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A new application of conducting polymers: a useful tool in concentration of viruses from water

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Fibre glass fabrics coated by polypyrrole or other polyene polymers in 'doped' state show high performances in trapping viruses from contaminated water. Also, the complete recovery of adsorbed viruses was easily performed. These findings suggest a completely new type of application for such materials.

1. Introduction
In recent years the interest in analytical methods for determining the virus concentration in surface, sewage and drinking water has been growing, mainly due to the concern about viral disease. Contrary to the quantification of chemicals, few satisfactory methods are available for the quantitative determination of viruses, due to the time-consuming and not always reliable methods of concentrating materials from large sample water volumes and the frequent unsatisfactory recovery of biological materials from filters, a procedure which has to be performed before inoculating in cell cultures and quantitatively estimating the viral charge.

Recently, the use of microporous filters appears to be the most promising technique for detecting viruses [1]; also, "charge modified" filters have been introduced on the market, where the modification of the charge is performed by surface treatments; "positive" and "negative" filters have been tested, the best performances being attributed to "positive" filters.

It was thought that conducting polymers in their "doped" state (polypyrrole, polyaniline and similar water stable materials) could find useful application in virus filtration, i.e. a purpose very different from the universal attention to their possible uses in electrical or electronic devices suggested by their electrical conductivity. In fact, most "doped" conducting polymers have the unique property of carrying a number of positive charges well spread over their polyconjugated backbone, while negative charges are typically localized on low basicity anions.

The formation of a membrane having suitable mechanical strength, flexibility and porosity did not appear easily feasible, when made of pure polymer; therefore, we took advantage of our previous experience in preparing polypyrrole composites by chemical oxidation of pyrrole monomer adsorbed on many different types of substrate, in water and/or other solvents [2, 3].

2. Results and discussion
After a preliminary screening of various supporting materials, we focused our attention on disc filters, made out of filter paper or glass fibres. Such porous membranes were treated with a pyrrole solution in ethyl acetate (1:1) in order to obtain a uniform distribution into the pores of the filters and to make the procedure well reproducible as far as final composite material is concerned.

Wet filters charged with the monomer were then dipped in an aqueous solution of iron(III) chloride (1 M), which caused pyrrole to be oxidatively polymerized to the corresponding conducting polymer, well spread all over the fibres and inside the pores. The polymerization reaction was allowed to proceed at 5–20 °C for 3 h; filters were then thoroughly washed with dilute hydrochloric acid, water, and finally dried in air.

Membranes prepared with this procedure were tested for weight increase upon polypyrrole deposition: 25% of the final weight was due to polypyrrole on the filter paper (Whatman, 0.15 mm thickness) and 60% on fibreglass supporting materials (0.25 mm thickness). Also, electrical conductivity was usually measured, in order to evaluate the efficiency and reproducibility of the procedure (approximately $50\ \mathrm{S\,cm^{-1}}$ for paper filters and $10\ \mathrm{S\,cm^{-1}}$ for fibreglass ones were obtained). Further control was made using SEM (see figures), which showed different morphologies for polypyrrole deposition according to the supporting materials used.

The supposed utility of such materials for the concentration of enteric viruses from water was tested against Polio 1, Coxackie B3 and Echo 7 viruses.

* Details on the virological experiments will be published elsewhere.

