Dr. M. Nawaz Tariq and Dr. Waris Ali

MANAGING MUNICIPAL WASTES

P N C S

A Pakistan National Conservation Strategy Sector Paper

11

MANAGING MUNICIPAL WASTES

Dr. M. Nawaz Tariq and Dr. Waris Ali

ENVIRONMENT &
URBAN AFFAIRS
DIVISION,
GOVERNMENT
OF PAKISTAN

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IUCN – The World Conservation Union, Pakistan
1 Bath Island Road, Karachi 75530

Editors: Tehmina Ahmed & Yasmin Qureshi
Editorial Advisors: Dhunmai Cowasjee & Saneeya Hussain

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PREFACE

This monograph is one of the 29 sectoral and programme papers produced to support the preparation of the Pakistan National Conservation Strategy. The NCS is a comprehensive review of the state of the country's environment, and of government and corporate policies, the voluntary sector, community and individual practices, which support or hinder sustainable development. The objective of the NCS is to identify strategic initiatives to conserve the country's natural resources which are the base for lasting improvements in the quality of life.

Environmental impacts do not respect sectoral or administrative boundaries. Yet, conventional development planning is frequently focused on narrow performance criteria and associated financial requirements, ignoring huge costs on downstream ecosystems and economic activities dependent on them. These costs cannot be avoided and must be paid by society, the only questions are when and by which group.

To facilitate an understanding of such 'externalities', one of the first steps of the National Conservation Strategy was to undertake assessments of cross-sectoral impacts from the point of view of each major activity sector. In order to facilitate comparison, the reports were prepared according to common terms of reference. Subsequently, major programme areas that must be given priority in the transition to a sustainable society were identified. The list of economic, environment and programme areas is given overleaf.

A paper on each sector was produced by a well recognised expert supported by peer reviewers in related specialities. The key insights have been incorporated into the Strategy. Since the papers are the reference base of the strategy and contain special interest material, a decision was taken to publish them serially in the form of monographs. It is hoped they will be found useful by researchers of sustainable development in various facets of national life as well as by the interested lay reader.

The sectors are:

1. Economic sectors:

- Agriculture, forestry, livestock, fisheries.

- Mining, energy, industries, transport.
- Human settlements and recreation.

2. Environmental impact sectors:

- Soil degradation, loss of biodiversity, and over harvesting of renewable resources.
- Municipal and industrial discharges, environmental health effects, and misuse of water resources.
- Destruction of cultural heritage.

3. Programme areas:

- Incorporation of environment in education, communication, and research; enforcement of laws and regulations; improved administration; use of economic instruments to align market forces with sustainability; promotion of conservation ethics.
- Programmes to promote population planning, women in development, and regional equity.
- Creation of grassroots institutions, with participative management.

MANAGING MUNICIPAL WASTES

1. INTRODUCTION

The discharge of municipal wastes in quantities that surpass the assimilative capacity of air, water and soil has created serious pollution problems in Pakistan.

The insanitary disposal of human wastes has resulted in the contamination of surface and groundwater, used as sources of drinking water by communities and cities. This is apparent from the high incidence of infectious and parasitic diseases in the population. Approximately 60% of infant deaths (24), 30% of all reported cases of illness and 40% of deaths in the country are attributable to water-borne diseases (4). Soil contamination by human excreta causes worm infections, estimated to affect over 80% of children by the time they are two years of age in certain areas of the country (4).

The contamination of food crops through the indiscriminate use of municipal sewage for irrigation is a source of enteric diseases. The increasing use of pesticides and chemical fertilizers to boost food production is bound to cause soil and water pollution, if proper control strategies are not adopted.

Insanitary conditions caused by improper collection and disposal of solid wastes are readily visible in almost all our cities, towns and villages. Open dumps of refuse on the roadside, streets, walkways and vacant lots provide breeding grounds for flies and other vectors and cause serious environmental health problems.

The increased use of automobiles in the major urban centres of the country has given rise to the problems of noise and air pollution. Vehicles, especially smoke-emitting buses and noisy rickshaws, pollute the air and are a source of public discomfort. Preliminary surveys in Lahore and Karachi have indicated that air pollution is reaching alarming levels and there is a need to adopt control measures.

Water, soil and air are natural resources with the capacity to assimilate pollution created by people. It is time to ensure that these resources are not strained beyond their limit. This paper addresses the interactions of municipal waste, urban transportation, agricultural practices and deforestation with the assimilative capacities of water, soil and air and suggests strategies for the conservation of these resources in Pakistan.

2. ENVIRONMENT AND DEVELOPMENT: STATUS AND REQUIREMENTS

The water supply and sanitation sector has been somewhat neglected and has not received the attention it deserves. In recent years, financial allocations have increased and there has been some improvement in institutional arrangements. However, much remains to be done to provide safe drinking water and adequate sanitation to people living in both urban and rural areas. As of 1988, water supply facilities were available to 80% and 40% of the urban and rural population respectively, whereas 52% of the urban versus 10% of the rural population had sanitation facilities (18).

WATER SUPPLY AND SANITATION SECTOR

Systematic planning for the provision of water supply and sanitation facilities started with the introduction of the First Five-Year Plan in 1955-60. These projects were allocated Rs. 305 million, or 3.3% of the gross public sector programmes (21).

The Karachi Water Supply and Sewerage project was undertaken during this period. Although the cost of the first phase of the project was Rs. 270 million, financial limitations meant that only Rs. 205 million was provided. In addition, Rs. 20 million each was allocated to water supply, sewerage and drainage schemes in other cities. Actual financial implementation of the First Plan was 83% for Karachi and 80% for the other cities. Another allocation of Rs. 10 million was also made for drilling tube-wells and developing groundwater reservoirs. However, negligible progress was made in this respect.

