行政院國家科學委員會專題研究計畫申請書

一、基本資料　　申請編號　請貼條碼

計畫類別（單選）	☑一般型研究計畫　☐特約研究計畫 ☐新進人員研究計畫　☐其他 _____				
研究型別	☑個別型計畫　☐整合型計畫				
計畫歸屬	☐自然處☐工程處☑生物處☐人文處☐科教處☐永續會☐應用科技小組				
申請機關	臺北醫學大學		申請系所（單位）	公共衛生學系	
本計畫主持人姓名	何玉山	職稱	助理教授	身分證號碼	K101100885
本計畫名稱	中文	利用蛇木屑吸附物去除水中重金屬之研究			
	英文	Removal of heavy metals from water by using tree fern as a sorbent			
整合型總計畫名稱					
整合型總計畫主持人			身分證號碼		
全程執行期限	自民國 91 年 8 月 1 日起至民國 94 年 7 月 31 日				
研究學門（請參考本申請書所附之學門專長代碼表填寫）	代碼	名稱（如為其他類，請自行填寫學門）			
	B0	土壤、環保及農化			
研究性質	☑基礎研究　☐應用研究　☐技術發展				
本學年度申請主持國科會各類研究計畫共 2 件。 本件在本學年度所申請之計畫中優先順序（不得重複）為第 1 （共同主持之計畫不予計入）					
本計畫是否為國際合作計畫　☑否　☐是，請加填國際合作研究計畫資料表 I001～I003					
計畫連絡人	姓名：何玉山　電話：（公）2736 1661 分機 6514（宅）2704 1889				
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計畫申請人（主持人）簽章：_____　日期：2002/02/01

二、申請補助經費

1. 請將本計畫申請書之第五項（表 C005）、第六項（表 C006）、第七項（表 C007）、及第八項（表 C008）及第九項（表 C009）所列費用個別加總後，分別填入「研究人力費」、「研究設備費」、「赴國外或大陸地區差旅費」、「出席國際學術會議差旅費」及「其他研究有關費用」欄內。
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4. 「貴重儀器使用中心使用額度」係將第十項（表 C010）所列使用費用合計數填入。
5. 請依各年度申請博士後研究之名額填入下表。　　金額單位：新台幣元

補助項目 \ 執行年次	第一年 (91 年 8 月 ～92 年 7 月)	第二年 (92 年 8 月 ～93 年 7 月)	第三年 (93 年 8 月 ～94 年 7 月)	第四年 (__年__月 ～__年_月)	第五年 (__年__月 ～__年_月)
研究人力費	0	0	0		
研究設備費	0	0	0		
赴國外或大陸地區差旅費	0	0	0		
出席國際學術會議費用	0	0	0		
其他研究有關費用	1	0	0		
管理費	0	0	0		
小計	1	0	0		
國際合作研究計畫差旅費	0	0	0		
總計	1	0	0		
貴重儀器中心使用額度	134220	1152000	648000		
博士後研究	共 0 名	共 0 名	共 0 名	共_____名	共_____名

申請機構或其他單位（含產業界）提供之配合項目（無配合項目者免填）

配合單位名稱	配合補助項目	配合補助金額	配合年次

配合單位系所主任或機構首長會簽：_____　日期：_____

三、主要研究人力：

(一) 請依照「主持人」、「共同主持人」、「協同研究人員」及「博士後研究」等類別之順序分別填寫。

類別	姓名	身分證號碼	服務機構/系所	職稱	工作月數	在本研究計畫內擔任之具體工作性質、項目及範圍
主持人	何玉山	K101100885	臺北醫學大學/公共衛生學系	助理教授	36	資料收集、閱讀、整理，實驗設計與執行，數據分析與討論，報告撰寫與論文寫作與發表，經費支援

(二) 如申請博士後研究，請分年列述博士後研究參與本研究之

1. 目的及必要專長。
2. 研究項目。
3. 工作份量及其對該計畫之影響程度。
4. 工作績效準則。
5. 若已有人選者，請務必填註人選姓名，並將其個人資料表併同本計畫書送本會。

四、整合型研究計畫項目及重點說明：（總計畫及子計畫之主持人均需填寫此表）

(一) 整合型研究計畫項目

計畫項目	主持人	服務單位系所	職稱	計畫名稱	申請經費
總計畫					
子計畫一					
子計畫二					
子計畫三					
子計畫四					
子計畫五					
子計畫六					

(二) 整合型研究計畫重點說明

請就下列各點分項述明：

1. 整合之必要性：包括總體目標、整體分工合作架構及子計畫間之相關性與整合程度。
2. 人力配合度：包括總計畫主持人協調領導能力、各子計畫主持人之專業能力及合作諧和性。
3. 資源之整合：包括各子計畫所需各項儀器設備之共用情況及研究經驗與成果交流情況。
4. 申請機構或其他單位之配合度。
5. 預期綜合效益。

五、研究人力費：

1. 類別/級別欄請依專任助理（含碩士、學士、三專、五（二）專及高中職）、兼任助理（含博士生、碩士生、大專學生、講師及助教）及臨時工等填寫。
2. 博士班研究生獎助金、碩士班研究生及大專學生研究助學金自 90 年 8 月 1 日起案獎助單元申請，每單元為新台幣 2,000 元。博士生每名每月至多申請 14 個獎助單元，碩士生每名每月至多申請 4 個獎助單元，大專學生每名每月至多申請 2 個獎助單元。
3. 本會九十年碩士論文獎或大專學生研究創作獎之獲獎人，於本會公佈獲獎之日起三年內就讀國內公私立大專校院博士般或碩士班，並參與本計畫研究工作，申請每月研究助學金 28,000 元及 10,000 元部分請務必於及別或姓名欄填列姓名，並檢附得獎證明影本及學生證正反面影本，以利審核。
4. 申請專任助理者，除依工作月述填列工作酬金外，需另填列投保勞保及健保之「雇主應負擔之勞、健保費」。
5. 請分年列述。

