MULTIFUNCTIONAL TOXIN DECONTAMINATION COATINGS

for Sustained Protection of People and the Environment

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November 17, 2004

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
17 NOV 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Multifunctional Toxin Decontamination Coatings For Sustained Protection Of People And The Environment	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Center for Bio/Molecular Science & Engineering Naval Research Laboratory, Washington DC**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001849, 2004 Scientific Conference on Chemical and Biological Defense Research. Held in Hunt Valley, Maryland on 15-17 November 2004 . , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**16**	

CURRENT TECHNOLOGIES AND LIMITATIONS

Physical Barrier Protection

- Selective Adsorption
  - Activated charcoal - HEPA system
- Impermeable Polymer Barriers

Drawbacks:

- Contaminated barriers are hazardous and cause disposal problem
- Impermeable barriers cause heat and perspiration

Active Protection

Chemical Catalysis Approach

- Oxidants (TiO2) - Metal chelators - Engineered catalysts

Drawbacks: Catalysts destroy filter; Very slow, Not efficient

Enzymatic Catalysis Approach

- Free enzyme in solution - Cross-linked to a substrate

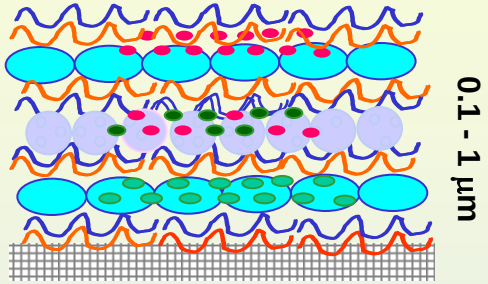
Drawbacks: - Limited stability in working environment

- Loss of activity during processing

Our Approach Removes Most of these Limitations
and
Provides Additional Capabilities

OUR APPROACH

Enzyme Based Multifunctional Coatings



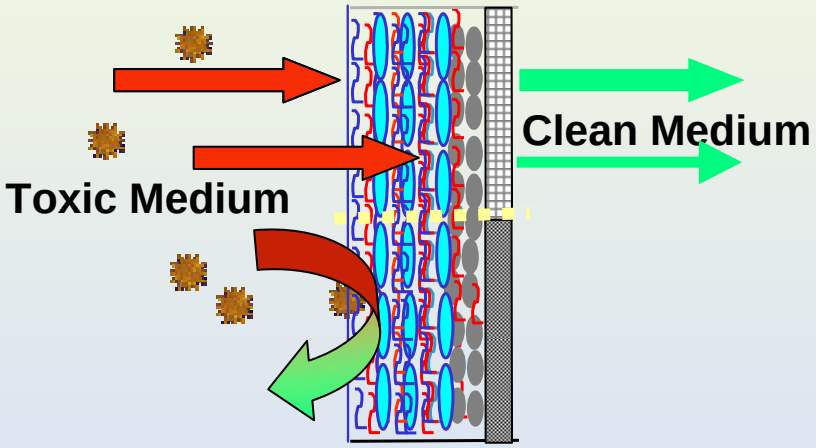
Incorporates advantages of enzymes by embedding them in multilayers, which leads to

- Stability
- Sustained catalytic efficiency
- Multifunctional capability

• Light weight • Cost effective • Hazmat-free • Reusable

MULTIFUNCTIONAL SELF-CLEANING FILTERS

Protect personnel and the environment from chemical and biological agents, and toxins produced during their degradation.



(100 nm -1 μm)

