

**REMOVING TOXIC METALS FROM WATER
FOR CULTURE OF TIGER PRAWN,
*Penaeus monodon***

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DECLARATION

The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

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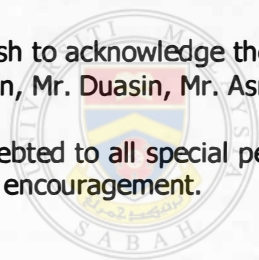
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ABSTRAK

REMOVING TOXIC METALS FROM WATER FOR CULTURE OF TIGER PRAWN, *Penaeus monodon*

Kualiti air merupakan salah satu faktor penting dalam akuakultur. Penggunaan air yang berkualiti tinggi pada kos yang berpatutan adalah perlu untuk membesarkan udang pada kadar yang lebih cepat dan untuk membekalkan bahan makanan yang selamat untuk manusia. Kajian ini bertujuan untuk menghasilkan satu kaedah yang berkesan dan murah untuk mengeluarkan kadmium dan plumbum dari air laut. Bahan-bahan buangan pertanian yang dihasilkan oleh industri kelapa sawit, daun-daun teh yang telah digunakan, kulit-kulit pisang, durian, nangka, manggis dan kelapa telah ditukarkan menjadi bahan separa arang melalui proses terma. Pada langkah pertama, keupayaan bahan-bahan separa arang ini untuk menyerap plumbum dari larutan akueus menggunakan teknik berkumpulan dan turus telah dikaji. Kedua-dua teknik menunjukkan bahawa kesemua bahan separa arang mampu menyerap lebih daripada 69% plumbum. Namun didapati bahawa teknik berkumpulan adalah lebih baik daripada teknik turus. Bahan penyerap yang disediakan daripada daun teh dan kelapa sawit telah dipilih untuk perbandingan dalam eksperimen yang seterusnya. Daun teh telah menunjukkan penyerapan plumbum yang paling tinggi (99%). Kedua-dua bahan penyerap tersebut mampu menyerap 98% kadmium dari larutan akueus dan juga dari larutan yang mengandungi kedua-dua logam kadmium dan plumbum. Walaubagaimanapun dalam air laut, bahan penyerap yang disediakan daripada daun teh dapat menyerap kedua-dua logam sehingga 29%. Penggunaan bahan-bahan buangan pertanian tersebut (daun teh dan kelapa sawit) bersama-sama dengan produk bergred komersil 'Dia Miracle' (DM) dan asid askorbik (Faktor-C) telah diuji keberkesanan masing-masing dalam penternakan udang harimau, *Penaeus monodon*. Parameter-parameter air laut yang telah diambil ialah pH, kemasinan, oksigen terlarut, hidrogen sulfida, nitrit, nitrat, ammonia, kadmium dan plumbum. Walaupun bahan-bahan buangan pertanian tersebut menyerap sehingga 29% kadmium dan plumbum dari air laut, namun bahan-bahan ini telah menyumbang kepada kandungan ammonia di dalam air yang mengakibatkan kematian ke atas udang-udang tersebut. Oleh yang demikian, ujian seterusnya yang melibatkan bahan-bahan separa arang tersebut telah dihentikan. Manakala, eksperimen menggunakan DM dan Faktor-C telah diteruskan. Kedua-dua bahan ini dapat meningkatkan kualiti air laut dan mengurangkan kepekatan logam toksik dalam tisu udang.