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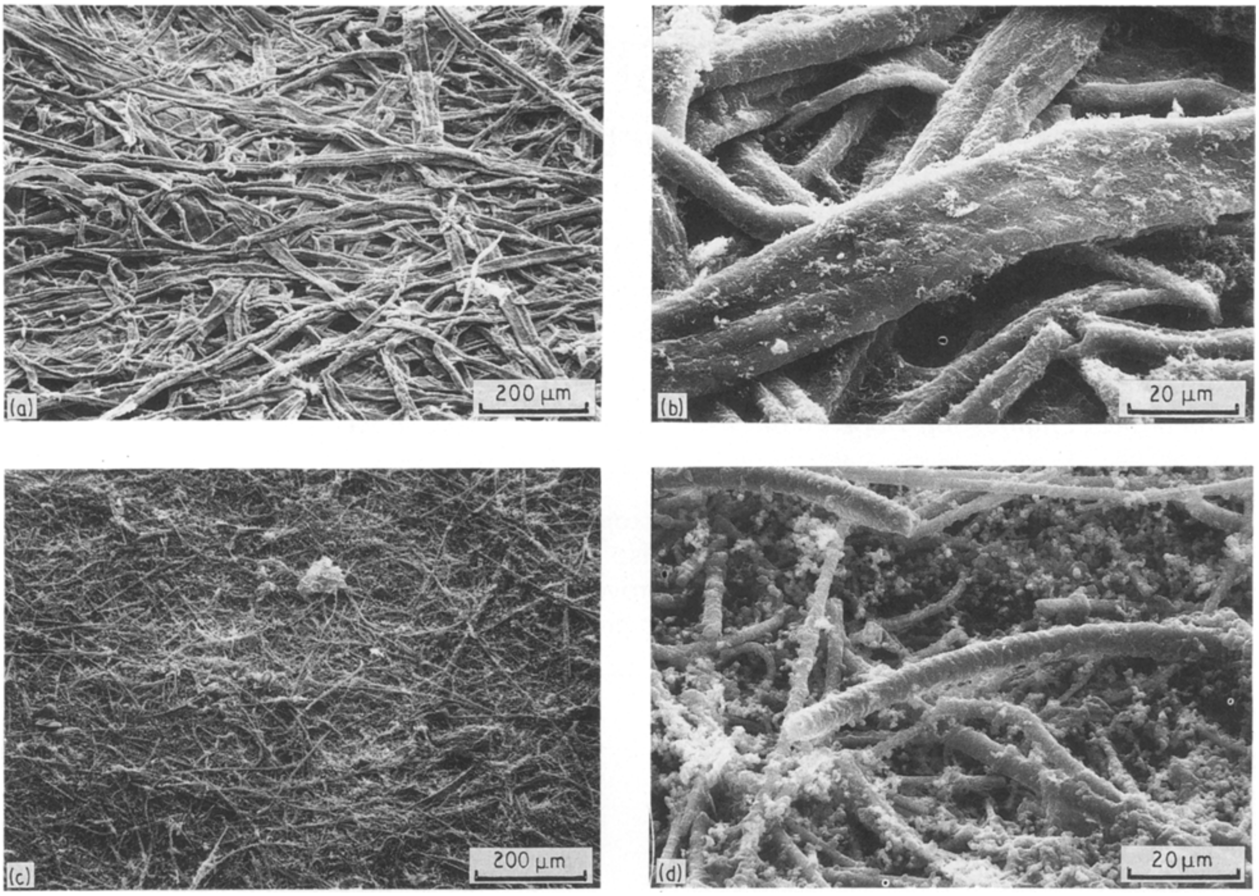

Figure 1 Scanning electron micrographs of polypyrrole deposited on (a, b) filter paper and (c, d) fibreglass fabrics.

We first used small plated filters (47 mm diameter) to check the efficiency of our materials in comparison with commercially available ones, using the tentative procedure for virus detection in water reported in the "Standard Methods" [1].

It was soon evident that polypyrrole deposited on glass-fibre membranes was much more efficient in virus retention than the same polymer deposited on paper membranes, probably due to a more uniform distribution of polymer on the fibres. Also, a slight improvement of this feature with respect to existing "charge modified" membranes was noticed.*

Further ascertained advantages for the proposed application of conducting polymers in this field are:

(i) the efficiency of virus filtration is practically constant over the pH range from 4–8;

(ii) there is no need to modify the pH of the water samples, nor to add chemicals of any kind before filtration, in order to improve the efficiency of virus retention;

(iii) the easy removal of trapped viruses from polymer membranes (90%–100%) by elution with beef extract;

(iv) the easy preparation of membranes and the possibility of scaling up to cartridge filters or large-area filters; we tested cartridge filters (5 cm diameter and 12 cm height) with excellent results in filtration of large samples of artificially contaminated waters ($\geqslant$ 200 litre);

(v) short filtration time, being virus removal due more to electrostatic interactions between viral particles and the polymer than to the pore size.

We are presently testing the efficiency of our materials in field studies, still using cartridges on large water volumes, eventually prefiltered in order to remove larger particles of solids. Sampling of large volumes is, in fact, necessary when a very low, but positive, virus contamination of water has to be detected.

Finally, preliminary experiments show that conducting polymer composite membranes could be recycled more than once by a suitable chemical treatment of used filters, a feature which should be very important in the case of the foreseeable future widespread application of these materials in environmental control studies.

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