rates between 65 and 85 % at the exposure to fog – clearly improved values compared to 52 % in the case of Raschel meshed fabrics.

- **Practice tests**

The textile variants with optimum water separation rates are currently tested at the desert research station Gobabeb, Namib Desert/Namibia – under conditions of long-term field trials (Fig. 3). The first results of the field trials are promising. They confirm the results of the lab tests and certify the 3D-textiles a water yield that is 2 to 3 times higher on average compared to the materials used so far such as the Raschel meshed fabrics. The amount of water separated by the meshed fabrics was 300 ml/mm^2 fog event and that of the 3D-textiles was about 660 and 730 respectively (as of 25/09/2008).

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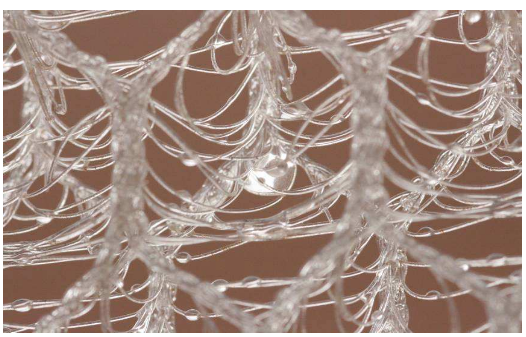

Fig. 1: Fibre-based fog collector with adhesed water droplet

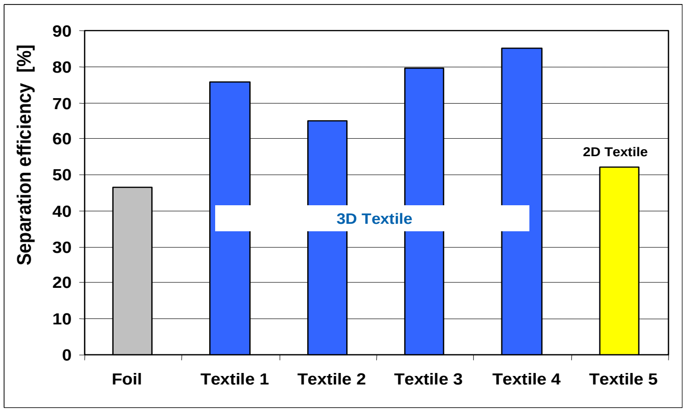

Fig. 2: Separation rates of investigated materials

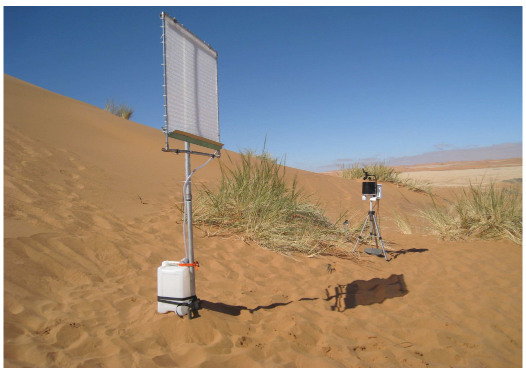

Fig. 3: Field trials at desert station Gobabeb (Namib Desert), Namibia