ABSTRACT

REMOVING TOXIC METALS FROM WATER FOR CULTURE OF TIGER PRAWN, *Penaeus monodon*

*Water quality is one of the most important factors to be considered in aquaculture. There is a need to use high quality water at affordable cost to grow prawns at faster rate and supply a safe quality crop for human consumption. This study was undertaken with the aim of developing a low-cost but effective method for the removal of cadmium and lead from seawater. Agricultural wastes produced by palm oil industry, along with used tea leaves, banana peeling, covering of durian, Jackfruit, mangosteen and coconut shells were converted into charred materials by thermal processing. In the first instance, ability of these charred materials to adsorb lead from aqueous solution using batch and column techniques was investigated. Both techniques showed that all the charred materials were able to adsorb more than 69% of lead. However, batch technique was found to be better than the column technique. Adsorbents prepared from used tea leaves and palm oil wastes were chosen for comparison in further experiments. The used tea leaves gave the highest lead adsorption (99%). Both materials were found to adsorb 98% of cadmium from aqueous solution as well as both the cadmium and lead present in the same solution. However, in seawater adsorbent prepared from used tea leaves was able to adsorb both metals up to 29%. The utility of the agricultural wastes (used tea leaves and palm kernel) along with a commercial grade product 'Dia Miracle' (DM) and ascorbic acid (Factor-C) were tested for their efficiency on rearing tiger prawn (*Penaeus monodon*). Water quality parameters observed were pH, salinity, dissolved oxygen, hydrogen sulfide, nitrite, nitrate, ammonia, cadmium and lead. While the agricultural products adsorbed about 29% of cadmium and lead from the water, they left sufficient amount of ammonia in the water that proved fatal for the prawn. Further trials involving these charred materials were, therefore, discontinued. Instead, experiments using DM and Factor-C were carried forward. Both improved the seawater quality and reduced the toxic metal concentrations in the prawn tissues.*

ABBREVIATIONS

AAS	-	atomic absorption spectrophotometer
BL	-	body length
BW	-	body weight
CL	-	carapace length
cm	-	centimeter
DM	-	Dia Miracle
g	-	gram
g/L	-	gram per liter
kg	-	kilogram
mg/kg	-	milligram per kilogram
mg/L	-	milligram per liter
mL	-	milliliter
mm	-	millimeter
M	-	molar
nm	-	nanometer
PET	-	polyethylene
SD	-	standard deviation
SE	-	standard error
TL	-	total length
USA	-	United States of America
µg/g	-	microgram per gram
µg/mL	-	microgram per millimeter
µL	-	microliter
µm	-	micrometer



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SYMBOLS

°C	-	degree celcius
=	-	equal
<	-	less than
>	-	more than
‰	-	parts per thousand
%	-	percentage
US\$	-	US dollar



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CHAPTER 1

GENERAL INTRODUCTION

1.1 Prawn culture and its importance

Prawn is one of the coveted species in aquaculture which has developed rapidly in the last 25 years (Neiland *et al.*, 2001). Prawn farming is one of the fastest growing food production sectors in many countries including Asia and Latin America (Wickins & Lee, 2002). It contributes substantially to national development, food supply, food security, poverty alleviation, income generation and employment (Subasinghe, 2000). It is also becoming increasingly important in meeting the global demand for fisheries products.

There are many factors that have led to the growth of prawn farming. These include increasing demand for prawn in developed countries such as North America, Europe, Japan and also in developing countries such as Malaysia, Thailand and Indonesia. Coupled with falling catches and leveling-off in the production of capture fisheries, market prices have increased since the 1980s (Neiland *et al.*, 2001; Frid & Dobson, 2002). Simultaneously, the emergences of new production technologies, such as hatchery-reared post-larvae and improved artificial feeds have allowed large-scale production (Neiland *et al.*, 2001).

There are at least 60 species of commercially important penaeid prawns around the world but *Penaeus monodon* known as tiger prawn (Figure 1.1) accounts for more than half of the total world prawn aquaculture output (Wickins & Lee, 2002). It is also the largest and fastest growing of all prawn species (Arrignon *et al.*, 1994). In Southeast Asia, this species is extensively cultured, amounting to 90% of the total prawn production (Saleem & Ridzwan, 2000; Mohammad, Saleem &

Shabbir, 2002). This marine prawn has received special attention in Malaysia where its forecast production, together with that of White Prawn, *Penaeus penicillatus*, will be increased in the year 2010 to 13 times the 1998 level, that is from 9, 835 to 129, 100 metric tones (Raman, 2001).

