PAKISTAN ENGINEERING CONGRESS

SEMINAR ON

WORLD WATER DAY – 20TH MARCH 2008

ADDRESS BY

CHIEF GUEST

MUHAMMAD MUSHTAQ CHAUDHRY

MEMBER (WATER), WAPDA, LAHORE

Distinguished Guests and Members of the Congress
Ladies and Gentleman – Assalam-o-Alikum

To improve sanitation, communities should promote the construction of household infrastructure, the construction of open drains with street pavements and also impart hygiene education. The anticipated population by the year 2010 would be 168 million & by 2025 would explode to 221 million with an average growth rate of 1.81percent. By the fast growing rate of population, water requirements are increasing to meet the needs of the growing population, water supply and sanitation etc. This situation is because the population has grown by five times whereas available water supplies have been enhanced by about three times only.

As per the World Bank Report, Pakistan is included in the list of 17 countries which are water deficit and will face severe water scarcity in the near future. Since independence, the population of Pakistan's major cities Karachi, Lahore, Peshawar has been growing at very fast rate and the water needs of the nation for domestic, agriculture and industrial purposes are increasing. There is a serious shortage of drinking water for increasing population of the country. Even Government of Pakistan is trying to implement various schemes for enhancing the water availability to improve the sanitation system in the country but still the demand is not being met with these schemes. The non-developed areas especially in Balochistan, the households depend on the poorest supplies and have to travel long distances for the water.

In Pakistan as a whole, 30percent households do not have any toilet facility. This varies largely between urban and rural areas. The percentage of households with no toilet facility is highest in rural Balochistan and lowest in NWFP. Rich households have greater use of flush toilets than poor households. Discharge of sewage effluents and industrial wastewater is putting a serious stress on aquatic ecosystem and quality of irrigation supplies. Almost all sugar mills in Sindh are discharging their effluents in drains, many of which outfall into wetlands. Further there is very little separation between municipal and industrial effluents and both flow directly into the open drains, which then flow into nearby natural water bodies. In the absence of the latter, the effluent is collected in stagnant pools, within residential areas. In Lahore only 3 out of 100 industries (which use hazardous chemicals) treat their wastewater. The Kasur water treatment plant is considered to be the only common effluent plant for industrial wastewater that is currently functioning in the country, but it is only a pre-treatment plant and causes major odor problems.

Presently about 5.6 million tons of fertilizer and 70 thousand tons of pesticides are consumed in the country every year and certain part of such chemicals is creating pollution. The water pollution is a main concern in Pakistan. The source is municipal and industrial effluent of which only 1percent of wastewater being treated before disposal. It has become one of the largest environmental problems in Pakistan.

Pakistan is urbanizing and industrializing very rapidly. The number of people living in cities has increased almost four times over the last 2 decades. To date there has been little effective action to reduce the environmental impact of this rapid concentration of people and activity. There is very little treatment of wastewater or of industrial effluent in the cities; it is estimated that only source 8 percent of urban wastewater is treated in municipal treatment plants.

At the end, I once again thank (Pakistan Engineering Congress) for celebration of the World Water Day, 2008 on a special reckoned theme of sanitation. In fact, it provides awareness for necessary improvements for drinking water, health care and environment. Special thanks are due to the authors for refreshing our memories and providing us impact of inadequate sanitation on human health and living standards. The interest and interaction of all the participants is encouraging and appreciated.

Please work sincerely for achieving the targets to improve the sanitary conditions of our surroundings and country as a whole. The Engineers and Scientists will further deliberate on the subject of 'Sanitation'. I hope at the end of the World Water Day concrete recommendations will be framed for policy makers in the field of Sanitation.

Thank you, God bless you all and Allah Hafiz.

Dr. Allah Bakhsh Sufi

ACCESS TO BASIC SANITATION –A CHALLENGE FOR ALL

BY

JAWED ALI KHAN

1. Introduction

The theme of "Sanitation" chosen this year for the "World Water day" fortunately falls within the "International Year of Sanitation as the United Nations General Assembly vide its resolution dated 04 Dec 2006 declared 2008 as the International Year of Sanitation. Furthermore, the United Nations General Assembly at the turn of the 21st century held a UN Millennium Summit and under the declaration it adopted seven Millennium Development Goals (MDG's). The goal seven *calls for halving by 2015, the proportion of population without access to basic sanitation and safe drinking water and 100 per cent coverage by the year 2025.

Sanitation is one of the basic necessities, which not only contributes to human dignity and quality of life but is a prerequisite to fight against disease. Every year over 1.5 million people particularly children under five worldwide die of diarrhea apart from typhoid, Acute Respiratory Infection (ARI), (AHI) and Polio resulting from inadequate and unsafe water, poor sanitation, and insufficient attention to hygiene behaviors. According to World Health Organization (WHO) estimates water borne diseases account for over 20 percent disease worldwide.

The vast majority of environment health impacts are in developing countries where there is a strong correlation between the level of poverty and the environmental burden of disease. It has been estimated that improving excreta disposal can decrease diarrhoea rates by 35%.

Hand-washing with soap at critical times can decrease diarrhoea by over 47%. Such improvements do nothing less than save children's lives. In addition to lowering the rates of diarrhoea, improved excreta disposal and hand-washing have significant impact on parasitic infections, worm infestations and trachoma, the leading cause of blindness in the world.

Avian Human Influenza poses another greater threat, both in Pakistan and globally. The risk of spread of this disease can be reduced by hand washing with soap.

We know that this will be one of the primary behaviours that we can promote to reduce the risk of spread of this disease.

*1 Diarrhea

DIRECTOR GENERAL (Env) MINISTRY OF ENVIRONMENT GOVERNMENT OF PAKISTAN

As we found, hand washing was instrumental in the containment of SARS. Similarly, if we are to contain Avian Human Influenza, hand washing will play a critical role.

2. Sanitation Situation in Pakistan

It is estimated that around 42% population has access to sanitation facilities in Pakistan of which 65% live in urban areas and 30% in rural areas. With the exception of a few big cities, the sewerage facilities are generally inadequate. Almost 45% households do not have access to latrines, while 51% households lack drainage facilities. Around 35% dispose off their wastewater into open drains and 16% are connected to underground sewerage or drains. About 30% of urban population lives in katchi abadis and slums with inadequate sanitation facilities.

Large and intermediate cities have underground sewage systems most of which are at risk due to lack of monitoring and inadequate maintenance. Consequently, most of the sewage is discharged untreated into the natural water bodies resulting in severe contamination and making the water harmful to human and aquatic life. Public toilets are few in cities and are not properly maintained, thereby creating health hazards and a negative impact.

There are almost no public toilets in small and medium size towns and villages. Solid waste management system exists in all large and some intermediate cities. As a consequence of rapid urbanisation, garbage disposal systems in most major cities are under pressure. It is estimated that around 50% of the garbage generated by major cities is disposed off part of it at informal dumping sites.

As per a USAID report, estimated 250,000 child deaths occur each year in Pakistan due to water-borne disease. It is estimated that more than 1.6 million DALYs (Disability Adjusted Life Years) are lost annually as a result of death and disease due to diarrhoeal and typhoid morality in children accounts for the bulk of the losses, reflecting the vulnerability of children to these diseases.

According to a World Bank report the mean estimated annual cost of environmental and natural resource damage is about 365 billion Rs. per year of 6 percent of GDP. The highest cost is from inadequate water supply, sanitation and hygiene (Rs 112 billion) which is approximately 1.8 percent of GDP.

3. Resource Dimension

According to the Local Government Ordinance (LGO) 2001, the delivery of water and sanitation services is a local government responsibility. Ironically, many local governments suffer from resource constraint and therefore cannot adequate by operate and maintain these services. Inadequate institutional capacity and lack of sufficient technical and planning and social development skills is another issue faced by the local governments.

Further, the federal government has launched special vertical programmes in all four provinces. Through these programmes MPAs identify development schemes of up to Rs 10 million for any sector in their electorate.