By the end of the First Plan in 1960, only a handful of water supply schemes had been undertaken in major urban centres while the rural areas remained largely neglected. During this period, public health engineering works remained the domain of the Public Works Department. No significant effort was made to train people or to develop a local sanitary fittings industry — the latter continued to be imported.

An institutional framework was provided during the Second and Third Five-Year Plans. Separate Public Health Engineering Departments were set up at the provincial level in the Punjab, Sindh and the North West Frontier Province (NWFP). The Second Plan, from 1960-65, allocated Rs. 265 million to water supply and sanitation projects. This was about 4.5% of the total outlay in the public and semi-public sector (21). Allocations included Rs. 130 million for the Karachi project, Rs. 85 million for other towns and Rs. 50 million for rural water supply and sanitation schemes. Progress was not satisfactory, on the whole, because of the delay in the start of the programme, a dearth of qualified personnel, scarcity of key construction materials and inadequacy of funds allocated for the purpose.

The allocations came to Rs. 902.5 million, about 2.6% of the planned public sector outlay in the Third Five-Year Plan from 1965-70 (21). Special priority was assigned to comprehensive water supply, sewerage, drainage and solid waste disposal projects for the major cities of Karachi, Hyderabad, Multan, Lahore, Faisalabad, Rawalpindi and Peshawar. The Plan envisaged the provision of water supply and sanitation facilities to 35 urban centres and the provision of water supply facilities to 600 villages. In addition, it was proposed that several thousand villages be covered by pilot projects for rural latrines and sanitation. General Advisory Services were set up for on-the-job training of engineers from 1964-68 under a United States government loan. A 5 million gallons per day (mgd) sludge plant for sewage treatment was introduced in Islamabad in 1962. Two trickling-filter plants, each of 20 mgd capacity, were provided for Karachi in 1963 and 1965. In spite of these developments, overall progress in the water supply and sanitation field in the 1960s remained rather limited.

Development planning was on an annual basis during 1970-78. In this period an allocation of Rs. 1,941 million was made, about 2.32% of the total development outlay (21). Major achievements included extending water supply and sanitation facilities to an additional 9.93 million of the urban population, completion of 200 small water supply schemes and installation of about 50,000 hand-pumps in rural areas of the Punjab and Sindh (17). By 1978, population coverage in terms of water supply was raised to 61% in urban and 14% in rural areas, whereas sanitation facilities became available to 35% of the urban and about 1% of the rural population. (See Annex Table 1).

The 1970s also saw considerable improvement in the institutional framework. Separate Housing and Physical Planning Departments were established in the Punjab, Sindh and the NWFP. At the Federal level, a separate Ministry of Housing and Works was created — with an Environment and Urban Affairs Division — which was given the responsibility of water supply and sanitation schemes. Development authorities, on the pattern of the Karachi Development Authority, were created in Lahore, Faisalabad, Multan, Hyderabad, Peshawar, Mardan and Quetta to undertake urban development in a comprehensive, planned manner. Realising that water supply and sanitation projects constitute a substantial portion of the activities of development authorities, separate Water and Sanitation Agencies were set up at Lahore, Faisalabad and Multan. These agencies were made responsible for the development of the sector as a whole, including revenue collection. In 1972, the Institute of Public Health Engineering and Research (IPHER) was set up at Lahore to undertake training, research and advisory services in the fields of water supply, sanitation and pollution control.

The Fifth Five-Year Plan (1978-83) aimed at further accelerating the pace of extending facilities. About 3.53% of the total public sector outlay, or Rs. 5,302 million was allocated for this purpose (21). Water supply coverage was to be extended to an additional 8.25 million (81.5%) urban and 14.25 million (36%) rural population. Sewerage and sanitation facilities were proposed for an additional 5.86 million in urban and 2 million in rural areas, increasing the coverage to 51% and 4% of the population respectively. In terms of actual achievements, water supply was extended to 77% and sanitation to 48% of the urban population. Water supply coverage could be extended to only 22% of the rural population (17) as the provincial governments concentrated more on taking up costlier piped water schemes instead of a larger programme of cheaper hand-pumps.

The United Nations General Assembly, in November 1980, declared 1981-90 as the International Water Supply and Sanitation Decade with the goal of providing safe drinking water and sanitation to all. Pakistan prepared targets for the decade, keeping in view financial, institutional and technical constraints. (See Annex Table 2). Under this plan, water was to be supplied to 66% of the rural and 100% of the urban population by the year 1990; sanitation facilities were to be extended to 59% of the urban and 13% of the rural population.

The Sixth Five-Year Plan (1983-88) allocated Rs.12,600 million to increase water supply coverage to 90% and 56% of the urban and rural areas respectively, whereas sanitation facilities were proposed to be extended to 60% of the urban and 10% of the rural population (17). A separate Department of Public Health Engineering was established in Balochistan in 1986 to improve the institutional framework of the water supply and sanitation sector in the province.

The enactment of the Pakistan Environmental Protection Ordinance of 1983 has paved the way for conservation of the environment and for pollution control.

SOLID WASTE MANAGEMENT AND POLLUTION CONTROL

Solid waste management is the responsibility of urban municipalities, which spend 24-26%

of their annual budget on this sector while providing only 40-70% coverage. Part of their load is shared by suburban farmers who use the waste as a soil conditioner.

Prevalent systems in the urban areas use century-old practices. Besides being inadequate, inefficient and insanitary, they are not economically sound.

Recently, with the help of international aid agencies, some steps have been taken to improve the situation in major cities. In Lahore, a solid waste management component has been included in the World Bank's Urban Development Project, with committed foreign financing of Rs. 31 million — collection vehicles are being imported. Even in Islamabad, only 50% of the waste is collected by modern collection vehicles. Sanitary landfills have been proposed in new projects for Lahore and Islamabad.