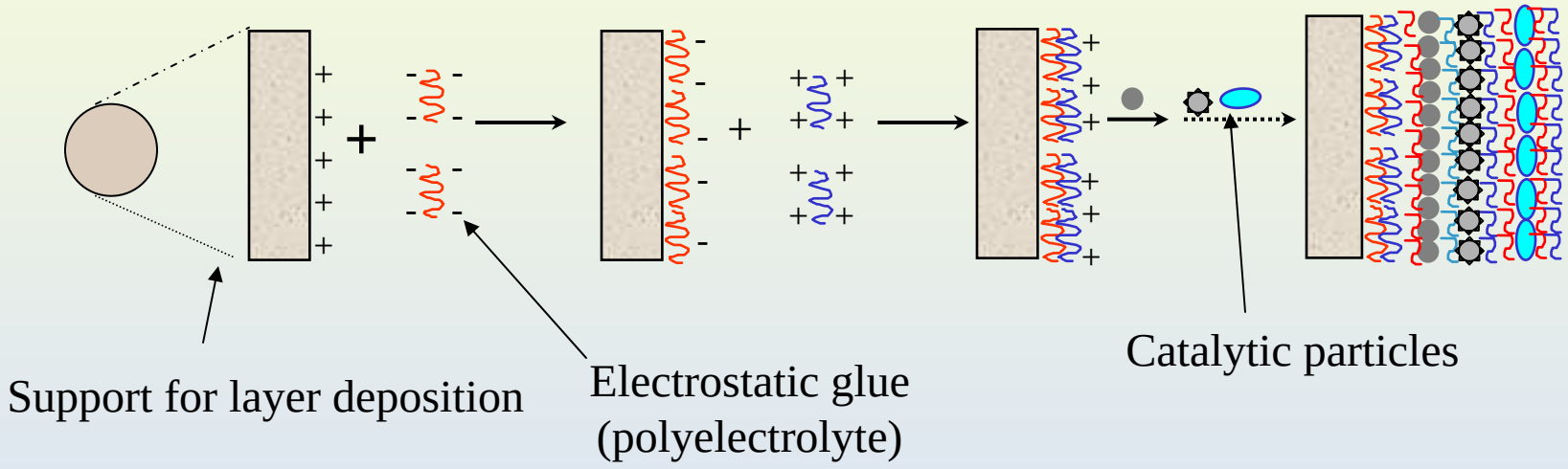
Remedial mode (Filter)

Protection mode (Fabric)

Single System ⇒ Multi-protection

MULTIFUNCTIONAL MULTILAYER FABRICATION

Layers are assembled by ***complementary association of macromolecules*** on surfaces varying in size, shape and texture



Fabrication Involves Water based Chemistry and Proven Film Deposition Techniques

- Dipping
- Spraying
- Spin coating

Automation Makes the Film Fabrication Cost Effective

CHEMECAL AGENT PASSIVATION: Components and Scheme

CATALYSTS

Organophosphorous Hydrolase (1) OPH

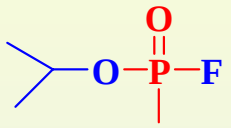
Organophosphoric acid anhydrolase (1) OPAA

SUBSTRATES

Cloth: Cotton, Glass

Beads: Polycyclodextrins

NERVE AGENTS/ PESTIIDES



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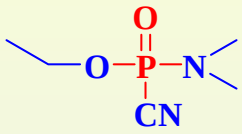

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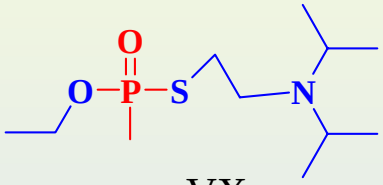
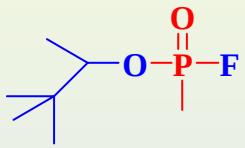


VX



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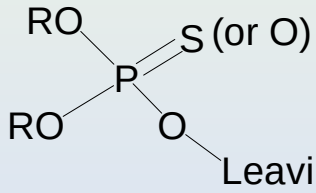
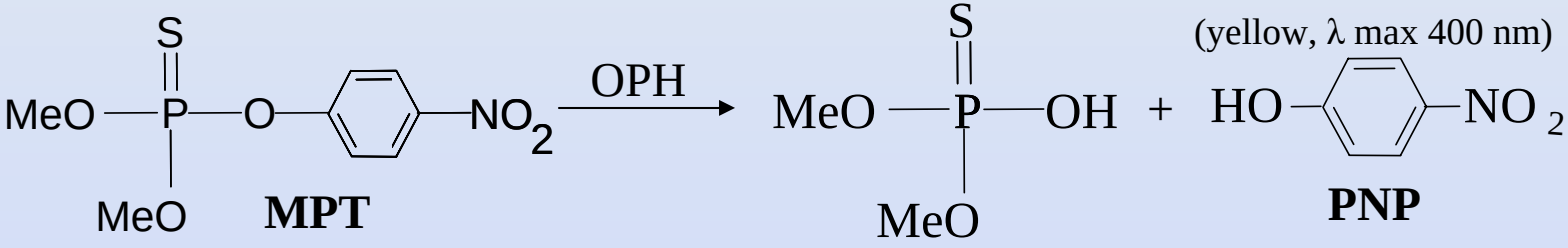


Methyl parathion (MPT) hydrolysis for activity assays:



NOVEL CAPABILITIES DEMONSTRATED

- Stability of Enzymes in Multilayers
- Stability of Multilayers in Working Environment
- Control over Enzyme Loading in Multilayers
- Enzyme Performance on Various Supports
- Enzyme Activity Independent of Solvent, pH, and Temperature