The concerned provincial or local governments have little say in the planning or budgeting of these programmes. The Khush'hal Pakistan Programme (KPP) is the recent version of earlier Tameer-e-Watan and People's Works Programme. In addition grants for NGOs and communities are also available through the federally administered Khush'hali Bank and the Pakistan Poverty Alleviation Fund (PPAF). The beneficiary communities are required to contribute 20% of the capital cost of such projects.

4. Technical Dimension

4.1. Mapping and Documentation

Over the years, local governments and development agencies have laid sewage lines in all the major urban areas of Pakistan. These programmes and projects often lack co-ordination. In addition, housing societies and some local communities have independently laid their sanitation infrastructure without co-ordinating with the concerned government institutions.

Most of this sanitation infrastructure uses natural drainage systems or depressions for the disposal of wastewater. Physical documentation of these enormous investments seldom exists. In the absence of this documentation, rational and economic solutions at the town and city level cannot be effectively developed. It is because of the hitherto absence of such mapping that the sanitation projects usually assume that such infrastructure does not exist and place treatment plants away from locations where sewage is actually disposed off.

Mapping of areas where sanitation projects are to be developed and investments have to be made is also required. Therefore, what exists and what is required has to be mapped at the city or respective local government levels both for urban and rural areas. Realising this essential need, the Ministry of Environment launched the "National Land-use Planning Project", which includes urban land-use planning as a major component.

4.2. Open Drains in Small Towns and Rural Areas

Government programmes have built open drains in many small towns and rural areas and have paved the lanes in which they have been built. These open drains are a constant health hazard and have also caused considerable damage through rising dampness to the houses along which they are laid. This needs to be discontinued as early as possible as the open drains can easily be converted into shallow covered drains by laying PVC pipes within them and covering up with brick paving. Experience shows that communities, if mobilised and given technical advice, are willing to fund and manage the construction or replacing open drains provided an effective disposal point exists within the vicinity.

4.3. Planning and Operation and Maintenance (O&M)

The planning of sewage systems is often carried out without involving agencies and departments that are in-charge of managing and maintaining them.

The two departments have very different views on what sanitation system should be. It is important that the O&M departments should be involved at the planning stage so that the O&M problems that they face can be overcome or minimised through the planning process.

4.4. Research

Considerable research-based information exists on sewage disposal designs and standards with most Pakistani universities and some NGOs. It is necessary to use this information for developing engineering standards and procedures that relate to the ground realities and community concerns.

5. Institutional Dimension

5.1. Local Government Ordinance 2001

According LGO 2001, planning and implementation of sanitation and related development programmes is a responsibility of the Taluka/Tehsil/Town Municipal Administrations (TMAs), or City governments in the case of larger cities. However, political decision-making on these issues is taken by the nazims, which is often biased in favour of their respective constituencies, irrespective of the actual need.

Although LGO 2001 has made the TMAs fully responsible for water and sanitation services, yet in practice a number of other agencies are involved in the development of sanitation projects. These include the katchi abadi authorities and/or directorates; railways (on railway land); cantonment boards; development authorities (they are still operative in many cities); Public Health Engineering Departments (PHEDs); and Water and Sewage Agencies (WASAs) which were supposed to be devolved to the local government levels.

At the Federal level, the Ministry of Environment is the lead agency in sanitation sector. Other ministries which deal with sanitation related matters include Health, Planning and Development, Local Government and Rural Development and Housing and Works. At the provincial level, water and sanitation is dealt with by a number of departments including Local Government and Rural Development, Works and Services and Public Health Engineering Departments. There is a need to develop effective coordination mechanism amongst these

5.2. Institutional Capacity

Technical and managerial capacity in the TMAs is weak. In most cases they are not able to design, implement and supervise sanitation schemes or to develop surveys and documentation. There is also the issue that most TMAs have an urban orientation and are not able to fully grasp rural issues and realities. At the UC level there is no staff except a secretary. Where technically skilled NGOs work with the UCs, these investments have proved to be useful and effective. Their success stories need to be highlighted and promoted.

5.3. Monitoring

The absence of an effective monitoring process and back-to-office reporting system is a major shortcoming with almost all government projects. This self-monitoring system needs to be put in place. At the level of projects, regular site visits and back-to-office reports are essentially required for all projects. A steering committee of interest groups/ community members also need to be created to oversee the project and monitor its progress and quality.

5.4. Citizen Community Boards

Under the provisions of LGO 2001, Citizen Community Boards (CCBs) can be formed to encourage and increase community participation in development projects. These boards are non-elected, registered voluntary organisations consisting of at least 25 members. Twenty five per cent of the total development budget of each tier of local government (district, tehsil and UC) is allocated for plans initiated by the CCBs who have full authority to implement schemes in their areas, provided they raise 20% of the total proposed budget within the community before applying for funding from their UC or district.

6. Communities, NGOs and Private Sector

6.1. Role of Communities

Communities all over urban Pakistan make investments in developing some form of sanitation in their homes and neighbourhoods. Surveys of 243 katchi abadis in Karachi show that people have invested Rs 1.191 million in building underground sewage systems and connecting them to government trunks or natural drainage channels.

This enormous investment could have been better utilised if technical advice had been available to the residents and if their investment had been co-ordinated with government investment through councillor funds, Members of National Assembly (MNA)/Member of Provincial Assembly (MPA) programmes, or local government investments. Studies in other cities such as Faisalabad, Lahore, Hyderabad and Peshawar have also yielded similar results

6.2. Role of NGOs

A number of NGOs and community based organisations are working in the sanitation sector in Pakistan. Evaluation of different community-based programmes in Pakistan shows that when people invest in internal development they also maintain it at their own cost. In addition, when they organise to finance build internal sanitation, they also monitor and participate in the public sector built sewerage systems. The NGOs and CBOs who participate in this work become partners of local governments in development planning and implementation. There are numerous NGO-mobilised and community-based initiatives in sanitation sector. These, inter-alia, include Orangi Pilot Project, Lodhran Pilot Project, Mardan Community Led Total Sanitation Project and Jaranwala Urban Development Project.

6.3. Role of Private Sector

6.3.1. Formal Sector Developers

Formal sector developers build most middle-income housing in Pakistan. They also develop plot townships with services. Very often they connect their sewage to the nearest natural drain or a water body without building a treatment plant. In addition, their plumbing works are of poor quality and hence cannot be maintained properly and become health hazards.

6.3.2. Informal Sector Developments

Almost all of Pakistan's low income settlements are developed through the informal subdivision of agricultural or wasteland. Informal sector developers carry out this work through small schemes. They do not provide sanitation infrastructure in these schemes and ultimately people develop this infrastructure themselves or through funds provided by their union councils. Since these investments are not co-ordinated and there are no proper disposal system. These settlements become environmentally degraded which results in social degradation as well.

7. Government Policies, Commitments and Programmes

7.1. Earlier Policies Programmes

The emphasis on provision of proper sanitation facilities were insufficient in the urban development and resettlement projects undertaken by the government in the past such as in the Townships developed for resettlement of the affectees of Tarbela and Mangla dams, labour colonies and other low income settlement.

In 1988, a sanitation sector review and follow-up conference was held. Based on its recommendation, development partners supported the preparation of a strategic investment plan and project preparation for rural water supply and sanitation. The basic principle of this plan was integration of sanitation and hygiene education with all water supply interventions. This was the first policy statement of the government for a comprehensive combined water and sanitation initiative. Subsequent to this policy, sanitation received high attention and was one of the major recipients of the Social Action Programme (SAP) funding during the decade of the nineties. Facilitated by large donor programmes, the provincial, Public Health Engineering Departments (PHEDs) announced a uniform policy in which NGO and community participation was introduced as a centre point. The policy principle also stated that users will pay for the O&M of the service provided to them. Subsidies were allowed where high energy cost was involved due to pumping.

SAP was approved in 1990 and became operative in 1992-93 at a cost of $7.7 billion, of 76% was funded by the Government of Pakistan. The donors contributed the rest. Although SAP could not meet all its objectives, it succeeded in highlighting the water and sanitation issues and measures required for programme sustainability.