No public facilities to collect and dispose of solid wastes have been provided in rural areas, nor have such facilities been planned for the future. Solid wastes are often dumped haphazardly at every nook and corner of the village. This waste, mixed with animal dung, is allowed to decompose and then transported to farms to be utilised as compost, in a crude form.

Air pollution is also reaching alarming proportions. No attention has been given to this important sector, except recently through the promulgation of the Pollution Control Ordinance 1983 and the establishment of Environmental Protection Agencies (EPAs). The Punjab EPA has started collecting relevant data as have IPHER and the Pakistan Council for Scientific and Industrial Research.

ECONOMIC AND SOCIAL SIGNIFICANCE

Safe drinking water, adequate sanitation, clean air and unpolluted water bodies are essential ingredients for a healthy and productive society. Improvements in water supply, sewerage, solid waste management and air quality can result in improvements in health, income and societal well-being. The discharge of municipal wastes beyond the assimilative capacity of land, water and air affects the productive use of these resources. The quantification of socio-economic and health benefits of improved water supply and controlled waste discharges are not possible in the absence of relevant studies, and these benefits are, therefore, addressed only in qualitative terms.

A large percentage of the population of Pakistan does not have reasonable access to safe drinking water and adequate means of waste disposal. The results are high morbidity and mortality rates. The link between water supply, sanitation and health is well established, although not in quantitative terms, because health statistics are not very reliable. Notifiable diseases are reported only by hospitals and health care units. These represent approximately 50% of the actual cases because of under-reporting and because of non-reporting by private practitioners (24). A World Health Organization (WHO) study reports that gastrointestinal diseases are widely prevalent and account for 25-30% of total cases in public hospitals and dispensaries. Approximately 60% of infant deaths in the country are due to infectious and parasitic diseases. Malaria is still a major problem and about 50,000 parasitologically confirmed cases occur every year (25). Stagnant waste water ponds and solid waste dumps provide breeding places for mosquitoes and other vectors. Ill health has its socio-economic repercussions. Those who are sick and unable to work cannot earn, resulting in a drop in family nutritional levels which in turn increases susceptibility to disease and death.

Human excreta assumes great importance when discussing health for it is the principal vehicle for the transmission and spread of communicable diseases. It is essential that human wastes be adequately collected, transported, treated and efficiently disposed of. Human excreta in the form of night soil or waste water can be reused in agriculture or aquaculture and can play a positive role in supporting economic activity and food production. For example, a

5-centimetre per week application of municipal waste water has been reported to provide the commercial fertilizer equivalent of approximately 233 kilograms (kg) nitrogen, 224 kg phosphate and 254 kg potash per hectare (7). By contrast, untreated human wastes are a threat to public health in Pakistan and indiscriminate fouling of the soil with human excreta is common as people defecate in open fields in the rural areas.

The economic loss that results from lack of sanitation can be high. Farmers, craftsmen, fishermen and others contribute sizeably to the gross national product. Studies in India have shown that water-borne diseases alone claim some 73 million work days annually (22). This cost, in terms of medical treatment and lost production, has been reported at US$ 600 million per year. A study comparing health and economic output across 22 African, Asian and Latin American countries suggests that the influence of health on economic output is quite high, relative to the influence of other factors including agricultural inputs such as labour and commercial fertilizer (20). Studies regarding the costs of typhoid fever, diarrhoea and enteritis in countries like Portugal, Japan, Columbia, Sri Lanka, the Dominican Republic and India have shown that it would be possible to amortise the cost of water supply and rural sanitation within a period of 5 years from the savings that would accrue from the reduction in these diseases (22). Additional advantages would accrue from control and reduction in the incidence of cholera, dysentery, ascariasis, guinea worm, hook worm and other enteric and parasitic diseases.

There are also the indirect benefits of water supply and sanitation facilities such as savings in time and energy. Reduced walking distances through the provision of rural water supplies can be used for other productive activities, to increase economic output and earnings. Even if the economic value of the saved labour is zero, there is a social benefit from the time saved and drudgery eliminated. More time can be spent with the family or on domestic activities and leisure. Relieving children from water carrying chores can allow them to attend school more regularly and to take better advantage of existing investment in educational facilities. Savings in energy can be measured in terms of the cost of calories not needed to carry water. If substitute activity results in reduced caloric needs, estimates of the value of food not consumed can be made. Such estimates have been made for several areas in East Africa (20). One estimate states that a tonne of sorghum was needed to meet the energy expended by 360 women fetching water over 60 kilometres for 150 days of the dry season.

Besides use for drinking, surface and groundwater can be put to other beneficial uses. The indiscriminate discharge of untreated municipal wastes into rivers has resulted in anaerobic conditions near disposal points. This has not only resulted in unaesthetic conditions but also affected river fish, due to the depletion of oxygen in water. Fish is an important source of protein as well as a means of livelihood. The loss in potential production of riverine fish can be significant: for example, the discharge of various types of pollutants into the river Ravi and its tributaries has resulted in the loss of over 5,000 tonnes of fish per year (10).

Air pollution affects the health of human beings, animals and plants. It soils and deteriorates property, impairs various production processes and generally makes living things less comfortable and healthy. However, most of these effects are ill-defined and difficult to measure.

One of the major benefits of air pollution control can be an improvement in the quality of life or a general increase in human happiness. Air pollution is associated with respiratory diseases of many sorts, including lung cancer. Studies have revealed that lung cancer death rates are higher in cities than in rural areas, when other variables are taken into consideration. In one study a male mortality ratio of 4:1 between large cities and rural areas in Sweden and Denmark has been reported. Research has also established a quantitative link between air pollution and health. But the benefits of air pollution control — the value of earnings foregone as a result of morbidity and mortality, and willingness to pay to lessen pain and premature death — are more difficult to quantify. Also, benefit estimates are of little use in Pakistan at present, at a stage when air pollution problems are not quantitatively well-defined.