金額單位：新台幣元

（一）專任助理、講師及助教級兼任助理、臨時工資

類別/級別	人數	姓名	工作月數	月支酬金	小計	請述明：1. 最高學歷 2. 曾擔任專題研究計劃助理之經歷 3. 在本研究計畫內擔任之具體工作性質、項目及範圍
合計（一）						

（二）博士研究生、碩士班研究生及大專學生兼任助理

級別或姓名	人數（1）	每人每月單元數（2）	獎助月數（3）	小計（4）＝$2000×（1）×（2）×（3）	在本研究計畫內擔任之具體工作性質、項目及範圍
合計（二）					
總計（三）= 合計（一）+ 合計（二）					

六、研究設備費：

1. 類別分為儀器、圖書、資訊軟硬等。
2. 設備名稱欄內請填寫儀器、資訊軟硬體或書籍雜誌期刊等之中文/英文名稱。
3. 說明欄內請詳細填寫設備之規格、製造廠商、型號及用途，以利審查，若為圖書設備，則於說明欄內填寫作者姓名、出版社及出版日期。
4. 購置設備單價在新臺幣二十萬元以上者，須檢附估價單。
5. 若申請機構及其他機構有提供配合款，請務必註明提供配合款之機構及金額。
6. 儀器設備單價超過新臺幣六十萬元（含）以上者，請詳述本項設備之規格與功能（諸如靈敏度、精確度...等），其他重要特性與重要附件，以及申購設備對計畫執行之必要性。本項設備若或補助，主持人應負維護保養之責，並且在不妨礙個人研究計劃或研究群計畫之工作下，同意他人共同使用，以避免設備閒置。
7. 請分年列述。

金額單位：新台幣元

類別	設備名稱（中文/英文）	說明	數量	單價	金額	經費來源	
						本會補助經費需求	提供配合款之機構名稱及金額
合計							

七、赴國外或大陸地區差旅費：

1. 類別分為「實驗」、「研究」、「田野調查」等。
2. 若各出國人員之出國行程、停留國家地區城市有所不同，則請就各段行程之出國人員姓名一一填寫，以便計算生活費人次。
3. 生活費請依照行政院頒布之「國外出差旅費規則」規定標準填列。其他費用包括證照、保險或其他相關費用等。
4. 請將所列各項費用換算為台幣後，加總填入合計欄內，並於說明欄內註明估算匯率。
5. 如申請赴大陸地區差旅費務請加填表 C104。
6. 請分年列述。

金額單位：新台幣元

申請補助費用		
補助項目	預估經費	說明
交通費		
生活費		
其他費用		
合計		

出國人員姓名	參與本計畫之職務	類別	具體工作內容、行程及停留國家地區之城市名稱

八、出席國際學術會議費用：

1. 限主持人及計畫內博士班研究生申請。
2. 請詳述預定參加國際學術會議之性質、預估經費、天數及地點。
3. 請詳述申請人近三年參加國外舉辦之國際學術會議論文之發表情形。(包括會議名稱、時間、地點、發表之論文題目、補助機構，及後續收錄於期刊或專書之名稱、卷號、頁數、出版日期。
4. 請分年列述。

九、其他研究有關費用：

1. 凡與本研究計畫之執行直接有關之費用如消耗性器材及藥品費、電腦使用費、問卷調查費、郵電費、國內差旅費、印刷費、資料檢索費、論文發表費（限國科會補助計畫之成果）、意外險之保險費等，均可填入本表內。
2. 說明欄請就該項目之規格、用途等相關資料詳細填寫，以利審查。
3. 若申請單位有配合款，請於備註欄註明。
4. 請分年列述。

金額單位：新台幣元

項目名稱	說明	單位	數量	單價	金額	備註
蛇木屑	實驗用			1	1	
合				計	1	

十、貴重儀器使用中心之使用額度：

1. 若需使用本會補助之貴重儀器，請於下表內分年列述使用之貴重儀器所屬機構、儀器名稱、使用目的（送檢目的、送檢樣本、對本研究之貢獻）及所需費用。
2. 貴重儀器之使用方法與計費標準請至本會網站之「貴重儀器管理系統」（http://www.nsc.gov.tw/DEFAULT.htm）及「附屬機構及國家實驗室」（http://www.nsc.gov.tw/org-lab-1.htm）項下查詢。
3. 本項費用獨立計算，不列入計畫總經費之中。
4. 請分年列述。

金額單位：新台幣元

貴重儀器所屬機構及設備名稱	說明	使用點數	使用費用	備註
台灣大學理學院貴重儀器中心，元素分析儀（EA）	測 C, H, N, O, S 元素	3 件	每件 800 元	
清華大學貴重儀器中心，感應耦合電漿原子發射光譜分析儀（ICP-AES）	單元素系列水溶液樣品 1056 件 雙元素系列水溶液樣品 540 件	1596 件	每件 1200 元（3 元素以內）	
清華大學貴重儀器中心，感應耦合電漿原子發射光譜分析儀（ICP-AES）	多元素水溶液樣品 3 件	3 件	每件 4800 元（11 至 20 元素）	
掃描式電子顯微鏡（Scanning Electron Microscope）	SEM：每小時收費 300 元。 照相（含底片沖洗）：SEM 底片每張 40 元。 鍍金：每次收費 400 元。	3 件	每件 740 元	
合計		1605	1934220	

十一、研究計畫中英文摘要：請就本計劃要點做一概述，並依本計劃性質自訂關鍵詞。

(一) 計畫中文摘要。（五百字內）

關鍵詞：

蛇木屑、吸附、重金屬、動力學、吸附等溫線、生物性吸附劑

摘要：

吸附技術是一種高效率且經濟的淨化水及廢水之處理技術。最常被工業應用的吸附物是活性碳。然而，儘管它有再生的能力，它還是一種昂貴的吸附材。因此，近年來，有非常多的研究被執行來尋找較便宜的吸附材，以去除飲用水及排放水中的污染物，如重金屬及染料。近來許多價廉、自然與廣泛可獲得的材質被研究，以做為適合去除水中污染物的吸附物。而且，這些令人振奮的結果也被應用在許多領域。Table 1 即是一些被用來去除水中污染物的廉價吸附物相關研究。