7.2. National Sanitation Policy

The Ministry of Environment, with the support of UNICEF, has formulated the National Sanitation Policy through a countrywide consultative process. The policy envisions creation of an open defection-free environment with safe disposal of liquid and solid wastes and promotion of hygiene practices in the country. The National Sanitation Policy, which was approved by the Cabinet in October 2006, provides a broad framework and guidance to enhance and support sanitation coverage in the country through formulation of their sanitation strategies, plans and programmes at all respective levels for improving the quality of life of the people of Pakistan and the physical environment necessary for healthy life.

The primary focus of sanitation for the purpose of the Policy is on the safe disposal of excreta away from the dwelling units and work places by using a sanitary latrine and includes creation of an open defecation free environment along with the safe disposal of liquid and solid wastes; and the promotion of health and hygiene practices in the country. The Policy resolves to meet the Millennium Development Goals (MDGs) and targets whereby the proportion of people without sustainable access to improved sanitation will be reduced by half, by the year 2015 and 100 per cent population will be served by 2025 with improved sanitation. The Policy proposes rewards for all "Open Defecation Free" Tehsils/ Towns; for achieving "100 percent sanitation coverage of tehsils/towns"; the "cleanest tehsils/towns" as well as rewards for the "cleaner industrial estates/clusters. The Policy will be implemented by the federal and local government / agencies in accordance with the guidelines, principles and measures spelt out in the policy.

In the follow up of the National Sanitation Policy, the provincial governments are in the process of developing provincial sanitation strategies, action plans and programme for implementmentation of the Policy by engaging all stakeholders and on cost sharing basis. The Balochistan sanitation strategy has already been approved by the Provincial Cabinet and currently various programmes are being developed for its implementation. The strategies for Punjab, Sindh, NWFP, AJK and Northern Areas have been drafted and are in the process of being finalized.

The Ministry of Environment, availing the opportunity created by the declaration of 2008 as the International Year of Sanitation, has developed a comprehensive plan to accelerate the ongoing efforts for improving the sanitation situation in Pakistan in collaboration with the Provincial/AJK/NA Governments and development partners. The Plan envisages the following key targets in the context of the International Year of Sanitaion-2008:

(i) Finalization and approval of the provincial sanitation strategies/action plans;

(ii) Dissemination of hygiene messages focusing on hand washing with soap, construction and use of latrine and use of safe water among 20% of Pakistan's population;

(iii) Provision of improved sanitation facilities to 6% of the country's population which currently lacks access to the same; and

(iv) Finalization and approval of the National Drinking Water Supply Policy by the Cabinet and development of action plan for its implementation.

The Ministry of Environment, in collaboration with the Provincial Governments and partners, is supporting implementation of various projects and programmes including, inter-alia, scaling-up of the community-led total sanitation throughout the country to achieve the above mentioned targets as well as objectives of the National Sanitation Policy.

8. Conclusion

It is clearly established that sanitation is the root cause of environmental degradation, poor health and hygiene conditions, rising level of poverty and impact on economic growth. This situation can be averted by giving due recognition and attaching high priority to the sanitation sector interventions by all stakeholders as well as launching of public awareness and sensitization programmes through electronic and print media. This not only can make a dent in achieving the millennium development goals of halving by 2015, the proportion of population without access to basic sanitation and safe drinking water and 100 per cent coverage by the year 2025 but can also help in achieving other millennium development goals related to eradication of extreme poverty and hunger, reducing child mortality, improving maternal health and combating HIV/AIDS, malaria and other diseases, etc.

Further, strong and continued Government-NGO-Community partnership is essential to ensure sustainability. Sanitation programmes must be promoted on incremental basis in a phased manner beginning from creation of open defecation free environment and adoption of Community Lead Total Sanitation (CLTS) approach. The improvement in sanitation must be integrated with health, education, nutrition and other local livelihood aspects. As school-based water and sanitation has contributed a lot in addressing the need for gender-sensitive programmes, it could be beneficial to address gender-related sanitation issues such as separate school toilets for girls. Involvement of women and children from the inception as an essential element in all sanitation programmes. Last but not the least capacity building and attitudinal changes of every individual, all stakeholders, imams of mosques, religious scholars and all the local authorities can be essential if we are committed and have a resolve to reach out not only to every citizen of Pakistan but to the world over for improving their health, hygiene and to alleviate poverty through providing access to basic sanitation to all.

ACKNOWLEDGEMENTS

This paper draws on various reports of the government and partners including, inter-alia, Pakistan Country Paper for the 2nd South Asian Conference on Sanitation (SACOSAN) which was hosted in 2006 by the Ministry of Environment, Government of Pakistan.

Generation and Disposal of Solid Waste at Model Town Park, Lahore

BY

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ABSTRACT

This Paper deals with the generation and disposal of solid waste at Model Town Central Park, a tourist / recreational spot in Lahore, Pakistan. The concept of the paper is sanitation and disposal of unwanted wastes from public parks.

The people used to visit the Park and throw away discarded refuge around them while some of it is deposited in collection bins. The solid waste of the park was observed as 98 KG per day on an average, out of which 64.1% is the bio-degradable waste and 35.9% is non-biodegradable waste. The study was undertaken considering normal days, Sundays, Fridays and Eid days to assess the diversity in quantity and components of the solid waste. The biodegradable material mainly consisted of twigs, leaps, paper bags, paper plates, textile waste; lemon refuse etc. while non-biodegradable includes rubber, glass, plastic, metallic and polythene waste. At the current rate of solid waste generation is 697 KG per week or 2910 KG per month while it is 34920 KG per year. Major share of the solid waste is disposed of properly on daily basis except on Eid days. The study was mainly carried out to know about the type of solid waste, its ultimate management including recycling or uses, its disposal in composting or recycling source segregation of municipal wastes.

Keywords: Solid Waste, biodegradable, non-biodegradable, disposal, recycling

1. INTRODUCTION

The problems arising from solid waste started emerging at the dawn of civilization, when man started living in groups and communities in clustered settlements. Pre-civilization waste products were readily absorbed and dissipated by insignificant natural process because population densities were low and available land was generous to absorb / accommodate solid waste which got decayed with time. Furthermore, the nomadic nature of man further rendered it difficult that he could have accumulated waste which he had generated at various having mobile life style.

With the passage of time, as the villages grew into towns and ultimately to cities, it was order of the day to throw waste into access ways, watercourses and vacant places, and here they got intermingled with the excrement of community and that of domesticated animals with the gradual development of human societies the solid wastes further diversified into domestic wastes, animal wastes, agricultural wastes, industrial wastes, hospital wastes and wastes at the public places. It is elaborated that in a natural ecosystem, there is no waste; the waste of an organism is a necessary raw material upon which other organisms depend. The pros & cons of saga of wastes reveals that the

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only culprits are humans who when typically generate the waste, it cannot be easily recycled and reused by the other parts of the biosphere Deshpande, 1984, recommended, for the urgent need of solid waste management. Vajifdar, 1985, reported about the handling of municipal solid waste present practices and future plans. Sandwar, 1991 reported harmful effects of solid waste on human health. Khan, et al 1992 reported characteristic composition and sources of solid waste on difficult localities to designate the solid waste management system of a particular area; the foremost important is to know about the kind and amount of solid waste.

The present study has been carried out to study solid waste generation and disposal at Model Town Central Public Park located in the heart of Model Town, Lahore (Figure-1). This is a public resort, having a well managed park. This park was inaugurated by Lt. Gen. Ghulam Gilani, Ex-Governor Punjab in 1984. There are 950 trees in the Park. The park was constructed after renovations on this site. The park has a well-established peripheral jogging track with a total length of 2.5 KM. Its interior is well kept, having artificial dunes, a small boat-able circular watercourse of 25' width and lush green lawns with paved paths and a Cafeteria near the main gate are present. Total green area of the whole model town is 19% of the total land consisting of 278 acres out of which this Park occupied a space of 125 acres.