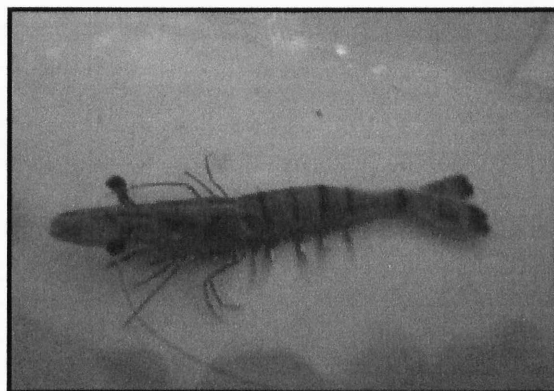


Figure 1.1 : Tiger prawn (*Penaeus monodon*).

P.monodon is of great importance in aquaculture because of some outstanding characteristics when farmed. It has a fast growth rate even at high stocking densities (Arrignon *et al.*, 1994), in that it can reach about 200 mm to 330 mm or more in length and a marketable weight of 33 g in three to six months (Wickins & Lee, 2002). According to Boyd & Fast (1992), Arrignon *et al.*, (1994) and Whetstone *et al.*, (2002), this species has a good tolerance to a wide range of salinity from 20‰ to 40‰, to temperature variations between 25°C to 32°C and resistance to non-ideal environmental condition. In general, it is suitable for farming together with a high market value of about US\$15.00/kg to US\$20.00/kg, depending on size, form (whether alive or dead) and the time of sale (Patimah & Dainal, 1997).

As *P. monodon* is a very valuable seafood commodity where consumer demand far exceeds the supply (Mohammad, Saleem & Shabbir, 2002), it holds promise for the commercial aqua culturists, seeking a more rapid cash flow than is given by cultured fish and shellfish. Further, it serves as a major food in many

countries and is thus of major commercial interest (Arrignon *et al.*, 1994; Kennish, 2001).

1.2 Seawater quality in prawn culture

Successful production of aquaculture animals depends on providing them a satisfactory environment for living and growth. Seawater quality is one of the major factors in survival and growth of tiger prawns (Jiann-Chu, Tzong-Shean & Chin-Kai, 1986). Monitoring and optimizing the seawater quality are primary considerations in all types of aquacultures. High quality of seawater, which contains no excessive nutrients, chemicals or toxic metals, will produce high quality seafood in large quantities. Conversely, low quality seawater will cause poor biological performance and thereby the expected aquaculture outcomes will not be achieved.

1.2.1 Presence of toxic metals in seawater

Cadmium and lead occur naturally in seawater via processes including weathering of rocks, leaching of soils and emissions from hydrothermal vents (Kennish, 2001). Concentrations of both metals are usually only in traces or very low quantities. According to Turekian (1968), a seawater specimen contained 1.1×10^{-4} mg/L of cadmium and 3.0×10^{-5} mg/L of lead, while Dobson & Frid (1998) reported that the concentrations of both metals present naturally were 1.0×10^{-4} mg/L and 5.0×10^{-7} mg/L respectively. Cadmium may be present as chloride complexes such as CdCl_2^0 , CdCl^+ , CdCl_3^- , Cd^{2+} (Rainbow, 1991) while lead may be present as PbCO_3 , $\text{Pb}(\text{CO}_3)_2^{2-}$, PbCl^+ and Pb^{2+} (Bruland, 1983).

However, toxic metal concentrations in seawater have increased recently at a rate far higher than that of the natural processes mentioned above (Ayres, 1992). It is also difficult to attain these extremely low levels of metals in seawater since

natural waters are prone to external pollution governed by human activities. For example, cadmium and lead have been used extensively in electronics manufacturing, electroplating and steel mills (Filov *et al.*, 1993; Marcus, 2001). Inevitably, each industrial process generates wastes, which generally contaminate the environment and pollute water bodies.

