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Wound dressings made of drug-releasing polymers

Electrospinning has been used to produce polymer fibres containing the well-known antibacterial drug metronidazole. The mats formed from them at the Institute of Nuclear Physics of the Polish Academy of Sciences could potentially be used as wound dressings, thanks to an appropriately selected polymeric structure capable of releasing the drug into the body in a controlled manner.

A good drug should cure without harming. A lot depends, however, not so much on the therapeutic substance itself, as on the way it is administered – it should precisely reach the affected area, in a specific amount, for a sufficiently long period of time. This is exactly how the mats made of polymer fibres containing the antibacterial metronidazole, produced using the electrospinning method at the Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) in Cracow, Poland, work.

“Metronidazole is a drug used, amongst others, for mucous membrane infections of the skin, for example in the treatment of periodontal disease. However, it is known to have some harmful properties, occurring when it unintentionally spreads in the patient's body. We set ourselves the task of developing a molecular delivery system for metronidazole which would guarantee its controlled and prolonged release in small amounts exactly where it is needed,” says Ewa Juszynska-Galazka, professor at the IFJ PAN, and emphasises that the proposed method, consisting of placing metronidazole in electrospun polymeric fibres, including those with carefully selected coatings, is universal in nature and could potentially be adapted to carry other therapeutic substances.

Electrospinning is a fibre manufacturing technique that has been under development worldwide for a long time. The main role is played by an electrostatic field generated by a high-voltage generator between a needle and a collector plate. When the needle starts to release the spinning solution in a laminar manner, the surface of the expelled liquid starts to stretch and bend. The identical (positive) electrical charges accumulated on it begin to attract, modifying the shape of the surface. It forms into a cone (called a Taylor cone) with an increasingly narrowing apex, which extends towards the negatively charged collector. The resulting fibre descends in a spiral motion, while undergoing chemical transformations that harden it (depending on the spinning solution, this may be solvent evaporation or polymer deposition). In order to produce a physically stable multilayer mat, it is necessary to maintain constant environmental conditions (temperature, humidity) as well as system geometry (fixed needle-to-collector distance, type of collector) throughout the process.

In the course of the research at the IFJ PAN, fibres with homogeneous structures and those built from a polymer envelope and a polymer-drug core were produced. In the latter case, a coaxial needle, which can be imagined as a needle within a needle, plays a critical role during electrospinning. In its outer part, which has a ring cross-section, a solution of the polymer selected for the coating material is introduced, while a mixture of the polymer with the target drug is directed into the central part, responsible for the core of the future fibre.

“In as much as the electrospinning process itself is well understood and in suitable, not particularly complicated, apparatus runs basically spontaneously, matching a polymer or coating to the characteristics of a specific drug is not an easy task. The problems that arise here are due to the fact that placing a molecular substance in a nano-restraint usually results in changes in its physical and

chemical properties," explains M. Sc. Olga Adamczyk, who started her research on electrospun fibers containing drugs under the supervision of IFJ PAN professor Małgorzata Jasiurkowska-Delaporte, and intends to continue it as part of her doctoral thesis.

In vitro baseline studies on metronidazole mats, carried out using two types of polymer, established that to provide an adequate surface area for absorption and release of the encapsulated drug, the fibre diameter should be between 0.7 and 1.3 micrometres. During the storage period, the polymeric fibres with the drug provide an airtight seal to the dressing, while after application they become sufficiently porous in response to the fluids in the environment to start releasing the drug.

Measurements show that the metronidazole contained in the mats is gradually released from them over several hours. However, there is an additional time limitation: the mats can be stored for no more than one month prior to application. Importantly, this limitation is not due to the method of drug delivery, but to the properties of metronidazole itself, which starts to crystallise after this time.

The metronidazole-containing polymer fibre mats produced at IFJ PAN are 2x2 cm in size and in the form of a product potentially ready for therapeutic applications. Their physical and chemical properties are already well understood, so further stages of research will require cooperation with interested scientific and medical institutions.

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SCIENTIFIC PUBLICATIONS:

"Electrospun Fiber Mats with Metronidazole: Design, Evaluation, and Release Kinetics"
O. Adamczyk, A. Deptuch, T. R. Tarnawski, P. M. Zieliński, A. Drzewicz, E. Juszyńska-Gałązka
The Journal of Physical Chemistry B 2025, 129, 18, 4535–4546
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LINKS:

http://www.ifj.edu.pl/
The website of the Institute of Nuclear Physics, Polish Academy of Sciences.

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Press releases of the Institute of Nuclear Physics, Polish Academy of Sciences.

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Controlled drug delivery to the body can be achieved using dressings made of electrospun mats, composed of polymer fibers combined with a suitable therapeutic agent. The inset shows a microscopic image of polymer fibers containing the antibacterial agent metronidazole. (Source: IFJ PAN)