2. OBJECTIVES

The specific objectives are, to assess the diversity in solid waste generated in the Model Town Park, its quantification and division into bio-degradable and non-biodegradable types, its generation pattern encompassing various representative days, the percentage composition of various components, the generation pattern on daily, weekly, monthly and yearly basis, and the measures to be suggested for the proper disposal and quantify the potential of recycling or composting.

3. STUDY AREA

The study area was divided into three sites for assigning solid waste generation as indicated in Figure-2. These sites are; i) Eastern side of park beyond the round watercourse; ii) This site includes northern part of park including its surroundings cafeteria and main gate and iii) Divisional Public School Adjacent Area: This site includes western and southern sites of the park.

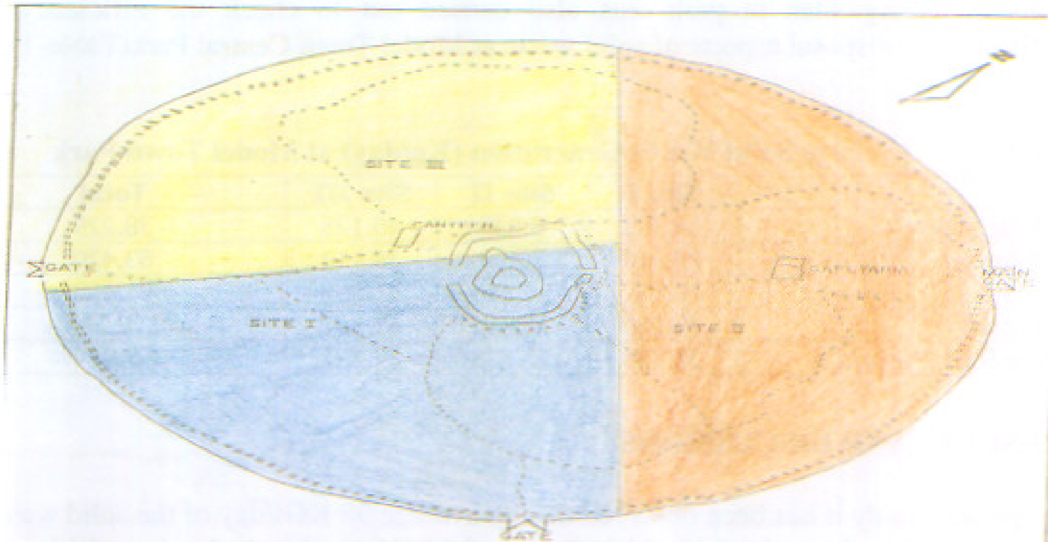
3.1 Sampling of Solid Waste

The average solid waste generation per day at study area was calculated by taking 40 samples of solid waste from each site for the period 01.07.2007 to 31.12.2007. Forty samples at each site were taken in a sequence that 10 samples were taken on

Friday evenings, 10 samples were taken on Sundays, and 10 samples during Eid days, 10 samples were taken during normal days. The data of all sites was compiled to calculate average solid waste generation per day at each site.

FIGURE-I - MAP SHOWING THE PARK

FIGURE-2- SITES FOR SOLID WASTE OBSERVATION



3.2 Composition of Solid Waste

During each sampling total solid waste generated during twenty four hours at each site was weighed. Afterwards, it is differentiated into biodegradable and non-biodegradable waste. The biodegradable waste included paper waste (paper napkins, newspaper wastes, camera rolls wrappers, paper bags, sweet boxes, chocolate wrappers, gourmet stuff wrappers, paper plates, cups and glasses, etc., textile wastes, any discarded cloths and organic wastes (lemon refuse, radish refuse, pakora refuse, grams and bread refuse, orange refuse, plucked flowers, uprooted vegetation and dry twigs, ice-creams, wooden spoons, ice-cream cups, sticks, match boxes, etc.

The non-biodegradable wastes include rubber wastes (ruptured balloons, rubber pieces or nylon chappals, etc.). Glass waste (soft drink glass bottles and broken glass pieces, etc), plastic waste (mineral water, bottles, soft drink liters plastic bottles, camera rolls, plastic covers, disposable cups, plastic ropes, ice-cream cups, etc.),

metallic waste (cold drink tins and crowns etc.), polythene waste included (pan masala cover, biscuit covers, candy and gum wrappers, plain polythene bags, ice-cream wrappers, chips wrappers) and inert material litter, concrete etc.).

The composition of biodegradable or non-biodegradable wastes generated per day was expressed as percentage by weight. The weight of various items like paper plates, cigarette case covers, paper bags, fruity packs, match boxes, disposal cups, cold drink tins and crowns, ice-cream cups and wrappers, cold drink tins, mineral water bottles Gourmet bakery packages, chips, nimko packages and candy wrappers and biscuits tacky packs, cold drink glass bottles, which were scattered on park and collected in dustbins at different sites was calculated by multiplying to total number of each items by average weight of each item.

The average weight of each item was calculated by weighing twenty items. The survey of various collecting sites in park was also carried out to check the efficiency and effectiveness of disposal aspects of solid waste at Model Town Central Park(Table-1).

Table-1 **Average Solid Waste Generation (Kg/day) at Model Town Park**

	Site I	Site II	Site III	Total
On normal days	19.283	8.820	10.126	38.229
On Sundays	27.310	20.00	36.110	83.420
On Fridays	29.142	21.210	41.256	91.608
On Eid days	78.560	38.516	61.327	178.323
Average Solid Waste/day	37.573	22.136	37.205	97.914

4. RESULTS AND DISCUSSIONS

In the present study it has been observed that an average 98 KGs/day of the solid waste is being generated in the park of this 64.10% (i.e. 63.03 KG/day) is the biodegradable waste and 35.90% (i.e. 33.97 KG/day) is non-biodegradable waste. The critical analysis of the data revealed that average solid waste generation was maximum during Eid days at all three sites of the study area. The analysis further revealed that percentage of the bio-degradable waste was observed to be maximum at Site-III (area adjacent to D.P.S.) with maximum 84.68% of organic waste, where the percentage of non-biodegradable waste was observed to be maximum at Site-I (Cafeteria Site) with maximum percentage of polythene or plastic waste (Table-2).

Table-2 - Qualitative Composition of Solid Waste at Model Town Central Park (Percent by Weight)

	Site-I	Site-II	Site-III	Total
(A) Biodegradable	55.33	70.22	84.68	70.09
Paper	30.86	25.98	19.51	25.45
Textile	0.54	2.29	2.59	1.80
Organic	23.97	41.95	62.58	42.83
(B) Non-Biodegradable	44.67	29.78	15.32	29.94
Rubber	0.78	1.31	0.08	0.72
Plastic	2.42	2.20	0.61	1.74
Metal	1.88	1.91	0.04	1.27
Glass	0.54	0.46	Nil	Nil
Polythene	10.19	5.34	2.34	5.95
Inert Material	28.92	18.56	12.25	19.87

During this course of study it was noted that solid waste collection facility was provided on daily basis by Model Town Authority. Upkeep and watering of the whole park is carried out by 90 malies. This means that solid waste collected in 16 solid waste collection bins and scattered on whole park is removed from the study area on daily basis provided that collection efficiency is 100%. The solid waste of both types i.e. biodegradable or non-biodegradable after collection is carried to main dumping sites away from study area from all three sites. Some part of the biodegradable waste is deposited in some underground dumping sites present in the Park for manuring purpose.
Though the bulk of waste is biodegradable and organic in origin yet some of it decays within study area i.e. (twigs and leaves) provide breeding grounds for germs but also enriches the organic quality of soil. So, at the current rate of solid waste generation i.e. 98 kg/day the total solid waste generation would be 679 kg/week or 2910 kg/month or 34920 kg/year.
The increasing quantity of solid waste is disposed off properly except on Eid days. During Eid holidays the solid waste scattered in the Model Town Central Park not only serves as breeding ground for germs but also tarnishes the beauty of park. Some way may be chalked out to take care of such solid waste during holidays also to maintain the

scenic beauty of the spot. Furthermore, 25% of solid waste is the paper waste, while 7.5% is polythene. This means 30 kg/day has potential of recycling and reuse for proper management of solid waste. Besides this, presence of high organic matter i.e. about 40 kg/day indicates that such solid waste can be disposed off by composting. Khan, 1994 also stressed for the recovery of solid waste as one of disposal methods of solid waste – Vajifdar, 1985 recommended the implementation of new methods like composting for disposal of solid waste. Shah, 1994 recommended the recycling source separation of municipal waste.