Marine monitoring studies which were conducted throughout Malaysia in 1999 revealed that discharges associated with partially treated and untreated industrial wastes greatly influenced the levels of metal contaminants in marine waters (Malaysia : Environmental Quality Report, 1999). Industries situated close to the sea may release high amounts of metals including cadmium and lead. The permitted level of these metals in the Malaysian waters as described in the Twenty-Fifth Schedule, Regulations 394(1) and 360B(3) (Laws of Malaysia, 1997) and Interim National Marine Water Quality Standards for Malaysia (Malaysia : Environmental Quality Report, 1999) is 0.005 mg/L for cadmium and 0.05 mg/L for lead.

Cadmium and lead are not readily biodegradable, and hence persist in the environment for a long period of time (Nriagu, 1988). Aquatic organisms can accumulate these toxic metals in their tissues, even at low concentrations with prolonged exposure (Rainbow, 1991; Arrignon *et al.*, 1994). Furthermore, these metals pose a threat not only to aquatic life, but also to the whole food chain. These metals are likely to build up to higher concentrations, multiplying in the food chain, ultimately endangering human health (Aytac, 2002).

1.3 Toxicity of metals towards aquatic organisms

Metals, even at very low concentrations, enter into body of organisms from an aqueous medium (Kennish, 2001). There are three main pathways for metal accumulation : (i) absorption through the respiratory surface; (ii) adsorption onto

body surfaces and (iii) ingestion via food and water (Ramamoorthy & Baddaloo, 1995). According to Laws (1981) these metals have a great affinity for sulphydryl (-SH) groups of proteins in the animal body and when the two combine, the enzyme-mediated processes and other cellular functions are disrupted. Although different metals attach to different types of protein, but the nature of biochemical interaction in metal toxicity is similar. Cadmium and lead are extremely toxic even in relatively low concentrations in chronic exposure. Under a long exposure they tend to substitute for the essential metals such as calcium because of chemical similarities on one hand and on the other they block metabolic pathways for the reason that only calcium can play that role (Rainbow, 1991).

In most cases, marine organisms can assimilate toxic metals in seawater and can also adapt to minor influences of other pollutants (Ramamoorthy & Baddaloo, 1995) while retaining their normal life cycles. This arises because each species is uniquely adapted to the environment in which it has evolved and each has developed mechanisms to process toxic substances harmlessly both from the natural environment and from its own metabolic pathways. These mechanisms involve metal detoxification through induction of metallothionein synthesis (Moiseenko & Kudryavtseva, 2001). In this mechanism, the metallothionein binds specifically to the excess toxic metals which are subsequently excreted as metabolites. These adaptations however, are not designed to counteract pollutants beyond the adaptive capabilities or tolerance of the species. According to Ramamoorthy & Baddaloo (1995), when the load of the toxic metals exceeds the protective functions of the organisms, the following changes may occur in the aquatic organisms : (1) histological or morphological changes in tissues; (2) changes in physiology; (3) changes in biochemistry; (4) changes in behavior and (5) changes in reproduction.

The harmful effects of the metals may also affect other aquatic life through food chain and pose health hazards to humans when they consume the contaminated prawn. It is, therefore, necessary to eliminate or drastically reduce concentrations of these metals to some established safe levels in the seawater supply to avoid toxic metal accumulation in the prawn, thus meeting the food quality requirements.

1.4 Effects of metal-contaminated seafood consumption

Consumption of seafood contaminated with metals, particularly cadmium and lead, may pose significant risk to human health. According to the Food Act 1983 (Act 281) and Regulations (as at 30th June 1997) of Malaysia, Fourteenth Schedule (Regulation 38) Table 1 (Laws of Malaysia, 1997), the maximum permitted metal contamination in fish and fish products is 1 mg/kg for cadmium and 2 mg/kg for lead.