在台灣，蛇木屑是被廣泛用在園藝方面的產品。在過去 SCI 發表的研究論文中，發現沒有以蛇木屑作為吸附物處理水污染的相關研究。然而，蛇木屑是一種深咖啡色組成複雜的有機物質，其主要成分為木質素與纖維素（Newman, 1997）。化學吸附可在木質素的極性官能基上發生，如醇類、醛類、酮類、醚類及酚式羥基（Adler and Lundquist, 1963）。基本上，蛇木屑的極性及酸性特質，對金屬陽離子具有良好的吸附作用。本計劃嘗試以台灣特有的蛇木屑作為吸附物，以去除水中的重金屬。

由於吸附等溫線於設計吸附系統時是重要的研究，所以，在此計劃中將探討重金屬種類、吸附材的顆粒大小、溶液酸鹼度及溫度等對此吸附系統之的吸附平衡之影響。同時本計劃亦探討 Langmuir、Freundlich 和 Redlich-Peterson 等三種吸附等溫線與此吸附系統之關聯性。本計劃亦將進行此吸附系統之動力學相關探討。探討污染物種類、吸附劑之粒徑、攪拌速度、溶液之初濃度、pH 值及溫度對吸附反應機制之影響。亦探討偽一級（Lagergren, 1898）、偽二級（Ho, 1995）和擴散動力學模式與此吸附系統之關聯性。另外，兩成分系統之吸附也將被研究，包括初濃度比例、吸附劑之粒徑、pH 值及溫度對此吸附系統之的吸附平衡之影響以及 pH 值及溫度對吸附反應機制之影響。

(二) 計畫英文摘要。(五百字內)

Keywords:

tree fern, sorption, isotherm, kinetic, heavy metals, biosorbent

Abstract:

Sorption has been accepted as one of the most appropriate processes for the purification of water and wastewater. The sorbent used most widely for industrial applications is activated carbon. However, it is an expensive material despite its ability for regeneration. Therefore, in recent years extensive studies have been undertaken to find cheaper sorbent materials to remove heavy metals and dyes from water as well as aqueous effluents. Recently many cheap, natural and widely-available materials have been tested as suitable sorbents for the removal of pollutants from water, and given encouraging results in several areas of application. Table 1 shows a number of cheap sorbents available for pollutants removal from water.

Tree fern is naturally, commercially available in Taiwan. This variety of tree fern is generally marketed as a soil conditioner for horticultural purposes because of its character of sorbability to keep water and manure for plants. Tree fern is generally dark brown in colour. It is a complex material containing lignin and cellulose as major constituents (Newman, 1997). Chemical sorption can occur by the polar functional groups of lignin, which include alcohols, aldehydes, ketones, acids, phenolic hydroxides and ethers as chemical bonding (Adler and Lundquist, 1963). Because of the fairly polar character of tree fern, the specific sorption for dissolved solids such as transition metals and polar organic molecules is very high.

Tree fern has never been studied in wastewater treatment as a biosorbent for any pollutant removal. However, it could be a useful biosorbent because of its polar and porous characters. Moreover, tree fern is especially natural in Taiwan and is not expensive. In this study, an attempt will be made to use tree fern as a new biosorbent for heavy metal removal from water.

It is significant to establish the equilibrium sorption of such systems under various sorption conditions. Three sorption isotherms, Langmuir, Freundlich and Redlich-Peterson will be tested. The factors studied include the influence of heavy metal, material particle size, solution pH and temperature on the sorption isotherm of the system. The kinetic studies will also be carried out using a shaking batch sorber to study the effects of initial metal ion concentration, particle size, stir speed, initial pH value of solution and temperature. Kinetic analysis was performed to correlate the experimental data, based on the pseudo-first order (Lagergren, 1898), the pseudo-second order (Ho, 1995) and the intraparticle diffusion (Weber and Morris, 1963) models. In addition, the studies will investigate the binary sorption isotherm of zinc and cadmium ions onto tree fern to study the effects of concentration ratio, particle size, initial pH value of solution and temperature. Moreover, The kinetic studies in the binary sorption system will also be carried out to study the effects of initial pH value of solution and temperature. Kinetic analysis was also performed to correlate the experimental data, based on the pseudo-first order, the pseudo-second order and the intraparticle diffusion models.

十二、研究計畫內容：

(一) 近五年內主要研究成果說明。

(二) 研究計畫之背景及目的。詳述本研究計畫之背景、目的、重要性以及國內外有關本計畫之研究情況，重要參考文獻之評述等。本計畫如為整合型計畫之子計畫，請就以上各點分別述明與其他子計畫之相關性。

(三) 研究方法、進行步驟及執行進度。請分年列述：1. 本計畫採用之研究方法與原因。2. 預計可能遭遇之困難及解決途徑。3. 重要儀器之配合使用情形。4. 如為整合型計畫，請就以上各點分別說明與其他子計畫之相關性。5. 如為須赴國外或大陸地區研究，請詳述其必要性以及預期成果等。

(四) 預期完成之工作項目及具體成果。1. 執行期限內預期完成之工作項目。2. 對於學術研究、國家發展及其他應用方面預期之貢獻。3. 對於參與之工作人員，預期可獲之訓練。4. 本計畫如為整合型計畫之子計畫，請就以上各點分別說明與其他子計畫之相關性。

（一）近五年內主要研究成果說明

Publications:

Academic Publication

1. Wase, D.A.J., Forster, C.F. and Ho, Y.S. (1997), Low-cost biosorbents: Batch processes. in *Biosorbents for Metal Ions*, (Edited by Wase, D.A.J. and Forster, C.F.), Taylor and Francis, London and New York, 141-163.