5. CONCLUSIONS AND RECOMMENDATIONS

Based on study results, it is concluded that solid waste generation in public Park is entirely different from domestic or street refuse. The major portion consists of biodegradable which can be utilized in composting and recycling of non-biodegradable are the best options. Another purpose of the study is to encourage further research on generation and disposal of solid waste in historical places and other public parks in Pakistan. In this way one can suggest measures for sustainable environmental cleanliness and regular management of such public places, keeping their esthetic value intact.

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Drinking Water Quality: Removal of Heavy Metals from Contaminated water

BY

Muhammad Iqbal*, Asma Saeed and Muhammad Saleem

ABSTRACT

Water is the most important natural resource, absolutely essential for sustaining life on earth. For the human consumption, water should be of pristine quality without any chemical or microbiological contamination.

It is unfortunate, however, that human beings during the recent decades have unabatedly polluted water through industrial, household and agricultural activities.

Due to the improper sanitation systems in urban areas, sewage and other effluents are continuously entering into the water supply pipes natural water bodies, and the underground water reservoirs, thus making it unsafe for drinking purposes to the end-user.

In rural areas the most common water quality problem is the bacterial contamination from septic tanks, ponds, and open wastewater disposal lines running through the streets. Effluents overflow and leakage from these sources can seep down to the water table, even into the homeowners' pump/well water source.

Due to the use of this contaminated water, water-borne diseases, such as diarrhoea, dysentery, worm-infection and scabies, hepatitis-A, cholera and typhoid are very common in rural populations. It has been estimated that as many as 55-60% of the total deaths in Pakistan are caused due to the use of such contaminated water. To protect our drinking water from contaminants, so that the health of population groups is protected against this malice, it is very important to create awareness among the general public about quality parameters of drinking water, as set out by WHO/EPA, and some of the remedial actions that must be taken to avoid contamination of drinking water sources. PCSIR is involved in the R&D studies related to the development of low-cost innovative adsorbents for the removal of toxic metals, including arsenic, from contaminated water. Plant residues and immobilized fungal immobilized systems have been investigated for this purpose, which have proved to be very useful tools for achieving this objective. Results of these studies, along with the possible use of such metal removing systems and materials as biological ion-exchangers is presented in the present report.

INTRODUCTION

Water is inevitable for life. It not only serves as the principal vehicle and mediator of physiological activities, but is also the major source of all essential minerals that play

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important role in human nutrition and in proper body metabolism. Because of these attributes, consumers must ensure that water they drink conforms to satisfactory standards of quality. Water quality is an inclusive term used to describe the physical, chemical and biological characteristics. The physical parameters that together govern the quality of drinking water include pH, colour, taste, odour, turbidity and total hardness as calcium carbonate. The chemical status of drinking water, on the other hand, is described on the basis of cationic and anionic levels of the inorganic constituents and the organic compounds present in it, a brief mention of which is stated below.

(a) Cations, the positively charged metal ions present in drinking water (aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, sodium, tin, uranium, zinc) are essential for normal body growth in micro quantities and should be taken within permissible limits as described by the guidelines of World Health Organization (WHO)[(1)], European Union (EU)[(2)] and Ministry of Health, Government of Pakistan[(3)] as reported in Table 1. Excess of these metals is linked to several kinds of toxicity problems in humans and other forms of life.

(b) Anions, the negatively charged ions (chloride, cyanide, fluoride, sulfate, nitrate, nitrite) present in drinking water should also be within the range of permissible limits according to the recommendations of WHO or EU guidelines. Excess of these anions can be hazardous to human health in the same manner as are the cations.

Safe Drinking Water Quality Standards			
Parameters	**WHO**[1]	**EU**[2]	**Pakistan**[3]
		Physical	
Suspended solids	No guidelines	Not mentioned	Not mentioned
COD	No guidelines	Not mentioned	Not mentioned
BOD	No guidelines	Not mentioned	Not mentioned
Turbidity (NTU)	< 5	Not mentioned	<5
Grease/oil	No guidelines	Not mentioned	Not mentioned
pH	6.5-8.5	Not mentioned	6.5-8.5
Conductivity (µS/cm)	250	250	Not mentioned
Colour (TCU)	< 15	Not mentioned	≤ 15
Dissolved oxygen	< 75%	Not mentioned	Not mentioned
Hardness (mg/l)	150-500	Not mentioned	< 500
TDS (mg/l)	No guidelines	Not mentioned	< 1000
		Cations	
Aluminium (mg/l)	0.2	0.2	≤ 0.2
Ammonia (mg/l)	No guidelines	0.50	Not mentioned
Antimony (mg/l)	0.005	0.005	≤ 0.005
Arsenic (mg/l)	0.01	0.01	≤ 0.05
Barium (mg/l)	0.3	Not mentioned	≤ 2.0
Berillium (mg/l)	No guidelines	Not mentioned	Not mentioned
Boron (mg/l)	0.3	1.00	0.3-0.5
Bromate (mg/l)	No guidelines	0.01	Not mentioned
Cadmium (mg/l)	0.003	0.005	0.003-0.01
Chromium (mg/l)	0.05	0.05	≤ 0.05
Copper (mg/l)	2	2.0	1-2
Iron (mg/l)	0.3	0.2	Not mentioned
Lead (mg/l)	0.01	0.01	≤ 0.05
Manganese (mg/l)	0.5	0.05	≤ 0.5
Mercury (mg/l)	0.001	0.001	≤ 0.001
Molibdenum	0.07	Not mentioned	Not mentioned
Nickel (mg/l)	0.02	0.02	≤ 0.02
Nitrogen (mg/l)	50	Not mentioned	Not mentioned
Selenium (mg/l)	0.01	0.01	0.01
Silver (mg/l)	No guidelines	Not mentioned	Not mentioned
Sodium (mg/l)	200	200	Not mentioned
Tin (mg/l)	No guidelines	Not mentioned	Not mentioned
Uranium (mg/l)	1.4	Not mentioned	Not mentioned
Zinc (mg/l)	3	Not mentioned	2.0-5.0

Table 1. Guildelines as reported by World Health Organization (WHO), European Union (EU) and Ministry of Health, Government of Pakistan for the safe drinking water quality standards.

	Anion		
Chloride (mg/l)	250	250	$\leq$ 400
Cyanide (mg/l)	0.07	0.05	0.05-0.1
Fluoride (mg/l)	1.5	1.5	$\leq$ 1.5
Sulphate (mg/l)	500	250	Not mentioned
Nitrate (mg/l)	See nitrogen	50	$\leq$ 50
Nitrite (mg/l)	See nitrogen	0.50	$\leq$ 3.0
	Microbiological Parameters		
E. coli	Not mentioned	0 in 250 ml	0 in 100 ml
Enterococci	Not mentioned	0 in 250 ml	Not mentioned
Pseudomonas aeruginosa	Not mentioned	0 in 250 ml	Not mentioned
Clostridium perfringens	Not mentioned	0 in 100 ml	Not mentioned
Coliform bacteria	Not mentioned	0 in 100 ml	0 in 100 ml
Colony count 22°C	Not mentioned	100 / ml	Not mentioned
Colony count 37°C	Not mentioned	20 /ml	Not mentioned
	Other Parameters		
Acrylamide (mg/l)	Not mentioned	0.0001	Not mentioned
Benzene (mg/l)	Not mentioned	0.001	Not mentioned
Benzo pyrene (mg/l)	Not mentioned	0.00001	Not mentioned
Chlorine dioxide (mg/l)	0.4 mg/l	Not mentioned	Not mentioned
1,2-dichloroethane (mg/l)	Not mentioned	0.003	Not mentioned
Epichlorohydrin (mg/l)	Not mentioned	0.0001	Not mentioned
Pesticide (mg/l)	Not mentioned	0.0001	Not mentioned
Pesticide-Total (mg/l)	Not mentioned	0.0005	Not mentioned
PAH (mg/l)	Not mentioned	0.0001	Not mentioned
Tetrachloroethene (mg/l)	Not mentioned	0.01	Not mentioned
Trichloroethane (mg/l)	Not mentioned	0.01	Not mentioned
Trihalomethanes (mg/l)	Not mentioned	0.1	Not mentioned
Tritium (Bq/l)	Not mentioned	100	Not mentioned
Vinyl chloride (mg/l)	Not mentioned	0.0005	Not mentioned

(1) European Union (EU) directives for drinking water (source Ikem *et al.* 2002)

(2) World Health Organization (WHO) guidelines for drinking water (WHO 1993)

(3) Quality Drinking Water: Standards for Pakistan, (2006).