THE SEVENTH FIVE-YEAR PLAN

As of 1988, safe water was available to 53% of the population (80% in urban and 40% in rural areas), whereas sewerage and sanitation facilities were available to only 25% of the population (52% in urban and 20% in rural areas). Access to piped water was limited to large urban centres with approximately 40% having house connections and the balance being served by public water taps. This service level ratio will probably continue during the Seventh Plan, although the per cent coverage is being increased.

The water supply and sanitation targets for the Seventh Five-Year Plan (1988-93) have been worked out by the Planning Commission. In urban areas, by 1993, water supply coverage is to increase from 80% to 95% by serving an additional population of 13.6 million; and sewerage and drainage coverage from 52% to 70% by reaching out to an additional 12.4 million people.

Within the overall programme, 100% water supply coverage has been proposed for metropolitan and secondary cities and about 70% for other urban centres. Similarly, sewerage and drainage facilities are to cover 100% of metropolitan and secondary cities to match the water supply programme. However, a coverage of 50% is proposed for the remaining urban centres. The programme will be financed through public sector development programmes, special development programmes and funds from local council budgets.

In rural areas, the water supply coverage is to increase to 75% of the population from the existing 40%, by serving an additional population of 31.2 million. The current sanitation coverage of 10% is proposed to be increased to 30% by serving 17 million more people.

Water is to be supplied through standposts and hand-pumps, where appropriate. Priority has been given to those areas where sweet groundwater is not available at moderate depths and where water has to be fetched from distant sources. Treatment facilities for surface water supplies have been given special consideration.

Sanitation and disposal schemes will receive priority in those areas where people have installed their own hand-pumps.

3. ASSESSMENT OF THE PHYSICAL IMPACTS OF THE ECONOMIC SECTOR: CURRENT AND POTENTIAL

The municipal aspects of the pollution of water, land and air are directly related to activities in human settlements, urban transportation and agriculture.

The impact of these activities and measures to reduce their harmful effects are presented in this section.

WATER AND HUMAN SETTLEMENTS

Water is needed in human settlements to promote sanitary conditions for health and various domestic activities. The proper handling of wastes produced from these activities is of equal importance to sustain life in human settlements and for the life support systems of water, land and air.

Water Supply

Water is required in human settlements for drinking, personal hygiene and many domestic, industrial and economic activities. The normal daily requirement for drinking water is about two litres; adequate quantities of water are needed for washing and personal hygiene; but much larger amounts are required for other purposes. The quantity as well as the quality of supplied water is important for health, to safeguard against water-borne diseases. For a large segment of our population, the unavailability of reasonable access to safe drinking water is one of the major causes of infectious diseases in the country.

The domestic use of water includes drinking, bathing, washing, kitchen use, flushing toilets and watering lawns. About 40% of water delivered to homes is used for flushing toilets (where human excreta is disposed of through a water-borne system). In addition, bathing may account for upto 37% of in-house water use if water is available at the point of use. Water requirements, therefore, depend mainly on the type and extent of water and sanitation services. Domestic water demand will increase as the level of service is increased from public standposts to yards and ultimately to house connections. Other important factors affecting water use include climatic conditions, population density, city size, mode of charging and rates charged, and the type of supply (intermittent versus continuous). Hence, domestic water requirements can range from 8-50 gallons per capita per day depending upon community size and water supply/sanitation levels (19). Industrial and commercial activities can significantly increase water requirements in a community. Lahore and Islamabad, for instance, have an average water consumption of about 100 gallons per capita per day.

Water supply sources in Pakistan include ground and surface water. Groundwater, available in the form of shallow and deep layers of water-bearing strata and springs, is the main source in the provinces of the Punjab, the NWFP and Balochistan as given in Table 1. However, where groundwater of acceptable quality and quantity is not available, surface water sources like canals and reservoirs have been developed. In Sindh, surface water sources are commonly used, with water treatment plants serving major urban centres like Karachi.

Human settlements exert a large demand on water resources which could be used for other beneficial purposes. In large urban communities water abstraction is so high that even existing and nearby sources of water cannot meet the demands of an increasing population. For example, in Lahore the groundwater level is falling at the rate of one foot per year in the central part of the city. Groundwater sources in Quetta valley are insufficient and alternative sources are being investigated. Karachi's water supply has been expanding very rapidly, tapping various sources, mainly surface water from the Indus and Hub

TABLE 1

WATER SUPPLY SOURCES

PROVINCE	URBAN AREAS			RURAL AREAS		
	Surface	Groundwater	Total	Surface	Groundwater	Total
	(million gallons per day)					
Punjab (including Islamabad)	46	454	500	1.9	108.4	110.3
Sindh	420	37	457	2.1	125	127.1
NWFP and FATA	—	58	58	9.7	22.7	32.4
Balochistan	—	20	20	—	8.5	8.5
Total	**466**	**569**	**1035**	**13.7**	**264.6**	**278.3**

Source: Planning and Development Division. 1987a. *Development of Optimal Standards for Water Supply Systems for Urban and Rural Areas, HRH/IL Joint Venture.* Lahore: Government of Pakistan.

rivers. Rawalpindi and Islamabad are also investigating alternative water sources, such as the Khanpur Dam, to meet increasing demand. There is a need to control demand, by reducing wastage which accounts for upto 40% of water use in some cases. Metering water supply to consumers may also help reduce wastage and lower consumption rates.

To promote healthy living in human settlements, the water supplied must be free from disease-causing organisms and from chemicals hazardous to health. The settlement itself may be the cause of contaminated drinking water supplies, when human wastes are not properly handled and water sources are not protected. The aesthetic quality of water is also important, as consumers may switch to other sources which are aesthetically acceptable, but perhaps contaminated. Guidelines from WHO can be used to assess water quality for human consumption. Where treatment of surface waters is needed, appropriate technology suited to local conditions should be adopted. For large urban centres, chlorination of water supplies and regular monitoring are key measures to ensure the potability of water. In rural areas, source protection can be very effective as can the slow sand-filter method. The latter is simple in design and operation, and the bacteriological quality of its water is quite good.