Scientific Papers:

1. Adams, H., Fenton, D.E., Ho, Y.S., Najera, B.A. and Rodriguez de Barbarin, C.O. (1997), The X-ray crystal structures of two derivatives of 2,6-bis{[2-(dimethoxymethyl)phenoxy]methyl}pyridine. *Journal of Chemical Research-S*, **6**, 188-189. (**SCI**)
2. Adams, H., Fenton, D.E., Ho, Y.S., Najera, B.A. and Rodriguez de Barbarin, C.O. (1997), The X-ray crystal structures of two derivatives of 2,6-bis{[2-(dimethoxymethyl)phenoxy]methyl}pyridine. *Journal of Chemical Research. Miniprint.*, **6** (3), 1237-1251.
3. Ho, Y.S. and McKay, G. (1998), Kinetic models for the sorption of dye from aqueous solution by wood. *Process Safety and Environmental Protection*, **76** (B2), 183-191. (**SCI**)
4. Ho, Y.S. and McKay, G. (1998), Sorption of dye from aqueous solution by peat. *Chemical Engineering Journal*, **70** (2), 115-124. (**SCI**)
5. Ho, Y.S. and McKay, G. (1998), Kinetic model for lead(II) sorption on to peat. *Adsorption Science & Technology*, **16** (4), 243-255. (**SCI**)
6. Ho, Y.S. and McKay, G. (1998), The kinetics of sorption of basic dyes from aqueous solution by sphagnum moss peat. *Canadian Journal of Chemical Engineering*, **76** (4), 822-827. (**SCI**)
7. Ho, Y.S. and McKay, G. (1998), A comparison of chemisorption kinetic models applied to pollutant removal on various sorbents. *Process Safety and Environmental Protection*, **76** (B4), 332-340. (**SCI**)

8. Ho, Y.S. and McKay, G. (1998), A two-stage batch sorption optimized design for dye removal to minimum contact time. *Process Safety and Environmental Protection*, **76** (B4), 313-318. (**SCI**)
9. Ho, Y.S. and McKay, G. (1999), The sorption of lead(II) ions on peat. *Water Research*, **33** (2), 578-584. (**SCI**)
10. Ho, Y.S. and McKay, G. (1999), A kinetic study of dye sorption by biosorbent waste product pith. *Resources Conservation and Recycling*, **25** (3), 171-193. (**SCI**)
11. Ho, Y.S. and McKay, G. (1999), Comparative sorption kinetic studies of dye and aromatic compounds onto fly ash. *Journal of Environmental Science and Health Part A-Toxic/Hazardous Substances & Environmental Engineering*, **34** (5), 1179-1204. (**SCI**)
12. McKay, G., Ho, Y.S. and Ng, J.C.P. (1999), Biosorption of copper from waste waters: A review. *Separation and Purification Methods*, **28** (1), 87-125. (**SCI**)
13. Ho, Y.S. and McKay, G. (1999), Batch lead(II) removal from aqueous solution by peat: Equilibrium and kinetics. *Process Safety and Environmental Protection*, **77** (B3), 165-173. (**SCI**)
14. Ho, Y.S. and McKay, G. (1999), A multi-stage batch sorption design with experimental data. *Adsorption Science & Technology*, **17** (4), 233-243. (**SCI**)
15. Ho, Y.S. and McKay, G. (1999), Pseudo-second order model for sorption processes. *Process Biochemistry*, **34** (5), 451-465. (**SCI**)
16. Ho, Y.S. and McKay, G. (1999), Comment on "The sorption of lead(II) ions on peat" by Y. S. Ho and G. McKay, Water Research 33 (2), 578-584 (1999) - Authors' reply. *Water Research*, **33** (16), 3544. (**SCI**)
17. Ho, Y.S. and McKay, G. (1999), Competitive sorption of copper and nickel ions from aqueous solution using peat. *Adsorption-Journal of the International Adsorption Society*, **5** (4), 409-417. (**SCI**)
18. Ho, Y.S. and McKay, G. (2000), Correlative biosorption equilibria model for a binary batch system. *Chemical Engineering Science*, **55** (4), 817-825. (**SCI**)
19. Ho, Y.S. and McKay, G. (2000), The kinetics of sorption of divalent metal ions onto sphagnum moss peat. *Water Research*, **34** (3), 735-742. (**SCI**)
20. Ho, Y.S., Ng, J.C.Y. and McKay, G. (2000), Kinetics of pollutant sorption by biosorbents: Review. *Separation and Purification Methods*, **29** (2), 189-232. (**SCI**)
21. Ho, Y.S., McKay, G., Wase, D.A.J. and Forster, C.F. (2000), Study of the sorption of divalent metal ions on to peat. *Adsorption Science & Technology*, **18** (7), 639-650. (**SCI**)
22. Ho, Y.S. and McKay, G. (2000), Batch sorber design using equilibrium and contact time data for the removal of lead. *Water Air and Soil Pollution*, **124** (1-2), 141-153. (**SCI**)
23. Ho, Y.S., Ng, J.C.Y. and McKay, G. (2001), Removal of lead(II) from effluents by sorption on peat using second-order kinetics. *Separation Science & Technology*, **36** (2), 241-261. (**SCI**)
24. Ho, Y.S., Chiang, C.C. and Hsu, Y.C. (2001), Sorption kinetics for dye removal from aqueous solution using activated clay. *Separation Science and Technology*, **36** (11), 2473-2488. (**SCI**)
25. Ho, Y.S. and Chiang, C.C. (2001), Sorption studies of acid dye by mixed sorbents. *Adsorption-Journal of the International Adsorption Society*, **7** (2), 139-147. (**SCI**)

26. Ho, Y.S., Huang, C.T. and Huang, H.W., Equilibrium sorption isotherm for metal ions on tree fern. Accepted by *Process Biochemistry*. (**SCI**)