(a) Organic compounds in water are usually traceable to pesticides, phenolic compounds and polynuclear aromatic hydrocarbons, most of which have been reported to be carcinogenic in nature.

It is of the utmost importance that portable water conforms to the minimum standards prescribed by WHO/EU/Government of Pakistan for the desirable chemical quality of water. The third characteristic besides the physical and chemical standards and perhaps the most important parameter for evaluating the safety of drinking water, relates with its biological quality, which is measured in terms of its microbiological status. Water contaminated with disease-causing microbes is the most serious and immediate cause of health hazard to human beings. Microbiological contamination may be of feacal or non-feacal origin. Feacal coliform bacteria are extremely dangerous contaminants in the drinking water. Among these, the presence of *Escherechia coli* is the most serious cause of diarrhoea, cramps, nausea and headaches.

Quality of water may be adversely affected on exposure to pollutants, which occurs as a result of various human activities, such as industrial, domestic and agricultural. The following are some of the major routes of water pollution.

(a) Discharge of heavy metals and synthetic organic compounds from industry, mining and agriculture. Several of these, particularly heavy metals, are non-biodegradable and thus bioaccumulate in aquatic organisms.

(b) Excessive release into natural water bodies of nutrients from sewage and on account of soil erosion. This may lead to algal blooms, which eventually deplete the oxygen content of water resulting in high BOD and thus build-up of the microbial load of water.

(c) Microbiological contamination, which is mainly attributable to corrosion of pipes of the water system, leakage of pipes, and discharge of the domestic refuse into open land bodies. This may contaminate water distribution system and groundwater reservoirs with pathogenic microbes.

In Pakistan, microbiological contamination of drinking water is found more in both the rural and urban areas as compared to chemical pollutants. The major reason for microbiological pollution is attributed to the leakage of sewerage pipes, due to the problems within the distribution system, intermittent water supply, and shallow water table due to human activities.

PCSIR AND WATER QUALITY ISSUES

PCSIR is basically a research and development organization. Among various other research activities it is also involved in the issues related to the quality of drinking water and water quality assurance. It extends services to the public sector to create awareness about safe drinking water.

One such service relates with the assessment of water quality in terms of physical, chemical and microbiological status. During the year 2004 to 2006, for instance, a total of 308 water samples, received from different sources, were analyzed for the quality of drinking water in these respect. Fig. 1 shows that the percentage of microbiologically unfit samples was higher than the percentage of chemically unfit samples. Fortunately, microbial contamination.

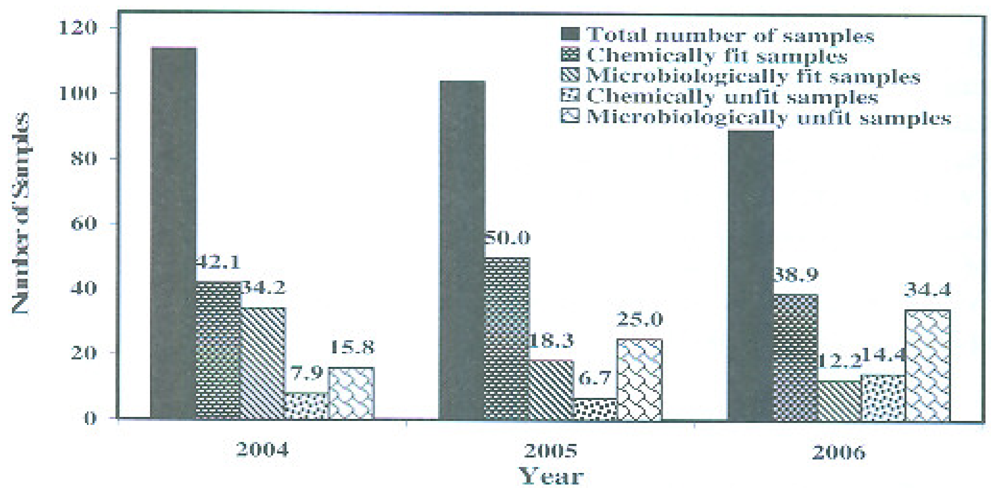

Fig. 1. Graphical results of drinking water analysed at PCSIR laboratories for the quality of drinking water during the year 2004 to 2006.

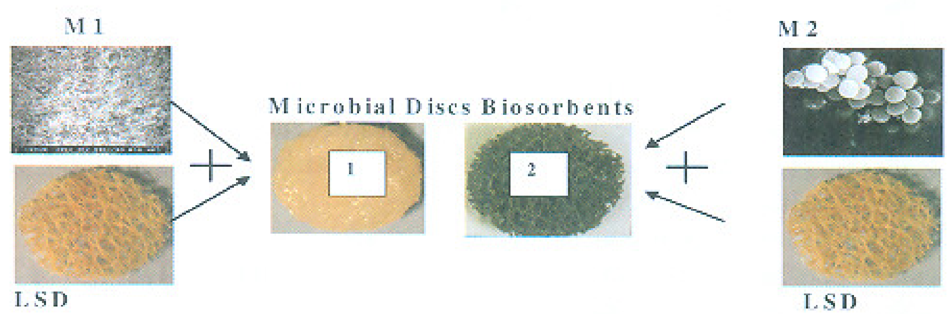

Fig. 2. Two microorganisms (fungal hyphal biomass (M1) and unicellular microalgal cells (M2) were entrapped within the loofa sponge discs (LSD) to produce microbial disc biosorbent 1 and 2.

can be simply removed by boiling water, followed by filtration. However, it is necessary to launch massive public awareness campaigns to educate people how can microbiologically unfit water may be rendered fit for human consumption through simple prophylactive measures and treatment procedures. The chemical contamination, nevertheless, is equally health hazardous, through more difficult to remove, and requires specialized techniques for treatment. Chemical contamination mainly occurs due to the discharge of effluents, produced during various industrial processes, into natural water bodies. Industries that are responsible for chemical pollution include metal electroplating, textile printing, metallurgical alloying, ceramics, photographics, pigment-works, mining and refining, alkaline batteries, smelting, metal alloy products used for coating telephone cables, etc. Several physicochemical methods conventionally used for the treatment of contaminated water include filtration, chemical precipitation, ion exchange, reverse osmosis, electrochemical treatment, membrane technology, evaporation recovery, solvent extraction, adsorption on activated carbon, and oxidation-reduction[4]. These techniques are often expensive and/or ineffective, particularly for the removal of chemical pollutants dissolved in large volumes of effluent solutions at relatively low concentrations of around 1-100 $\mu g\ ml^{-1}$.

Since these methods also involve technological operations and the level of technical knowledge of that general public in Pakistan is yet not enough to apply these methods, it is not techno-economically fearible to use the conventional methods to remedy the chemically unfit water. Due to the limitations presented by conventional water treatment technologies, we at PCSIR are trying to develop low- cost, easily available, environment friendly, and efficient technologies for the treatment chemical pollutants, most importantly the removal of heavy toxic metals. For this purpose, we are investigating plant residues that have no commercial value and are generated as wastes during milling and splitting processes of agricultural products. These materials are abundantly available at no or low-cost.