Human Wastes

Excreta generated in human settlements is the principal vehicle for the transmission of communicable diseases in Pakistan. When disposed of in water, the decomposing wastes consume the oxygen dissolved in water, oxygen necessary for aquatic life, besides introducing inorganic chemicals and pathogens into waterways. When applied to land as night soil or raw sewage, excreta may contaminate the land and the crops grown. Their contents can reach the groundwater and cause groundwater pollution.

There are marked differences in the human waste produced by different communities. The composition and quantity depends on various factors such as diet, climate and state of health. (See Annex Table 3 for the chemical constituents of faeces and urine). For developing countries faecal weights of about 250 grams per capita per day are reported for rural areas (6). The biological oxygen demand (BOD) of decomposing faeces and urine is about 20 grams per capita per day (12). Using these figures and current population estimates, it was calculated that 34,370 tonnes of wet human excreta with a BOD of 2,265 tonnes are produced per day as given in Table 2. This excreta is highly obnoxious and may contain huge quantities of pathogens such as viruses, bacteria, protozoa and worms.

Sewerage systems for the disposal of human waste are limited to parts of large cities, with the remaining urban population depending on septic tanks, soak pits and overflows into storm sewers. Sewage is a mixture of human excreta, urine and water used for flushing toilets, and water used for personal hygiene, laundry and in the kitchen. Therefore, the per capita BOD of sewage is greater than that of night soil and ranges from 30-40 grams per day (12). The amount of sewage from human settlements depends mainly on the quantity of water supplied. Other factors include climatic conditions, the nature of the soil and infiltration. In general, waste water volumes are 60-80% of a community's water consumption. Estimated sewage volumes from major urban centres are given in Table 3 (16).

Domestic sewage from various cities in Pakistan shows considerable variations in character as seen in Table 4. BOD varies from 100 milligrams per litre to as high as 485 milligrams per litre. These variations are due primarily to industrial wastes entering municipal sewer systems and to variations in water consumption in various cities.

Sewage produced in major cities is used for irrigation and the remainder disposed of in nearby bodies of water. The use of raw sewage for growing vegetables and other crops is obviously a health hazard for both farmers and consumers. Water bodies are becoming polluted as

TABLE 2

HUMAN WASTE: ESTIMATED WET QUANTITY AND BOD FOR PAKISTAN

PROVINCE	URBAN		RURAL		TOTAL	
	Wet Quantity[1]	BOD[2]	Wet Quantity	BOD	Wet Quantity	BOD
			(tonnes per day)			
Punjab	4,330	360	14,100	850	18,430	1,210
Sindh	2,690	230	4,800	290	7,490	520
NWFP	570	50	3,900	240	4,470	290
Balochistan	300	25	2,000	120	2,300	145
FATA	—	—	680	40	680	40
Azad Kashmir	80	6	700	40	780	46
Northern Areas	30	2	190	12	220	14
Total	**8,000**	**673**	**26,370**	**1,592**	**34,370**	**2,265**

1. Estimated using 250 grams per capita per day based on Feachem, R.G., D.J. Brodley, H. Garelick, and D.D. Mara. 1983. *Sanitation and Diseases: Health Aspects of Excreta and Wastewater Management.* New York: John Wiley and Sons.

2. Estimated using a Biological Oxygen Demand (BOD) of 20 grams per capita per day based on Mara, D. 1976. *Sewage Treatment in Hot Climates.* New York: John Wiley and Sons.

they are receiving untreated waste water; treatment facilities are available only at Karachi and Islamabad, and even these plants are not performing at the desired level. This practice is affecting downstream beneficial water uses. For example, Lahore discharges about 389 mgd of untreated sewage into the river Ravi with a minimum flow of about 400 cubic feet per second. Even a 1:1 dilution is barely available during low flows and the river acts merely as a sewer at such times.

Every natural body of water has the capacity to assimilate certain pollutants without upsetting its ecological balance. This is as long as the BOD load of the entering water does not exceed the river's BOD capacity. When this capacity is overstretched, sewage treatment becomes necessary. Such treatment may also be required to remove floating and sludge-forming materials for aesthetic reasons and to kill pathogens to protect against disease transmission.

The assimilative capacity of rivers and streams depends upon their discharge, depth,

TABLE 3

ESTIMATED SEWAGE QUANTITIES

CITY	SEWAGE QUANTITIES
	(million gallons per day)
Karachi	300
Lahore	241
Faisalabad	40
Multan	40
Peshawar	18
Hyderabad	15
Rawalpindi	13
Kohat	2.4
Quetta	2

Source: Planning and Development Division, 1987b. *Development of Optimal Standards of Quality for Disposal of Sewage. HRH/IL Joint Venture.* Lahore: Government of Pakistan.

TABLE 4

CHARACTERISTICS OF SEWAGE FROM VARIOUS CITIES

PARAMETER[1]	KARACHI	LAHORE	RAWALPINDI	MULTAN	QUETTA	PESHAWAR	KOHAT
BOD[2]	220-475	200-215	100-485	220-300	180-380	240-380	280-320
COD[3]	200-1,400	580-803	160-960	352-480	230-626	390-520	420-510
Chlorides	300-1,200	32-72	65-200	170-490	95-225	60-120	90-160
Dissolved solids	1,000-1,800	486-598	370-1,900	695-1,600	384-850	880-1,240	800-1,200
pH	7.0-8.0	7.2-8.3	6.5-8.0	8.3-8.9	6.5-7.1	7.8-8.1	7.6-8.0
Suspended solids	250-900	106-176	143-535	168-480	204-430	300-580	386-576
Sulphates	50-200	—	44-400	316-490	27-287	50-150	65-120

Source: Planning and Development Division, 1987b.