In general, the effect of metal toxicity towards humans is similar to that towards aquatic organisms. In particular, toxic metals can interfere with essential metallic nutrients of similar charge and radii such as calcium and zinc. For example, cadmium may interfere with the metallothionein's ability to regulate zinc concentrations in the body, and thus disrupt homeostasis levels (Manahan, 2001). It can also cause lung damage and kidney disease and may irritate the digestive tract (Mohammad, 2002).

Lead can substitute for calcium present in bones. Children are especially susceptible to lead because their developing skeletal systems require high calcium levels. The lead ion that is stored in bone is not harmful, but if high levels of calcium are ingested later, the lead in bone may be replaced by calcium and mobilized. Lead also affects the memory (Zarina, 2001), and damages kidneys and the reproductive system (Mohammad, 2002).

1.5 Objectives

The seawater that is pumped from the ocean for prawn culture generally passes through sand filters which do not perform chemical filtration. Hence, toxic metals if present in the water supply enter the culture medium. Currently, there is no economically-feasible technique for the removal of toxic metals from seawater. This investigation was aimed at developing a cost-effective method for chemical filtration so as to either remove the toxic metals from the water or to reduce their load. The specific objectives were:

- 1) To determine the capacity of charred agricultural waste products of adsorbing the toxic metals (cadmium and lead) in the seawater
- 2) To compare the metal removing capacity of the above products with that of the commercial preparations
- 3) To examine the effect of the seawater treatments involving the above-mentioned adsorbents and commercial products on overall water quality
- 4) To observe the effect of the various seawater treatments on survival and growth of tiger prawn.

CHAPTER 2

LITERATURE REVIEW

It is possible to remove suspended matter from seawater by filtration before its supply to aquaculture systems. However, the dissolved chemical pollutants pose a difficult problem. Some methods have been successfully applied to improve the seawater quality. Boyd & Tucker (1998) and Gräslund, Holmström & Wahlström (2003) have reviewed several techniques, including liming to neutralize acidity, addition of zeolites to remove ammonia and decrease turbidity, and chlorination (before stocking) to disinfect the water. Besides that, addition of egg white to culture medium has increased the rate of survival of aquatic animals (Tatsuya *et al.*, 2003), provision of a bio-film containing microbial consortium associated with extracellular polymeric substances has been shown to reduce the concentrations of ammonia and phosphate in seawater (Thompson, Abreu & Wasielesky, 2002) and application of quicklime to decrease the cadmium toxicity to carp (Anilava & Tapas, 2000).

Prawn aquaculture is currently facing an increasing threat from toxic metal pollution in seawater. Studies carried out by Mazlin, Almah & Low (1994), Mohammad *et al.*, (2002) and Mohammad, Saleem & Shabbir (2002) have reported that the seawater used in tiger prawn farms in Sabah contained a high load of toxic metals that originated from light industries, and pig and poultry farms located near the estuary. The metals at high concentrations were found to accumulate in the prawn tissues and caused excessive mortality and growth retardation. It is, therefore, necessary to eliminate or reduce concentrations of these metals to some established

safe levels to increase the quality of the seawater supply and avoid toxic metal accumulation in the prawn, thus meeting the food quality requirements.