HEAVY METAL CONTAMINATION PROBLEM AND ITS PROPOSED SOLUTION

Toxic metals are discharged by a number of industrial processes. Their presence in the environment is a major threat to plants, animals and human life due to their tendency to build up to toxic levels in tissues. Legislative measures, therefore, demand increasingly lower levels of discharge of toxic metals in municipal and industrial effluents. The most commonly used procedures for the treatment of effluents containing heavy metals include chemical precipitation, evaporation, ion exchange and membrane separation. Techno-economic considerations, however, limit their wide-scale applications worldwide, and particularly more so in the developing countries. Therefore, the need for the development of economical, effective and safe methods for the removal of toxic metals has led to the search for alternative procedures. In this context, a unique idea of producing low-cost biosorbent technologies by using microbial and agrowaste biomass was tested at the PCSIR laboratories for the removal of toxic metals from contaminated water. In one such approach, algal and fungal biomass was immobilized to produce a novel type of disc biosorbent (Fig. 2) and successfully used for the decontamination of water[5, 6, 7]. The results of this study as presented in Fig. 3 clearly indicate the effectiveness and efficiency of the immobilized disc biosorbent system. All the heavy metals were removed from contaminated water very rapidly as the whole process of metal removal was completed in about 30 minutes. The maximum metal uptake capacity of the immobilized disc biosorbent for all the metals, respectively, being 123.9, 61.8, 71.5, 114.7, 76.4 and 87.2 mg g^{-1} dry biosorbent for lead, nickel, chromium, cadmium, zinc and copper. The differences in the maximum uptake of various metal ions may be explained in terms of differences in the ionic size of the different metals, the nature and distribution of active groups on the hybrid biosorbent discs, and the mode of interaction between the metal ions and the biosorbent. The efficiency of this disc biosorbent was further checked in a continuous flow mode system for the continuous online removal of toxic metals from contaminated water. For this purpose, an immobilized disc biosorbent was packed in a fixed bed column bioreactor (Fig. 4) and operated for biosorption at various concentrations of lead. The column bioreactor packed with 1.5 g of immobilized disc biosorbent could purify 39.5 L of 5 mg L^{-1} lead solution before breakthrough, and purified 20.5 L and 11.0 L of the solution when the metal feed concentration was raised to 10 and 20 mg L^{-1}, respectively(Fig. 5).

The total biosorption capacity of disc biosorbent packed in column bioreactor for various concentrations ranged between 113.0 and 125.9 mg g^{-1}, which agree well with the maximum values of 123.6 mg g^{-1} obtained in batch studies. This indicates the sustainability of this novel biosorbent in the metal uptake under different operational mode (shake-batch system and fixed bed continuous flow column). The regeneration and reusability of the biosorbent is likely to be key the factor in assessing the potential

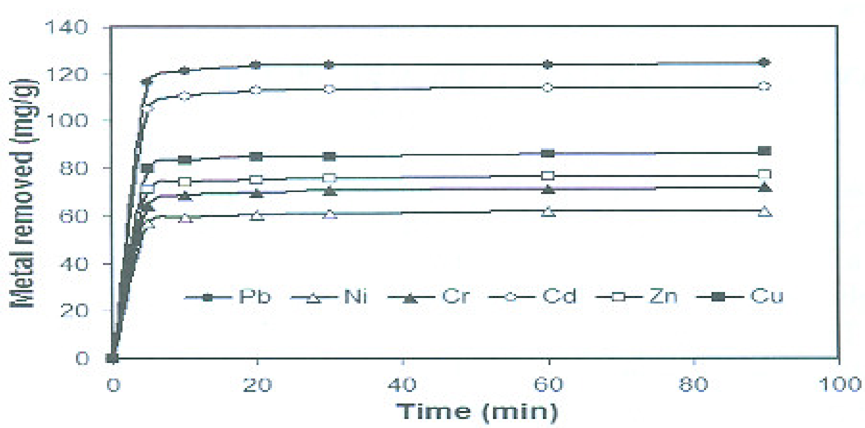

Figure 3. Time course profiles for heavy metal ions removal by immobilized microbial disc biosorbent.

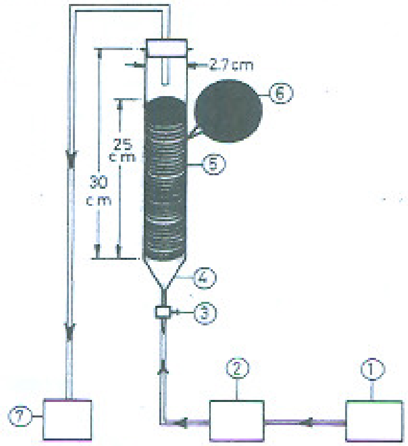

Fig. 4. Schematic diagram of fixed bed column reactor, packed with HB designed to function as a continuous flow system for biosorption of heavy metals. 1, metal solution reservoir; 2, peristaltic pump; 3, flow control; 4, glass column reactor; 5, HB biosorbent; 6, enlarged view of column packing; 7, effluent storage.

of the biosorbent for commercial applications. The metal biosorption capacity of the disc biosorbent was, therefore, determined by repeating the adsorption-desorption experiments in seven repeated cycles. HCl (5 mM) solution was used as a desorption agent. Higher than 98% desorption was obtained after seven cycles (Fig. 6). The immobilized disc biosorbent undergoing successive adsorption-desorption processes retained good metal adsorption capacity even after seven cycles, which clearly indicates that the immobilized microbial disc biosorbent had good potential to adsorb heavy metal ions from contaminated water and can be used repeatedly.

The second type of biosorbent system that we developed at PCSIR was based on the use of easily available low-cost agrowaste materials.

For the purpose, various types of agrowaste materials, such as black gram husk, moong bean husk, papaya wood, orange peel, loofa sponge, and palm fibres were investigated for the removal of heavy metals from contaminated water[8, 9, 10]. All these materials were noted to have varying degree of affinity to adsorb the heavy metals studied for removal (Fig. 7). Metal removing efficiency of black gram husk, moong bean husk and orange peel was noted to be efficient and comparable. These materials were used in further studies on the development of low-cost biosorbent systems. However, the results of metal removal studies from contaminated water by only black gram husk are being presented here. The capacity of black gram husk to accumulate cadmium, copper, nickel, lead, zinc and chromium from their respective metal solutions is given in Fig. 8.

The rate of removal of all the six metals was relatively fast, with more than 70% metal uptake taking place in the first five minutes. The whole cycle of metal removal

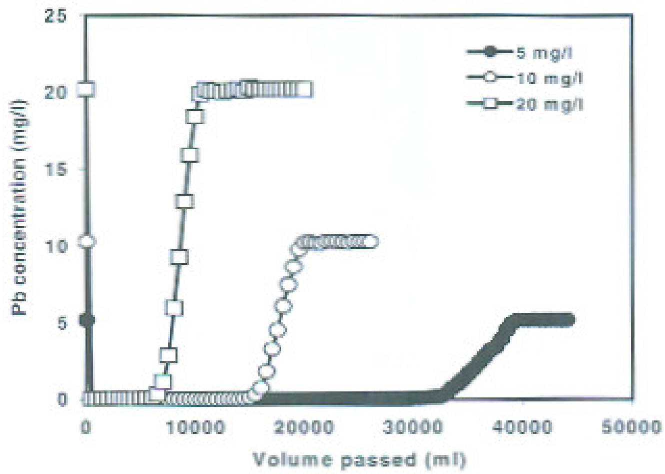

Fig. 5. Biosorption breakthrough curves for the sorption of lead(II) in a fixed bed column bioreactor packed with immobilized microbial disc biosorbent.
Column internal diameter=2.7 cm. Column length= 28 cm. Biosorbent=1.49±0.05 g. Flow rate=5 ml min^{-1}.