1. In mg/l except for pH.
2. Biological Oxygen Demand.
3. Chemical Oxygen Demand.

velocity, temperature and other physical conditions. The dissolved oxygen level in a river is a result of oxygen uptake by organic matter and natural reaeration. The magnitude of river flow at any point in time is a dominant factor in its waste assimilative capacity. This is because the larger the flow, the more diluted is the effluent, and a greater amount of dissolved oxygen is available for the stabilization of organic wastes. Since critical conditions occur during low flow, waste assimilative capacity and degree of treatment is determined by minimum flow.

The capacity of a river to recover is generally represented by its self-purification ratio; the latter depends on the nature of the receiving water (5). (See Annex Table 4). Most rivers in the Indus Basin fall under the large stream of low velocity category with a purification ratio of 1.5-2. A river's assimilative capacity — based on low flow and a minimum of 4 milligrams per litre of dissolved oxygen for the survival of river fish — is then calculated using the classical Streeter-Phelps equation. For example, the Indus below Chashma and Guddu can absorb the waste of 1.5 million and 1.1 million people respectively. (See Annex Table 5). The variable nature of assimilative capacity is evident and treatment requirements should be according to specific situations, especially as the rivers also receive industrial waste water.

There are various methods of waste water treatment, including activated sludge processes, trickling filters, aerated lagoons and waste stabilization ponds, in a decreasing order of sophistication, operation and maintenance requirements. The method of treatment selected should suit local conditions. Where land at a nominal rate is readily available, the use of waste stabilization ponds should be encouraged as they offer a simple and relatively cheap solution to pollution problems. Their principal advantage is that they remove pathogens efficiently and are simple to operate and maintain.

Solid Wastes

In the absence of proper collection, storage and disposal facilities, large amounts of solid wastes litter streets and find their way into open drains and sewers, ultimately clogging these facilities. Liquids leaching through open dumps at roadsides lead to food wastes putrefying — a process which releases odours and breeds disease-causing vectors. Prevalent collection practices bring the collection crew into direct contact with wastes giving rise to occupational health hazards. There are no proper disposal sites. Hence collected wastes are transported to low-lying areas in and around the city and dumped in the open, which results in unsightly and unhealthy conditions along with groundwater pollution. Uncontrolled open-air burning also causes air pollution. Limited studies are available for the characteristics and quantity of solid wastes produced in the country.

Data on solid waste for several cities of the world is presented in Table 5. Comparison of the characteristics of this waste shows that control measures adopted in developed countries may not be suitable for our conditions. For example, waste densities in Lahore and Karachi are almost double those found in industrialised countries and the use of compactor trucks may, therefore, not be of much benefit. The moisture and putrescible contents are also high. Generally, small communities have low generation rates and the country-wide average may be about 75% that of the large cities alone. On the average, with a generation rate of 0.46 kilogram per capita per day, approximately 47,920 tonnes of solid waste per day are generated in Pakistan. Area-wise generation of waste in the country is given in Table 6 (2).

To safeguard against the harmful effects of solid wastes, collection and disposal methods suited to our conditions are required. Collection systems need to be reorganised, keeping in view community development patterns. Sanitary landfilling can be used but resource recovery methods need to be encouraged.

Resource recovery for recyclable materials such as paper, plastics, metal and glass is already practised at source. Other recovery processes such as incineration and composting can be practised. Energy-from-waste technology can also be advantageously applied as the combustible content is reasonable enough in certain areas. Incineration to recover heat energy and steam can reduce the volume of waste to be ultimately handled, but it can give rise to air pollution. Composting to recover the organic components of solid waste may be the most suitable due to the high compostable content of local solid waste. Pathogenic organisms and insect larvae are killed by the high temperatures that occur during the decomposition process. Composting

TABLE 5

PROPERTIES OF SOLID WASTE FROM VARIOUS CITIES

CITY	GENERATION RATE (kg/capita/day)	DENSITY (kg/m^3)	COMPOSTABLE CONTENT (per cent)	MOISTURE CONTENT (per cent)	PAPER CONTENT (per cent)
New York	1.80	100	26	22	35
London	1.00	150	43	—	37
Singapore	0.87	175	37	40	43
Lahore	**0.64**	**500**	**73**	**42**	**5**
Karachi	**0.60**	**500**	**56**	**52**	**6**
Jakarta	0.60	250	86	80	2
Calcutta	0.51	500	78	29	3

Source: Cointreau, S.J. 1982. *Environmental Management of Urban Solid Wastes in Developing Countires. A Project Guide.* Washington D.C.: The World Bank.

TABLE 6

AREA-WISE GENERATION OF SOLID WASTE, 1988

AREA	POPULATION			GENERATION			COMPOSTABLE CONTENT		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
	(million)	(per cent)		(tonnes per day)					
Punjab	57,672	30	70	26,000	10,380	15,620	20,030	6,750	13,280
Sindh	24,447	44	56	11,000	6,470	4,530	8,050	4,200	3,850
NWFP	13,517	17	83	6,080	1,380	4,700	4,890	900	3,990
Balochistan	6,971	17	83	3,140	710	2,430	2,520	460	2,060
FATA	934	—	100	360	—	360	300	—	300
Azad Kashmir	2,310	13	87	1,040	180	860	850	120	730
Northern Areas	6,540	18	82	300	70	230	240	45	195
Total	**112,391**	**29**	**71**	**47,920**	**19,190**	**28,730**	**36,880**	**12,475**	**24,405**

Note: Estimated using 0.46 kilograms per capita per day.

also conserves plant nutrients in the waste and enhances their availability and value. The compost can therefore be used as a fertilizer and soil conditioner. Pakistani farmers are well acquainted with the utility of compost as a soil conditioner — the use of composting as a recovery process should also be encouraged in other areas.