2.1 Removal of toxic metals from water by adsorption process

Removal of toxic metals from water by adsorption process has become the choice for water treatment over many years (Sircar, 2000). Interest in the process has increased manifold in recent years because of its simplicity, selectivity and efficiency (Riaz & Hanif, 1994). Conventional methods such as chemical precipitation using sodium hydroxide, calcium carbonate or sodium carbonate (Vagn & Hans-Henrik, 1981) and solvent extraction (Dean, Bosqui & Lanoutte, 1972), have major disadvantages such as inefficiency when the metal concentrations in water are low (Nriagu, 1988), expensive when the dissolved metal concentration is very high and when the treated water is required to have a low metal concentration (Wilde & Benemann, 1993). In addition to the above disadvantages, the conventional methods create secondary problems with metal-bearing sludge (Brady *et al.*, 1994). The chemical precipitation is considered cheap by Vagn & Hans-Henrik (1981), but this method does not remove the metals quantitatively since the solubility products of the metal hydroxides or carbonates are not zero. Thus, these conventional methods become less attractive. Hence, the search for new and innovative technology to remove metals from water by adsorption has focused on the utilization of low cost materials such as agricultural waste products. Because of their availability in abundance at low or no cost at all, agricultural waste products have become popular as the adsorbents, thus providing alternative uses for excess materials which are likely to cause environmental pollution if left unused (Rios *et al.*, 1999; Aytac, 2002; Aytac, Shabbir & James, 2002).

2.1.1 Adsorption

Adsorption has been defined by Rios *et al.*, (1999) and Chipofya & McConnachie (2000) as the retention or separation of molecules or ions on to the surface of an adsorbent. Low cost materials from numerous agricultural waste products can be employed as such (Roy, Greenlaw & Shane, 1993; Sameer & Zdravko, 1999; Zacaria *et al.*, 2002) or after modifications as adsorbents in water treatment (Randall, Hautala & McDonald, 1978; Pawan & Dara, 1981; Vagn & Hans-Henrik, 1981; Jamaluddin & Ku Halim, 1991; Marshall, Champagne & Evans, 1993; Fadil, Mohd. Razman & Rahmalan, 1994, 1997; Srinath, Chung & Marshall, 2001; Pairat & Qiming, 2001; Wan Mohd. Ashri, Wan Shabuddin & Mohd. Zaki, 2001, 2002; Khim & Mohd. Ali, 2002; Ku Halim & Safari, 2002; Aytac, 2002; Aytac, Shabbir & James, 2002).

According to Riaz (1993) the adsorption mechanism can be of two types : physical and chemical. Physical adsorption or physisorption results from the action of Van der Waals forces. In this process, the electron distributions of the adsorbate molecules and solid surface molecules undergo some distortions in mutual proximity. However, the electrons maintain their association with the original nuclei. Chemical adsorption or chemisorption involves a reaction such as transfer and sharing of electrons between the adsorbed species and the adsorbent resulting in a change in the chemical nature of the adsorbate. The chemisorption bond is stronger than that derived from physical (Van der Waals) forces.

2.1.2 Agricultural waste products as adsorbents

Adsorption of metals by agricultural waste products has gained important credibility during recent years for metal removal from water (Sameer & Zdravko, 1999). This is due to the problems of using other waste materials such as fly ash (Scott *et al.*, 2001; Sébastien *et al.*, 2002), sawdust (Anoop, Sheela & Anirudhan, 2003), tyre

rubber (Guillermo *et al.*, 2001) and microbial biomass (Roy, Greenlaw & Shane, 1993; Pairat & Qiming, 2001) for water treatment. For example, the use of microbial biomass creates problems of microorganism separation if the removal process is operated continuously (Dong & Byoung, 2001). Even though immobilizing the microorganism may solve the problem of separation, operational costs increase and problems of desorption may occur. Hence, despite much effort, microbial biomass technology has not achieved commercial application (Dong & Byoung, 2001).

Many studies have been carried out on production of adsorbents at low cost utilizing agricultural waste products which have been found to be effective in removing metals from aqueous solutions. For example, Roy, Greenlaw & Shane (1993) have used raw rice hulls that adsorbed more than 90% of various metals including cadmium, nickel, lead, zinc and cobalt from aqueous solutions. Sameer & Zdravko (1999) investigated canola meal and observed that it adsorbed zinc, copper, cadmium, nickel and lead between 10% to 55%. Zacaria *et al.*, (2002) treated water containing copper, zinc, cadmium and nickel with sugar beet pulp and reported 30% to 60% adsorption. The metal uptake is believed to occur through accumulation processes involving organic functional groups attached to this material and associated with biopolymers such as proteins, polysaccharides and lignin (Carrilho, Ferreira & Gilbert, 2002).