（二）研究計畫之背景及目的

水處理是目前國內最重要的環保課題之一，在過去幾年中針對水處理方法做了許多的研究，發現「吸附」技術被廣泛運用在水的處理。就從水中去除污染物來說，它是目前被公認為一項有效與經濟的方法。目前最被廣泛使用的吸附材為活性碳，但由於活性碳價格高昂，過去幾十年以來，已有許多針對自然吸附物質的研究，以尋找出能夠降低成本且適合產業開發的吸附物質。研究者測試很多廢棄或自然產生的物質，以評估它們應用在水污染控制領域的可行性。這些被測試的物質，包括泥煤、黏土、樹皮、爐灰、穀殼、稻草、茶葉、氫氧化鐵、鋸屑、固體沈澱物、油棕櫚纖維、貝殼、米糠、海草、可可果殼褐煤、高嶺土、大豆與棉子殼、橘子皮、矽膠、矽藻土、活性白土、食品工廠殘渣殼纖維碳、廢輪胎、幾丁質、海藻、水仙、蔗渣、甜菜根、苔蘚類植物、香蕉木髓等（Table 1）。這些研究所使用的材料大多以當地方便取得為主要的考量。研究者如香港科技大學的 McKay；加拿大 Regina 大學的 Viraraghavan 與 Kapoor；馬來西亞 Putra 大學的 Lee 與 Low；英國 Birmingham 大學的 Forster 與 Al-Duri 以及 Queen's University Belfast 大學的 Allen；土耳其 Hacettepe 大學的 Sağ；以色列 An Najah 大學的 Salim；澳洲 Griffith 大學的 Yu；埃及 El Minia 大學的 Nassar；另外在印度也有許多的研究者在嘗試這類型的研究，如 Roorkee 大學的 Gupta, Sharma 與 Sharma 以及印度科學院的 Kumar 等都有相關的研究發表。從過去與英國、香港、印度、加拿大、土耳其、澳洲以及荷蘭研究者的討論經驗中得知，由當地尋求適合的吸附材質之研究是目前全球的趨勢。

本計畫的重點是探討蛇木屑對重金屬吸附的機制。蛇木屑是在台灣尋找出的一種地方性的材質。在台灣，蛇木屑被廣泛用在園藝方面，常被用來栽培蘭花。目前還未發現任何以蛇木屑當吸附材之相關發表研究論文。在初步評估後發覺，蛇木屑是一種深咖啡色組成複雜的有機物質，其主要成分為木質素與纖維素（Newman, 1997）。化學吸附可在木質素的極性官能基上發生，如醇類、醛類、酮類、醚類及酚式羥基（Adler and Lundquist, 1963）。基本上，蛇木屑的極性及酸性特質，對金屬陽離子具有良好的吸附作用；另外，其多孔性質也是作為吸附劑的重要考量之一。因此，本計劃嘗試以台灣特有的蛇木屑作為吸附物，以去除水中的重金屬。由於吸附等溫線於設計吸附系統時是重要的研究，所以，在此計劃中將探討重金屬種類、吸附材的顆粒大小、溶液酸鹼度及溫度等對此吸附系統之的吸附平衡之影響。同時，本計劃亦將進行此吸附系統之動力學相關探討。也將與其他吸附材做效果比較，以提供進一步實際運用之研究。

本計畫第一年的重點是以蛇木屑為吸附材去除水中之重金屬，針對其吸附之現象進行探討。辨識其吸附適用範圍，比較其平衡吸附量，探討重金屬種類、吸附材的顆粒大小、溶液酸鹼度及溫度對吸附平衡等溫線之影響。同時也與其他吸附材做效果比較，以提供第二年進一步的吸附動力學與吸附反應機構之研究。第二年將針對吸附劑之粒徑、溶液之 pH 值、溫度、攪拌速度及溶液初濃度進行吸附動力學之研究。第三年將針對競爭吸附進行吸附等溫線之研究，探討重金屬（鋅、鎘）溶液初濃度比、溶液 pH 值及溫度對吸附平衡等溫線之影響。在競爭吸附動力學方面，將針對重金屬（鋅、鎘）溶液初濃度比、溶液 pH 值及溫度進行競爭吸附反應機制之研究。

（三）研究方法、進行步驟及執行進度

1. 採用之方法

等溫吸附線之研究

利用蛇木屑吸附去除水溶液中之鋅、鎘

(1) 將選定之蛇木屑磨碎，烘乾後，用振動篩網篩成不同大小之粒徑，作為本研究之吸附劑。

(2) 以掃描式電子顯微鏡（Scanning Electron Microscope）觀察蛇木屑之表面。

(3) 測蛇木屑比表面積極孔隙度。

(4) 取適量蛇木屑以硝酸硝化後測定背景金屬（鐵、鋁、鈉、錳、鋅、鉛、鎳、鎘、鉀、鉻、銅、汞、銀、砷、硒、銻、鈣、鎂、鋇）之含量

(5) 吸附平衡時間：取定量（500 ml）之重金屬溶液於錐形瓶中，並將定量（2 g）之吸附劑置入，放置於恆溫振盪器中振盪，於特定時間分別取樣，以 0.45 μm 孔徑之濾膜過濾分離溶液後以感應耦合電漿原子發射光譜分析儀（Inductively Coupled Plasma Atomic Emission Spectrometer, ICP-AES）進行定量分析。

(6) 把選定之重金屬配製成不同濃度，分別取定量（50 ml）之重金屬溶液於錐形瓶中，並將定量（0.2 g）之吸附劑置入，將系列錐形瓶放置於恆溫振盪器中振盪至吸附平衡時間使吸附達平衡。

(7) 取出試樣，過濾分離溶液，以感應耦合電漿原子發射光譜分析儀（Inductively Coupled Plasma Atomic Emission Spectrometer, ICP-AES）進行定量分析。

(8) 改變重金屬種類（鋅、鎘）重複(6)與(7)步驟，進行等溫吸附之研究。

(9) 改變吸附劑之粒徑（38-43, 43-53, 53-61, 61-74, 74-88, 88-104, 104-124, 124-147 μm）重複(6)與(7)步驟，進行等溫吸附之研究。