LIVESTOCK

Animals which provide milk, meat and other valuable products, also produce waste. These wastes are high in organic content and contain nutrients such as nitrogen, phosphorus and potash. About 25 million cattle and buffaloes in the Indus Basin produce 18 million tonnes of dry dung each year (8). These wastes also contain a large number of pathogens, and their uncontrolled discharge into surface or groundwater can create health hazards for humans and animals. The organic content of waste from cattle colonies and concentrated livestock operations can over-fertilize aquatic plants, which then exert a significant oxygen demand.

Spreading livestock waste on cropland for fertilizer and soil-building value is an economical method of waste management. This method has been in use for centuries by our farmer. Livestock wastes are also utilised as fuel in the form of dried dung pats. The main concern, however, remains the haphazard storage of animal wastes near drinking water sources such as hand-pumps. Guidance is needed to facilitate proper handling and storage siting.

Animals pose a greater health hazard in urban areas. Their wastes remain littered on the streets and roadsides and proper collection and disposal methods are not exercised. After rain, these wastes find their way into storm drains and finally pollute surface waters. To protect public health, livestock should be moved away from urban areas. Detailed requirements for the safe disposal of wastes should be provided at such locations. Resource recovery through biogas plants is also viable. Based on a detailed assessment of existing plants, the use of this method may be considered on a wider scale.

PESTICIDES AND FERTILIZERS

The indiscriminate use of agricultural chemicals such as fertilizers and pesticides — insecticides, fungicides and herbicides — is contributing significantly to pollution of the environment. Pakistan has increasingly relied upon chemical fertilizers and pesticides to increase agricultural production. Between 1972 and 1978, the amount of cropland sprayed nearly tripled. Fertilizer use also dramatically increased, doubling between 1968 and 1977 (4).

Agricultural run-off containing fertilizers increases the nutrient load of the aquatic environment leading to algal growth and eutrophication. Certain chemicals, such as excess nitrates, drain into the soil or into shallow wells which supply water to villages and cities. High nitrates in drinking water cause methaemoglobinaemia in infants. Fertilizers must be used in the right proportion to avoid groundwater pollution.

Pesticides form residues in the soil and in living organisms, including human beings. Some pesticides such as DDT, 2,4-D, aldrin, and dieldrin are highly poisonous to people, fish and other aquatic organisms. Pesticides reach aquatic systems by direct application, spray drift, aerial spraying, being washed from the atmosphere by precipitation, and erosion and run-off from agricultural land. Agricultural run-off from fields sprayed with pesticides is the main source of gradual pollution, and often results in fish kill in large numbers. Dead fish on the banks of the Kabul River in certain seasons of the year are one example (4).

Many pesticides accumulate in the tissues of aquatic animals and plants. In general, organochlorine type compounds, which are relatively hydrophobic, accumulate in living tissue more than other types of pesticides (26). Bioaccumulation is an important tool for water quality monitoring. Fish are sometimes considered better indicators of pesticide pollution than water samples because residues in fish tissue are much higher and hence easier to analyse. In terms of pesticide type, persistence in the total aquatic system is longest for organochlorine insecticides, intermediate for organophosphate insecticides and shortest for herbicides (11).

Pesticide movement from the surface, through the soil, into groundwater, is governed by pesticide retention, transformation and volatilization. No studies have been conducted in Pakistan assessing groundwater contamination from pesticides. There is, therefore, a need for initiating groundwater monitoring programmes and studying the fate of pesticides in groundwater.

Pesticides affect the entire food chain, killing the predators and parasites which normally feed on insects regarded as pests. They simplify the biotic community and generate instability. Lacking effective enemies, pest species can increase more rapidly and to higher levels, before the former predator and parasite population can recover sufficiently to exercise some control. Chemical use thus tends to create a continuous demand for more potent chemicals in greater quantities.

Experience in many parts of the world has shown that with high crop diversity, the need for pest control is greatly reduced, if not eliminated. Biological controls using predatory insects or disease organisms which attack the pests themselves have been effective in some cases (3).

The development of alternative and innovative technologies to shift from complete reliance on pesticides to other methods of pest control is one answer to the pesticide pollution problem. For example, integrated pest management combines various non-chemical techniques with judicious chemical applications. Advances in genetic engineering, biological control and plant breeding may also result in the ultimate reduction of pesticide use. At present, legal and regulatory measures are needed to control excessive use.

DEFORESTATION AND EROSION

Pakistan falls among the group of countries with very low forest cover, with forest area at less than 0.05 hectares per capita (4). The situation is deteriorating due to the indiscriminate felling of trees and the resultant deforestation. Tree and vegetation cover loss increases the rate of erosion, and rainfall run-off carries large quantities of silt and clay into streams. The loss of topsoil not only affects the fertility of the soil, but the increased sediment load raises the sedimentation rate of storage reservoirs and reduces their useful life. Deforestation leads to smaller amounts of water seeping into the soil, reducing underground sources of water and increasing the chances of flash flooding.

Water erosion in Pakistan has been estimated to affect 36% of land area. Average annual soil loss on unprotected land is 1,000 kilograms per acre in the NWFP and in some critical parts of the Tarbela catchment. In the Punjab, soil erosion has been measured at 2-4 kilograms per square metre annually (4).

The sediment load in the Indus River is very high. Raw water from the Hyderabad water treatment plant receiving from the Indus River was analysed to be highly turbid. Turbidities of upto 3000 JTU (Jackson Turbidity Units) have been reported for the year 1986 (9).

Rawalpindi receives a major portion of its water supply from the Rawal Dam reservoir. Additional supplies are to come from the Khanpur Dam, across the Haro River, after its completion. During 1980, concentrations of suspended solids in the Soan River at Chira and the Haro River at Khanpur reached 3,860 and 317,300 parts per million (ppm) during the rainy season. Similarly, suspended sediment concentrations as high as 12,700 ppm have been noted in the Hub River at Karpasaniwat during 1980 (23). Several slow sand filters for rural water supplies have been reported to receive water of high turbidity.