UTILITY OF MULTIFUNCTIONAL COATINGS

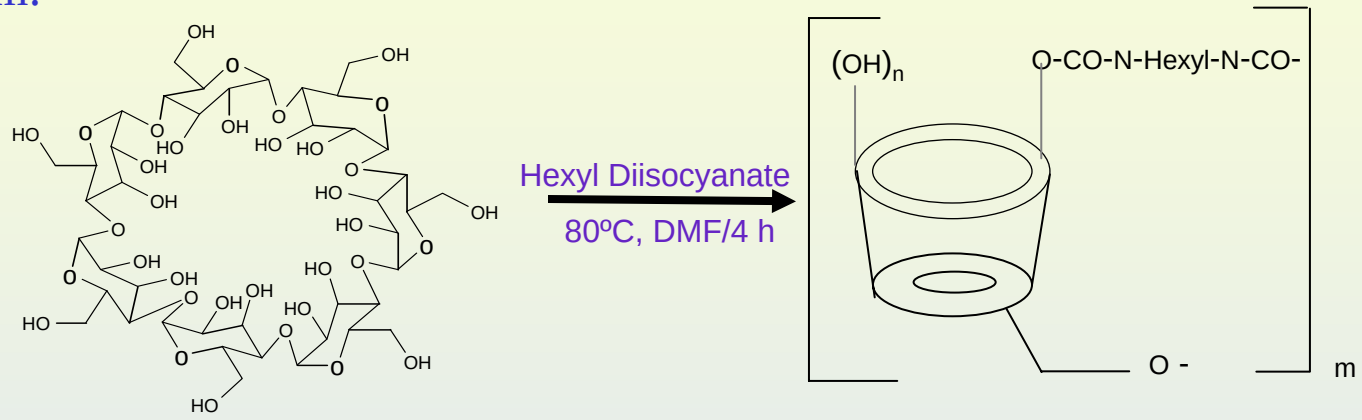
1. Environmental Protection:
   Support - Beads
   - Water filters
   - Air filters (● Small rooms; ● masks
2. Individual Protection:
   Support - Cloth
   - Full body aprons
   - Easy-breath masks
3. Surface Protection:
   - Appliqué
   - Paper Towel/Wipes

The application dictates the nature of the support

ENVIRONMENTAL PROTECTION: Poly-β-Cyclodextrin

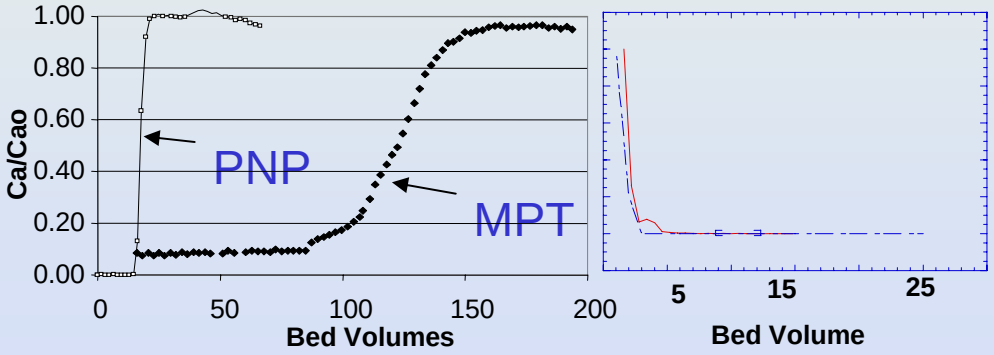
Substrate for Multilayer Assemblies

System:



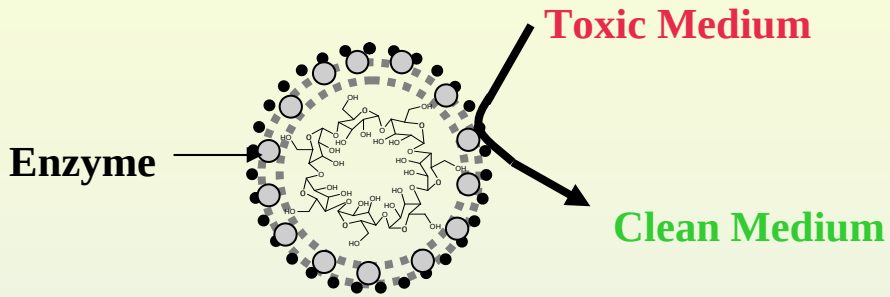
Features

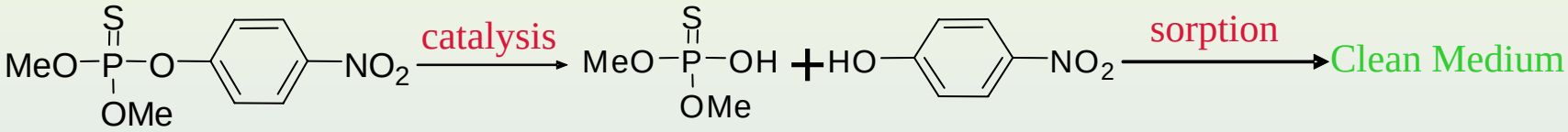
- surface area: 10.2 m^2/g
- A total pore volume : 0.06 cm^3 /g
- Insoluble in most organic solvents
- Inert to acidic, basic media and
- 4-Times lighter than glass beads
- Capture toxins such as pNP and MPT



ENZYME COATED POLY-β-CYCLODEXTRIN BEADS

Sequence: PCD-BPEIH2O(pH 8.6)-OPHBTP(pH 8.6)-BPEIBTP(pH 8.6)





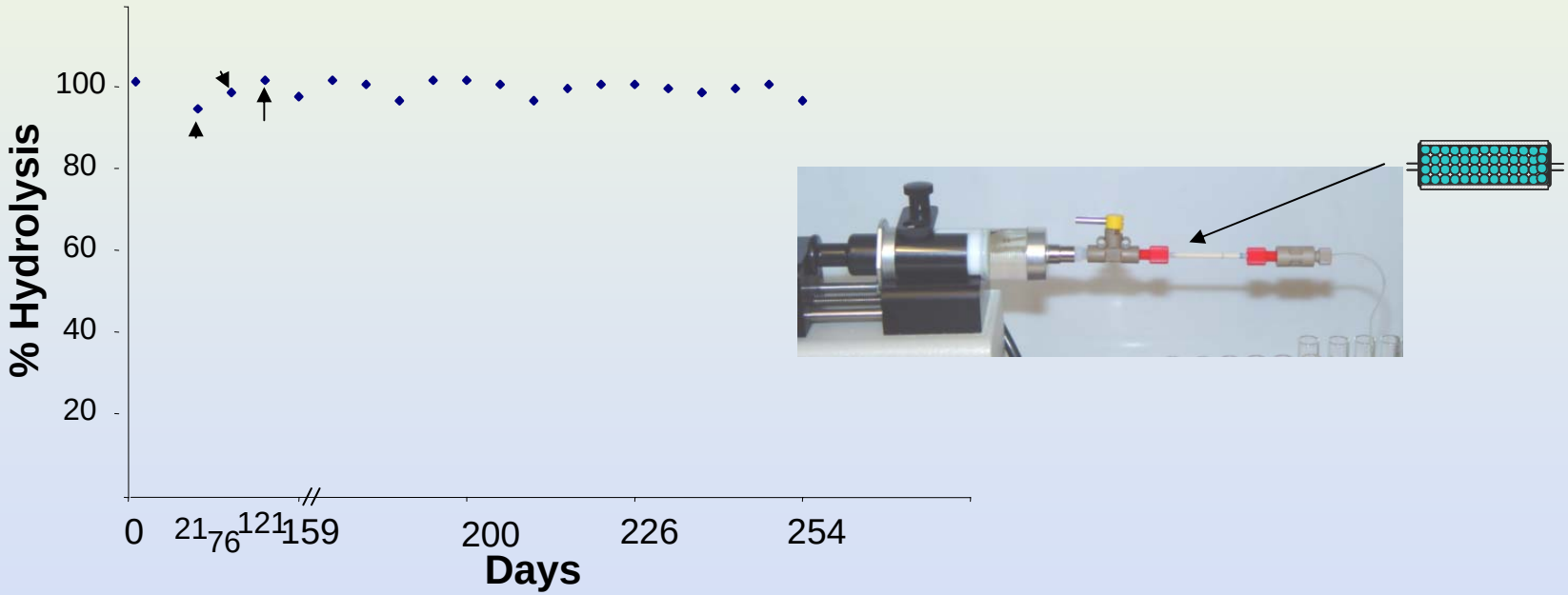
Catalytic Activity of OPH-PCD

Environment	***Initial velocity (Vo)***
Ambient condition(23 ºC)	1.9 x 10^{-7} M/sec
Low temperature (4 ºC)	1.4 x 10^{-7} M/sec
Methanol-2h	6.4 x 10^{-9} M/sec
Acetone 2h	1.8 x 10^{-8} M/sec
Salt Stress-NaCl (2M)-2 h	9.6 x 10^{-9} M/sec
Tap water for 24 h	1.1 x 10^{-7} M/sec
Water (pH 6.6)	3.6 x 10^{-7} M/sec