2.1.3 Modified adsorbents (chemical pre-treatment)

Vagn & Hans-Henrik (1981) used barley straw combined with calcium carbonate, which improved efficiency by 10% to 90% in removing zinc, copper, lead, nickel and cadmium from aqueous solutions, compared to untreated straw. Also, Marshall, Champagne & Evans (1993) reported that rice bran treated with hexane adsorbed 95.4% of zinc compared to 70.2% with untreated rice bran. Composted rice hulls

were also shown to be an improved adsorbent compared to raw rice hulls for removing (54% to 92% more) cadmium, lead, mercury and zinc from aqueous solutions (Aytac, 2000; Aytac, Shabbir & James, 2002). Pairat & Qiming (2001) reported that calcium treated marine algae adsorbed 90% of cadmium uptake from aqueous solutions.

These modifications were not only to increase the adsorption capacity, but also to overcome a number of problems arising from using the natural products. Thus for example, Randall, Hautala & McDonald (1978) reported that the use of raw peanut skin had two disadvantages. Firstly, it leached a reddish color into the solution upon contact with water. Secondly, the peanut skin tends to disintegrate on prolonged contact with water. Therefore, they treated the peanut skin using sulphuric acid containing formaldehyde at 50°C for 2 hours and the treatment resulted in an increasing metal binding capacity for cadmium, copper, mercury and lead. Besides that, the treated peanut skin was found to be competitive with synthetic ion exchange resins.

Pawan & Dara (1981) adopted the method of Randall, Hautala & McDonald (1978) in order to prevent color leaching from raw onion skin into the solutions. They were successful in improving the physical characteristics of the substrate and thus enhanced the adsorption capacity for copper, cadmium, zinc, nickel, mercury, and lead. Other researchers (Srinath, Chung & Marshall, 2001) have also modified the raw peanut shell. They treated the material with either phosphoric or citric acid. The treated peanut shell was found to increase the adsorption of metal ions such as cadmium, copper, lead, nickel and zinc.

2.1.4 Conversion of agricultural waste materials into activated carbon

Besides utilizing the waste materials as they are and after treatment with chemicals, considerable attention has been devoted in recent years on conversion of waste materials into activated carbon (Anoop, Sheela & Anirudhan, 2003). Activated carbon prepared from agricultural waste materials has long been utilized in water treatment because of its adsorbing effectiveness (Wartelle & Marshall, 2001; Khim & Mohd. Ali, 2002). Its adsorption property is due to its pore size distribution, surface area and chemical characteristics (Chipofya & McConnachie, 2000; Iliopoulos, Reclos & Reclos, 2002).

Almost any agricultural waste material can be converted into activated carbon since it contains a carbonaceous component (Hovanec, 1998; Iliopoulos, Reclos & Reclos, 2002). The activated carbon is prepared by carbonization followed by an activation process. In the carbonization process, the material is burnt at 500°C to 600°C in the presence of a small quantity of air to produce about 75% to 80% of carbon (Byrne & Nagle, 1997). The purpose of the carbonization process is to remove impurities and volatile matter (Hovanec, 1998; Anoop, Sheela & Anirudhan, 2003) and to increase the carbon content of the material. The desired porosity and some ordering of the carbon structure are created in the char produced (Wan Mohd. Ashri, Wan Shabuddin & Mohd. Zaki, 2002; Ku Halim & Safari, 2002). The activation process is frequently carried out at high temperatures starting from 600°C to 2000°C (Hovanec, 1998) in the presence of an activating agent such as sodium hydroxide and hydrochloric acid (Iliopoulos, Reclos & Reclos, 2002; Anoop, Sheela & Anirudhan, 2003). This is to enhance the structure developed in the first process to make the activated carbon produced more porous (Wan Mohd. Ashri, Wan Shabuddin & Mohd. Zaki, 2002).