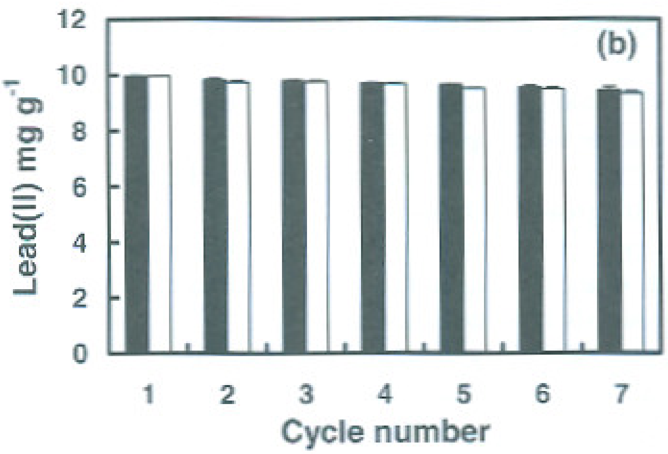

Fig. 6. Adsorption-desorption of lead(II) by immobilized microbial disc biosorbent in seven repeated cycles.

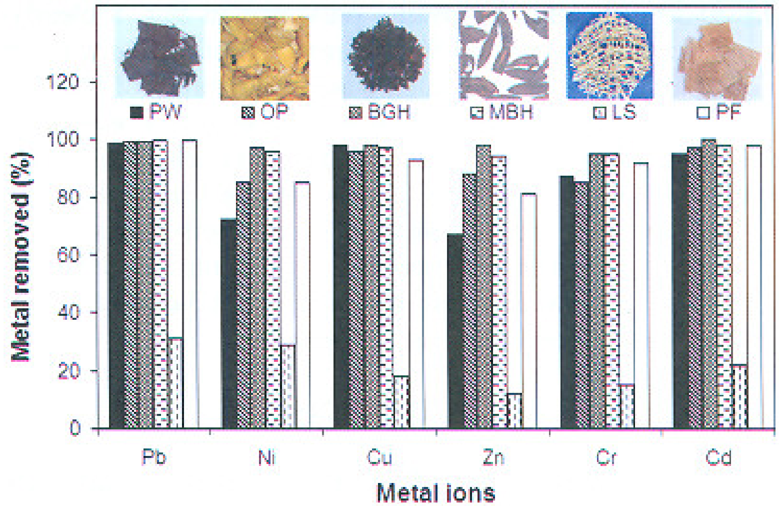

Fig. 7. Removal of heavy metals by agrowaste materials. PW, papaya wood; OP, orange peel; BGH, black gram husk; MBH, mong bean husk; LS, loofa sponge; PF, palm fibre.

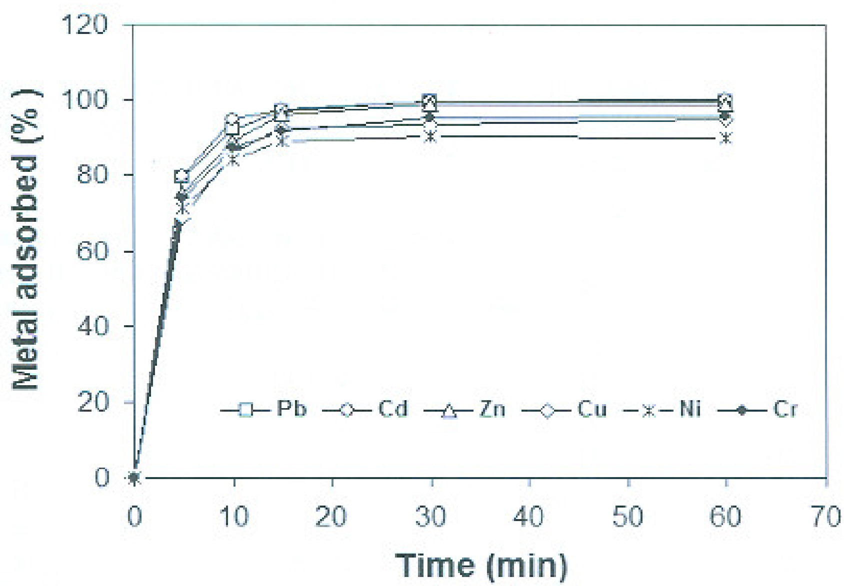

Fig. 8. Time course profiles for heavy metal ions removal by black gram husk.

was completed in 20-30 minutes. The results presented in Fig. 8 clearly indicate that black gram husk has very high potential for the removal of all the toxic metals ranging from 94-100% biosorption from contaminated water. The ability of black gram husk was so effective that the contaminated water after treatment with this biosorbent, packed in a column in the continuous flow mode, even met the maximum limits recommended by WHO (1993) for drinking water (Table 2). To investigate the economical efficiency of black gram husk, the same biosorbent was used in repeated cycles for the removal of cadmium after a simple regeneration procedure with dilute acid (HCl 50 mM). The results presented in Fig. 9 show that this biosorbent can be used in repeated cycles without any significant loss of metal removal efficiency.

CONCLUSIONS

1. Several different studies carried out at PCSIR has shown that easily grown algal and fungal biomass may be used to produce immobilized hybrid disc biosorbents for the efficient removal of heavy metal ions from contaminated wastewater.
2. In another set of studies carried out at PCSIR, we have successfully demonstrated that easily available agrowaste materials can be effectively used as low-cost biosorbents for the removal of heavy metals from contaminated water to permissible limits, even for rendering it fit for human consumption within the WHO/EU/Pakistan guidelines quality parameters for drinking water.

Table 2. WHO (1993) standard for drinking water an UNEP (1989) discharge limits for heavy metals in the industrial effluents, and the residual concentration of metals in contaminated water after adsorption by black gram husk

Metal ions	Concentration		Limits recommended by WHO for drinking water (mg/L)	UNEP maximum limits for effluent discharge (mg/L)
	Before biosorption (mg/L)	After biosorption (mg/L)		
Cadmium	10.02	0.001	0.003	0.1
Lead	09.98	0.009	0.01	0.6
Copper	10.04	0.43	2.0	3.3
Nickel	10.06	0.69	0.02	4.0
Zinc	10.36	0.19	3.00	2.6
Chromium	09.97	0.11	0.05	2.8

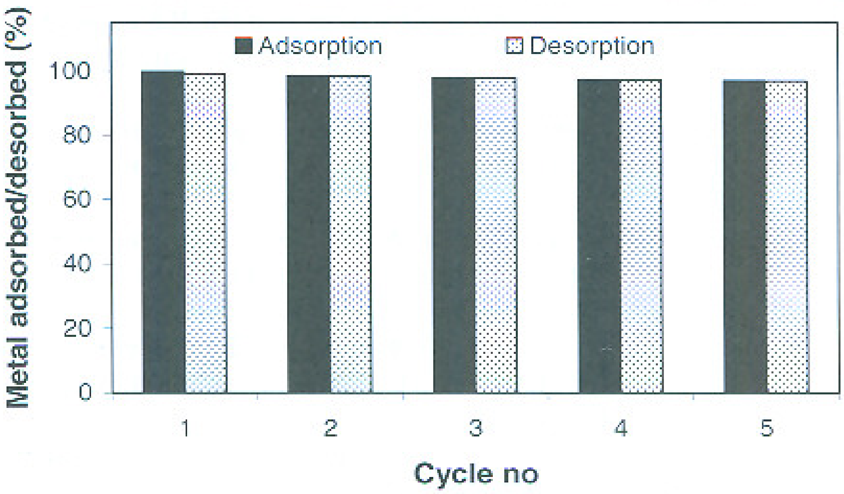

Fig. 9. Repeated use of immobilized black gram husk as a biosorbent for the removal of heavy metals.

1. The efficiency of black gram husk to bring down metal levels below the maximum allowable limits recommended for drinking water by WHO and for sewage by UNEP indicates that this material has the potential for its use in the development of a low cost water treatment technology.

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