(10) 改變溶液之 pH 值（1.5, 2, 3, 4, 4.5, 5, 5.5, 6）重複(6)與(7)步驟，進行等溫吸附之研究。

(11) 改變溶液溫度（5, 10, 15, 20, 25, 30, 35, 40℃）重複(6)與(7)步驟，進行等溫吸附之研究。

吸附動力學之研究

(1) 取定量之金屬溶液（1.7 dm^3），置於設有擋板之攪拌反應槽中，加入定量（6.8 g）之吸附劑，以固定之攪拌速度（300 rpm）進行吸附反應。

(2) 於特定時間分別取樣（2 ml），以 0.45 μm 孔徑之濾膜過濾分離溶液後以感應耦合電漿原子發射光譜分析儀（Inductively Coupled Plasma Atomic Emission Spectrometer, ICP-AES）進行定量分析。

(3) 改變重金屬種類（鋅、鎘）重複(1)與(2)步驟，進行吸附動力學之研究。

(4) 改變吸附劑之粒徑（38-43, 43-53, 53-61, 61-74, 74-88, 88-104, 104-124, 124-147 μm）重複(1)與(2)步驟，進行吸附動力學之研究。

(5) 改變溶液之 pH 值（1.5, 2, 3, 4, 4.5, 5, 5.5, 6）重複(1)與(2)步驟，進行吸附動力學之研究。

(6) 改變溶液溫度（5, 10, 15, 20, 25, 30, 35, 40℃）重複(1)與(2)步驟，進行吸附動力學之研究。

(7) 改變攪拌速度（270, 300, 330, 360, 390, 420, 450, 480）重複(1)與(2)步驟，進行吸附動力學之研究。

(8) 改變溶液初濃度（100, 150, 200, 250, 300, 350, 400, 450 mg/dm^3）重複(1)與(2)步驟，進行吸附動力學之研究。

競爭吸附等溫線之研究

(1) 把選定之重金屬配製成固定溶液初濃度比，配製成不同濃度後，分別取定量（50 ml）之重金屬溶液於錐形瓶中，並將定量（0.2 g）之吸附劑置入，將系列錐形瓶放置於恆溫振盪器中振盪至吸附平衡時間使吸附達平衡。

(2) 取出試樣，過濾分離溶液，以感應耦合電漿原子發射光譜分析儀（Inductively Coupled Plasma Atomic Emission Spectrometer, ICP-AES）進行定量分析。

(3) 改變重金屬（鋅、鎘）溶液初濃度比（1:1; 1:2; 1:3; 1:4; 1:5;1:6; 6:1; 5:1; 4:1; 3:1; 2:1），重複(1)與(2)步驟，進行競爭吸附等溫線之研究。

(4) 以固定溶液初濃度比，改變溶液 pH 值（1.5, 2, 3, 4, 4.5, 5, 5.5, 6），重複(1)與(2)步驟，進行競爭吸附等溫線之研究。

(5) 以固定溶液初濃度比，改變溶液溫度（5, 10, 15, 20, 25, 30, 35, 40℃），重複(1)與(2)步驟，進行競爭吸附等溫線之研究。

競爭吸附動力學之研究

(1) 取定量之混合金屬溶液（1.7 dm^3），置於設有擋板之攪拌反應槽中，加入定量（6.8 g）之吸附劑，以固定之攪拌速度（300 rpm）進行吸附反應。

(2) 於特定時間分別取樣，以 0.45 μm 孔徑之濾膜過濾分離溶液後以感應耦合電漿原子發射光譜分析儀（Inductively Coupled Plasma Atomic Emission Spectrometer, ICP-AES）進行定量分析。

(3) 改變重金屬（鋅、鎘）溶液初濃度比（1:1; 1:2; 1:3; 1:4; 1:5;1:6; 6:1; 5:1; 4:1; 3:1; 2:1），重複(1)與(2)步驟，進行競爭吸附反應機制之研究。

(4) 以固定溶液初濃度比，改變溫度（5, 10, 15, 20, 25, 30, 35, 40℃），重複(1)與(2)步驟，進行競爭吸附反應機制之研究。

(5) 以固定溶液初濃度比，改變溶液之 pH 值（1.5, 2, 3, 4, 4.5, 5, 5.5, 6）重複(1)與(2)步驟，進行競爭吸附反應機制之研究。

2. 採用本方法之原因

本方法是一種成熟的技術，已被廣泛使用於吸附研究。以此方法探討新的吸附物質之吸附現象，是為了減少因嘗試新的吸附物質可能產生的變數。

使用感應耦合電漿原子發射光譜分析儀（Inductively Coupled Plasma Atomic Emission Spectrophotometer，ICP-AES），是為了定量金屬濃度。同時考慮 ICP-AES 之多元素分析及其較寬之操作線性關係之特性。

3. 預計可能遭遇之困難及解決途徑

可能遭遇之困難：

國科會未能給予貴重儀器元素分析儀（EA），感應耦合電漿原子發射光譜分析儀（ICP-AES），掃描式電子顯微鏡（Scanning Electron Microscope）使用之支援。無表面積與孔隙度分析儀（Micromeritics）可使用。

國科會未能於執行期限開始時（民國 91 年 8 月 1 日）通知執行，或未能給予足夠的執行時間。

解決途徑：

自掏腰包，由薪水支付。

增加週末假期及下班後的時間執行計劃。

4. 重要儀器之配合使用情形

感應藕合電漿原子發射光譜儀（inductively coupled plasma atomic emission spectrophotometer，ICP-AES），掃描式電子顯微鏡（Scanning Electron Microscope），表面積與孔隙度分析儀（Micromeritics），元素分析儀（EA），振盪篩分器，烘箱，過濾，球磨機，pH 計，電子天平，超純水設備，攪拌實驗設備（電動攪拌器），低溫循環水槽，恆溫振盪器