FILTERS FOR ENVIRONMENTAL PROTECTION: Results

Self-cleaning Filter Using OPH Coated Polycyclodextrin Beads:

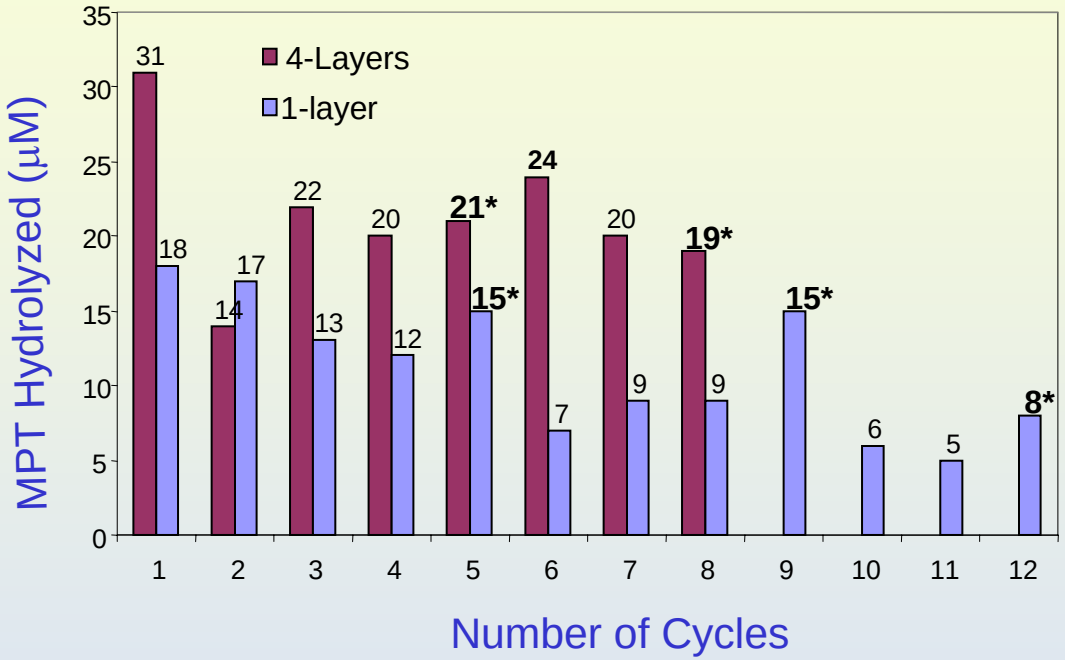
- Degrades 99+%, 100 µM MPT at a flow rate equaling 1.9 min column resident time
- 32 mg MPT was degraded by 23 mg OPH/PCD beads ≡ *1 g Enzyme degraded 177 g Pesticide MPT*
- Sustained hydrolytic activity for 250 Days demonstrated



US Patent Pending (Applications # 10/750,637; December 23.2003)

SELF-CLEANING FIBERGLASS: Results

Sequence: Cloth-BPEI(H_2O)-OPH/BTP-BPEI/BTP-(PSS-BPEI(H_2O)-OPH/BTP-BPEI/BTP)$_3$



MPT Hydrolysis capacity

56mg /g cloth (4-Layers in 2-week)

44 mg /g cloth (1-Layer in 3-weeks)

** Activity measured after storing the cloth at 4 ºC for the weekend*

Results Demonstrated:

- Retention of enzyme activity
- Resistance to washing cycles
- Reusability

OPH IN MULTILAYERS ON KNITTED FABRIC

OPH Coated Cotton String

Knitted Cotton Textile

Methyl parathion (MPT)

Both, cotton string coated with OPH (1-Layer) and the cloth knitted from the OPH-coated string showed identical activity: ~80% MPT (2mL, 100 μM) was hydrolyzed within 5 minutes.

Mechanical Stability Demonstrated

Cost to Cover 1 Enzyme layer on 100 m² Fabric ≤ $ 5.00

US Patent Pending (Applications # 10/849,621, May 20, 2004).

CONCLUSIONS

Proof-of-Principle for the Protection of Individuals and the Environment from chemical agents is established

* Light weight, reusable fabrics with mechanically stable coatings
* Filters for decontamination of water supplies
* Sustained catalytic activity independent of solvent, buffer or temperature

ACKNOWLEDGEMENTS

Yongwoo Lee

Vipin Rastogi

Ivan Stanish

James Palmer

Office of Naval Research for Financial Support

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