



Nano-Pervaporation Membrane With Heat Exchanger Generates Medical-Grade Water

A small system produces high-quality water using a heat exchanger that meets requirements for evaporation of substances such as pharmaceuticals and vitamins.

Lyndon B. Johnson Space Center, Houston, Texas

A nanoporous membrane is used for the pervaporation process in which potable water is maintained, at atmospheric pressure, on the feed side of the membrane. The water enters the non-pervaporation (NPV) membrane device where it is separated into two streams — retentate water and permeated water. The permeated pure water is removed by applying low vapor pressure on the permeate side to create water vapor before condensation. This permeated water vapor is subsequently condensed by coming in contact with the cool surface of a heat exchanger with heat being recovered through transfer to the feed water stream.

A thermoelectric heat exchanger is used here to pump heat from the condensing surface to the feed water stream. Because the temperature differential across this heat exchanger is relatively small, the thermoelectric process is highly energy efficient. This new heat exchanger provides high surface area for vapor condensation with controllable temperature on the hot and cold sides to meet the operating temperature requirements for the evaporation of solvent-containing, heat-sensitive sub-

stances, such as pharmacological substances, vitamins, etc.

The heat exchanger is a sandwich, with the copper interface plates on both sides of the heat pumps interfacing with the radiators. The outside of the radiators is insulated with two cover plates bolted together to hold the entire heat exchange unit together. Four heat-pump units are connected in series and are controlled by one circuit. The control electronics are built around a standard commercial voltage regulator. This was chosen in part because it has a 6.2-volt reference output that is needed for the bridge circuit. The radiator on the incoming potable-water side is heating, and the vapor side is cooling.

The NPV process can be operated at close to room temperature, and is driven by the space vacuum (provided by a secondary loop controlled by a secondary vacuum valve with built-in redundancy for safety) applied on the permeate side with minimal energy consumption. A primary valve controls the inlet space vacuum. The nanoporous membrane serves as a barrier, not only between liquid and water vapor phases, but also be-

tween pure water and dissolved solids to be removed. The nanopore selectively adsorbs liquid water and excludes undesirable constituents such as particles, microbes (e.g., bacteria), viruses, and volatile organic compounds.

The system only requires a low-pressure gradient across the membrane [<25 psi (≈ 172 kPa)] as compared to a high-pressure gradient required for reverse osmosis (RO) (>150 psi (≈ 1.03 MPa)], to achieve high water-flow rate. As a result, the novel membrane will not be prone to the fouling issues that are commonly seen in the RO system. The cross-flow design can also allow the concentration stream to sweep away retained molecules and prevent the membrane surface from clogging or fouling, making the system able to deliver medical-grade water to point of use. The overall process has no moving parts and has low maintenance requirements.

This work was done by Chung-Yi Tsai and Jerry Alexander of T3 Scientific Limited Liability for Johnson Space Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-24264-1/6-1

Micro-Organ Devices

Effects of drugs can be tested realistically, without experimentation on animals.

Lyndon B. Johnson Space Center, Houston, Texas

Micro-organ devices (MODs) are being developed to satisfy an emerging need for small, lightweight, reproducible, biological-experimentation apparatuses that are amenable to automated operation and that impose minimal demands for resources (principally, power and fluids). MODs are intended to overcome major disadvantages of conventional *in vitro* and conventional *in vivo* experimentation for purposes of investigating effects of

medicines, toxins, and possibly other foreign substances.

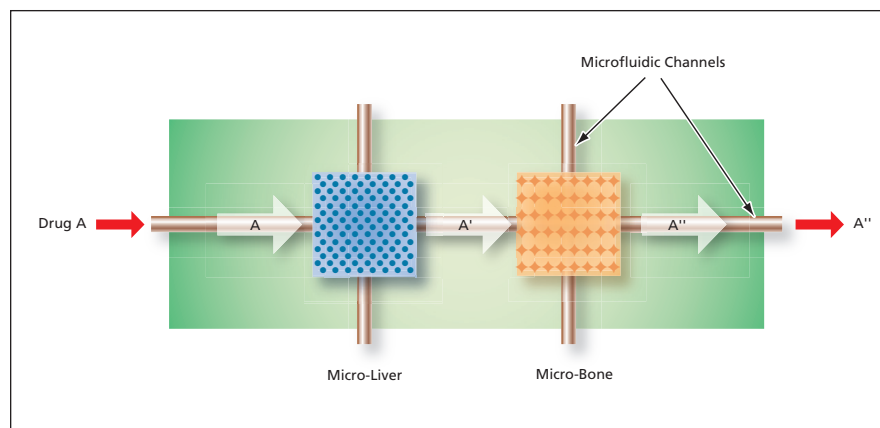
Conventional *in vitro* cell cultures do not mimic the complex environments to which toxins and medicines are subjected in living organisms. Conventional *in vivo* studies in non-human animals can account for complex intercellular and inter-tissue effects not observable in *in vitro* tests, but experimentation on animals is expensive, labor intensive, time-consuming, and unpopular. Moreover, cross-

species extrapolation of toxicity and pharmacokinetic characteristics is problematic. In contrast, because MODs could host life-like miniature assemblies of human cells, the effects observed in tests performed in MODs could be extrapolated more readily to humans than could effects observed in conventional *in vitro* cell cultures, making it possible to reduce or eliminate experimentation on animals.

In simplest terms, a MOD is a microfluidic device containing a variety of

microstructures and assemblies of cells (see figure), all designed to mimic a complex *in vivo* microenvironment by replicating one or more *in vivo* micro-organ structures, the architectures and composition of the extracellular matrices in the organs of interest, and the *in vivo* fluid flows. In addition to microscopic flow channels, a MOD contains one or more micro-organ wells containing cells residing in microscopic extracellular matrices and/or scaffolds, the shapes and compositions of which enable replication of the corresponding *in vivo* cell assemblies and flows.

Once the basic microfluidic device infrastructure of a MOD containing micro-organ wells and flow channels has been fabricated, single cells or multiple cells of the same type or different types needed for a given micro-organ are encapsulated or suspended in a solution that may contain micro-organ-specific extracellular matrix molecules and scaffolding. The suspension or solution is placed in a syringe that is part of a computer-controlled apparatus; under computer control, cells and any extracellular matrix material are dispensed as the syringe is moved, thereby effectively printing a unitary three-dimensional assem-



This **Simple Example MOD** is designed for use in monitoring (1) conversion of a drug from inactive form A to active form A' in the liver and (2) indirectly monitoring the effect of A' on a bone by monitoring the concentration of A'', which is a tertiary metabolite form of the drug.

bly of cells and extracellular matrix material into a micro-organ well. The dimensions of each printed micro-organ are chosen so as not to exceed optimum dimensions for perfusion of cells with nutrient fluid, exchange of gases between the cells and the nutrient fluid, and removal of non-gaseous cell wastes in the nutrient flow.

This work was done by Steven R. Gonda and Julia Leslie of Johnson Space Center; Robert C. Chang, Binil Starly, and Wei Sun

of Drexel University; Christopher Culbertson of Kansas State University; and Heidi Holtorf of USRA. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-1003. Refer to MSC-23988-1.