（四）預期完成之工作項目及具體成果

本研究計畫於完成後，希望達到的目標：

第一年：吸附平衡等溫線之建立

1. 辨識蛇木屑吸附物質的適用範圍，以便去除水中的重金屬污染物。

2. 比較蛇木屑對於重金屬污染物的最大平衡吸附量。

3. 探討重金屬種類對吸附平衡等溫線之影響。

4. 探討吸附材的顆粒大小對吸附平衡等溫線之影響。

5. 探討溶液酸鹼度對吸附平衡等溫線之影響。

6. 探討溶液溫度對吸附平衡等溫線之影響。

7. 與其他吸附材做效果比較，以提供第二年的吸附動力學與吸附反應機構之研究。

第二年：吸附反應機構之確立

1. 探討蛇木屑當吸附物質處理廢水中污染物之反應機制。

2. 探討蛇木屑當吸附物質處理重金屬之反應機制。

3. 探討吸附劑粒徑對吸附反應機制之影響。

4. 探討攪拌速度對吸附反應機制之影響。

5. 探討溶液初濃度對吸附反應機制之影響。

6. 探討溶液 pH 值對吸附反應機制之影響。

7. 探討溶液溫度對吸附反應機制之影響。

8. 與其他重金屬吸附系統做反應機制比較，以提供進一步實際應用之參考。

第三年：競爭吸附之探討

1. 探討重金屬溶液初濃度比對競爭吸附平衡等溫線之影響。

2. 探討溶液 pH 值對競爭吸附平衡等溫線之影響。

3. 探討溶液溫度對競爭吸附平衡等溫線之影響。

4. 探討溶液初濃度比對競爭吸附反應機制之影響。

5. 探討溶液 pH 值對競爭吸附反應機制之影響。

6. 探討溶液溫度對競爭吸附反應機制之影響。

由於國內經濟發展造成環境污染的嚴重性，民生用水已受到嚴重的威脅。本計劃研究以台灣特有、自然、廉價吸附物去除水中之重金屬，成果不但可提供相關研究之參考，未來也可提供國內產業界及政府相關單位吸附技術之改善與實際層面之運用。

本計劃於執行期間，蒐集分析國內外相關學術研究資料，並配合實驗之進行，提供學術理論探討同時也將近一步驗證本人於 1995 年所提出之動力學模式（Pseudo-second order kinetic model）。此模式發表至今，已被廣泛應用在各種吸附系統（Table 2），為提昇本人在此領域之國際地位，必須有更多進一步的研究。本計劃結案時，至少會有 10 篇以上 SCI 的論文發表。定可提升本領域研究之國際地位。

十三、未來三年內學術研究發展計畫：

1. 申請本會吳大猷先生紀念獎者，請務必填寫本表，以利審查。
2. 請分年列述。

補助學者專家赴大陸地區從事短期科技研究申請書

請檢附：

1.大陸地區協助研究機關（構）之同意書、邀請或許可文件。(各一式四份)

2.其他費用包括證照、保險或其他相關費用等。

3.請將所列各項費用換算為台幣後，加總填入合計欄內，並於說明欄內註明估算匯率。有關此部份之工作心得報告應於計畫執行完畢後以附件方式併同研究計畫成果報告繳交。

一、基本資料：

申請人姓名		身分證號碼	
推薦機構及系所		預定赴大陸地區研究期限	_____個月， 自__年__月__日起至 __年__月__日止
擬赴研究處所(請填寫前往地點及學校機關名稱)			

	補助項目	預　估　經　費	說　　明
申請補助費用	交 通 費		
	生 活 費		
	其他費用		
	合　　計		

二、研究計畫內容：(請就下列各項分年列述並詳盡填寫，若篇幅不敷使用，請另紙繕附)

（一）本計畫赴大陸研究之必要性及對台灣地區學術、科技、社會、經濟各層面之可能貢獻性。

（二）大陸地區協助研究之機構，其研究設備及人力配合情形暨特色。

（三）申請單位提供本計畫赴大陸地區短期科技研究之相關經費（或配合款）編列情形。

Table 1 A number of cheap sorbents available for pollutants removal from water.

Sorbent	Reference
1:1 Fly ash and coal	Gupta *et al.*, 1988
Algae	Ö zer *et al.*, 1994
Anaerobically digested sludge	Gould and Genetelli, 1978
Bagasse pith	McKay *et al.*, 1987
Banana pith	Namasivayam and Kanchana, 1992
Basic yttrium carbonate	Wasay *et al.*, 1996
Beech leaves	Salim *et al.*, 1992
Bicarbonate-treated peanut hulls	Namasivayam and Periasamy, 1993
Biogas residual slurry	Namasivayam and Yamuna, 1992
Biopolymers	Seki and Suzuki, 1996
Bituminous coal	Ong and Swanson, 1966
Blast furnace sludge	López *et al.*, 1995
Bone char	Cheung *et al.*, 2000
Bottom ash	Kaur *et al.*, 1991
C. vulgaris	Aksu, 2001
Casein	Mishra *et al.*, 1998
Chemically-reinforced biomass of marine algae	Leusch *et al.*, 1995
China clay	Sharma *et al.*, 1991
Chitin	McKay *et al.*, 1982
Chitosan	Findon *et al.*, 1993
Chlorella vulgaris	Mehta and Gaur, 2001
Coconut coir	Baes *et al.*, 1996
Coconut shell	Bhattacharya and Venkobachar, 1984
Coir	Quek *et al.*, 1998
Coir pith	Namasivayam *et al.*, 2001
Coke	López-delgado *et al.*, 1996
Composite biopolymer	Seki and Suzuki, 1996
Copper-coated moss	Lee *et al.*, 1995
Cottonseed hulls	Marshall and Johns, 1996
Cypress leaves	Salim *et al.*, 1994
Dried water hyacinth roots	Low *et al.*, 1994
Dyestuff-treated rice hulls	Suemitsu *et al.*, 1986
Dye-treated oil-palm fibre	Low *et al.*, 1993
Exhausted coffee	Orhan and Büyükgüngör, 1993
Feldspar	Singh *et al.*, 1996
Fireclay	Bajpai, 2001
Fly ash	Panday *et al.*, 1985
Formaldehyde-crosslinked seaweed biomass	de Carvalho *et al.*, 1994
Fuller's earth	McKay *et al.*, 1985
Fungal mycelia	Huang *et al.*, 1991
Goethite	Grossl *et al.*, 1994
Groundnut husks	Okieimen *et al.*, 1991
Haematite	Singh *et al.*, 1988
High carbon content sludge	López-delgado *et al.*, 1996
Hydrous ceric oxide	Mishra and Singh, 1995
Hydrous zirconium oxide	Mishra *et al.*, 1996
Illite clay	Farrah *et al.*, 1980

Immobilized bimomass	Ramelow *et al.*, 1996
Immobilized humic acid	Seki *et al.*, 1990
Impregnated fly ash	Singh and Rawat, 1994
Kaolinite	Holm and Zhu, 1994
Kaolinitic clay	Farrah *et al.*, 1980
Leaf mould	Sharma and Forster, 1994
Lignin	Srivastava *et al.*, 1994
Lignite	Ong and Swanson, 1966
Linden sawdust	Holan and Volesky, 1995
Magnetite	Ortiz *et al.*, 2001
Microcystis	Singh *et al.*, 2001
Montmorillonite clay	Farrah *et al.*, 1980
Moss	Low *et al.*, 1983
Natural oil-palm fibre	Low *et al.*, 1993
Neem sawdust	Khattri and Singh, 2000
Nut shell	Orhan and Büyükgüngör, 1993
Orange peel	Namasivayam *et al.*, 1996
Palm pressed fibers	Tan *et al.*, 1996
Peat	Ong and Swanson, 1966
Peat moss	Tinh *et al.*, 1971
Red mud	Gupta *et al.*, 2001
Resin	Yu *et al.*, 2001
Rice hulls	Suemitsu *et al.*, 1986
Ricebran	Verma and Rehal, 1994
Sago	Quek *et al.*, 1998
Sand	Hasany and Chaudhary, 1996
Sawdust	Vaishya and Prasad, 1991
Shea butter seed husks	Eromosele *et al.*, 1996
Sludge solid	Tien and Huang, 1991
Soil	Majid *et al.*, 1996
Soybean hulls	Marshall and Johns, 1996
Spruce sawdust	Holan and Volesky, 1995
Sugar cane dust	Khattri and Singh, 1999
Tea leaves	Tan and Abd. Rahman, 1988
Trametes versicolor	Arica *et al.*, 2001
Treated acacia bark	Kumar and Dara, 1982
Treated bagasse	Kumar and Dara, 1982
Treated laurel bark	Kumar and Dara, 1982
Treated techtona bark	Kumar and Dara, 1982
Turkish coffee	Orhan and Büyükgüngör, 1993
Tyres, Sawdust	Hamadi *et al.*, 2001
Walnut shell	Orhan and Büyükgüngör, 1993
Waste slurry	Srivastava *et al.*, 1989
Waste tea	Orhan and Büyükgüngör, 1993
Waste type rubber	Rowley *et al.*, 1984
Water hyacinth	Lee and Hardy, 1987
Water hyacinth roots	Lee*et al.*, 1995
Wollastonite	Singh *et al.*, 1988
Wood	McKay and McConvey, 1981
Yeast biomass	Brady *et al.*, 1994

Yeast cell walls	Brady and Duncan, 1994

Table 2. Pseudo-second order kinetic model of various related systems from the literature.

Sorbent	Sorbate	Reference
Activated carbon	Phenol	Juang *et al.*, 2000
Activated carbon	Phenol	Wu *et al.*, 2001
Activated clay	Basic Red 18, Acid Blue 9	Ho *et al.*, 2001
Activated clay	Basic Dye (BB69), Direct Dye (DR227)	Wu *et al.*, 2001
Aspergillus niger	Basic Blue 9	Fu and Viraraghavan, 2000
Aspergillus niger	Acid Blue 29	Fu and Viraraghavan, 2001
Aspergillus niger	Pb(II), Cd(II), Cu(II), Ni(II)	Kapoor *et al.*, 1999
C. vulgaris	Cd(II)	Aksu, 2001
Chitosan	Glutaraldehyde	Juang *et al.*, 2001
Chitosan	Reactive Dye RR222	Wu *et al.*, 2000
Chitosan	Reactive Dye RR222, RY145, RB222, Cu(II)	Wu *et al.*, 2001
Chlorella vulgaris	Cu(II) and Ni(II)	Mehta and Gaur, 2001
Chlorella vulgaris	Cu(II), Ni(II)	Mehta and Gaur, 2001
Coir	Cu(II), Pb(II)	Quek *et al.*, 1998
Cubic mesoporous silicate	Tetramethyl ammonium hydroxide	Kelleher *et al.*, 2001
Fly ash	Omega Chrome Red ME, *o*-cresol, *p*-nitrophenol	Ho and McKay, 1999
Glass	Cu(II)	Rappoli and Rowley, 2000
Lignite-based carbons	Cu(II), Ni(II)	Samra, 2000
Microcystis	Ni(II), Cr(VI)	Singh *et al.*, 2001
Mixed clay/carbon	Acid Blue 9	Ho and Chiang, 2001
Peat	Pb(II)	Ho and McKay, 1998
Peat	Basic Blue 69, Acid Blue 25	Ho and McKay, 1998
Pith	Basic Red 22, Acid Red 114	Ho and McKay, 1999
Rhizopus arrhizus	Remazol Black B	Aksu and Tezer, 2000
Sago	Cu(II), Pb(II)	Quek *et al.*, 1998
Sawdust, Waste tyre	Cr(VI)	Hamadi *et al.*, 2001
Spent grain	Pb(II), Cd(II)	Low *et al.*, 2000
Sphagnum moss peat	Chrysoidine (BO2), Astrazon Blue (BB3), Astrazone Blue (BB69)	Ho and McKay, 1998
Sphagnum moss peat	Cu(II), Ni(II), Pb(II)	Ho and McKay, 2000
Sphagnum moss peat	Cu(II), Ni(II)	Ho *et al.*, 1996
Trametes versicolor	Cd(II)	Arica *et al.*, 2001
Wood	Basic Blue 69, Acid Blue 25	Ho and McKay, 1998
Zeolite tuff	Pb(II)	El-Bishtawi and Ali, 2001

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