Highly turbid water not only fills storage reservoirs at a rapid rate but also requires more elaborate treatment. Sedimentation tanks need to be cleaned more frequently, and presedimentation tanks are sometimes required to reduce sediment loads on subsequent treatment units. The cost of treatment therefore increases. Highly turbid water may also require high doses of chemicals. Increased alum dosage during periods of high loads of suspended solids have been reported at the Simly and Rawal water treatment plants.

Watershed management should address itself to preventing deforestation and the resulting erosion. Improvements should be made in cultivation and soil stabilization practices through crop rotation and contour ploughing, gully plugging and the construction of check dams for erosion control.

AIR POLLUTION

Automobile Exhaust

From an air pollution standpoint, the spark-ignited internal-combustion engine using petrol as fuel is by far the most important polluting agent. The major components of exhaust emissions are the completely oxidised products of fuel i.e., carbon dioxide, water and nitrogen. The other constituents, regarded as pollutants, include carbon monoxide, unburnt or partially burnt hydrocarbons, oxides of nitrogen, and various particulates such as lead and sulphur compounds. In 1983, IPHER collected data on the total number of vehicles in Pakistan and estimated the total emissions for Lahore. In 1986 the Institute conducted a similar study to assess the emissions of air pollutants in and around Lahore, given in Table 7. Both studies indicate that motor vehicles are the major source of carbon monoxide, hydrocarbons, nitrogen oxides and sulphur dioxide in Lahore. IPHER's estimates of annual vehicular emissions for various cities in Pakistan are given in Table 8.

Carbon monoxide concentrations in the range of 8-30 ppm and 6-40 ppm have been reported for Lahore and Karachi respectively. The gas combines with haemoglobin in the blood to form carboxyhaemoglobin (COHB), reducing the oxygen carrying capacity of the blood. A carbon monoxide concentration of 10-15 ppm results in 2.5% COHB over an 8-hour exposure whereas 30 ppm corresponds to 5% COHB. COHB levels of 2-5% can affect the central nervous system, resulting in impairment of time interval discrimination and reducing the sharpness of eyesight. Many accidents along busy urban streets are attributed to this effect, although it cannot be proven conclusively.

As carbon monoxide is a product of incomplete combustion — which may be due to an improper air/fuel ratio or an insufficient reaction time — corrective measures are aimed at improving combustion. This may be achieved by improvements in engine design, by increasing the air/fuel ratio or by complete oxidization of exhaust gases before they are emitted into the atmosphere. After-burners and catalytic converters are two types of devices which may be used to oxidize exhaust gases. Catalytic converters are used in countries such as the USA, Japan and Australia; however, unleaded petrol has to be used in such cars to avoid fouling the catalyst. In Pakistan, currently there are no automobile emission standards; if standards are to be imposed, the amount of carbon monoxide given off by vehicles under idling conditions could be limited to 4.5% and 6% of exhaust gases for new

TABLE 7

LAHORE: TOTAL EMISSIONS, 1986

SOURCE	PARTI-CULATES	SULPHUR DIOXIDE	CARBON MONOXIDE	HYDRO-CARBONS	NITROGEN DIOXIDE	ALDE-HYDES
			(tonnes)			
Transport						
Vehicles	2,013.9	1,377.42	123,053.88	29,536.40	14,564.90	208.70
Railway	171.3	755.50	656.70	447.50	1,877.50	26.40
Stationary sources						
Natural gas	53.5	5.42	193.12	50.69	1,552.80	—
LPG, Wood, Coal, Solid Waste	1,119.1	301.88	4,622.10	1,568.90	3,423.53	—
Industrial Units	4,406.0	358.00	285.00	1,010.00	162.00	—
Total	**7,763.8**	**2,798.22**	**128,810.80**	**32,613.49**	**21,580.73**	**235.10**
			(per cent)			
Transport						
Vehicles	26.00	49.20	95.73	90.60	72.70	88.77
Railway	2.20	26.90	0.51	1.37	9.37	11.33
Stationary sources						
Natural gas	0.69	0.23	0.15	0.15	7.75	—
LPG, Wood, Coal, Solid Waste	14.49	10.77	3.69	4.79	9.35	—
Industrial Units	57.00	12.78	0.22	3.10	0.80	—
Total	**100.38**	**99.88**	**100.30**	**100.01**	**99.97**	**100.10**

Source: Unpublished data from the Institute of Public Health Engineering and Research (IPHER), Lahore.

TABLE 8

ESTIMATED ANNUAL VEHICULAR EMISSIONS IN MAJOR CITIES, 1988

CITY	PARTI-CULATES	SULPHUR DIOXIDE	CARBON MONOXIDE	HYDRO-CARBONS	NITROGEN DIOXIDE	ALDE-HYDES
			(tonnes)			
Karachi	6,175	4,224	377,380	90,584	44,675	640
Lahore	3,243	2,218	198,180	47,570	23,460	336
Islamabad	1,572	1,075	96,090	23,065	11,375	163
Faisalabad	1,344	920	82,130	19,714	9,722	139
Hyderabad	1,148	785	70,160	16,841	8,305	119
Multan	1,094	748	66,880	16,053	7,917	113
Peshawar	1,028	703	62,815	15,077	7,436	107
Quetta	495	338	30,235	7,257	3,579	51

Source: Unpublished data from IPHER, Lahore.

and in-use vehicles respectively.

Hydrocarbons in automobile exhaust may be unburnt petrol vapours, low molecular weight hydrocarbons due to incomplete combustion, and some high molecular weight compounds (polynuclear aromatic hydrocarbons) which may be formed by fusion during the combustion process. Some hydrocarbons are also emitted through the evaporation of petrol from fuel tanks and carburettors or through the crankcase blowby via the road draught tube. Another source is the incomplete combustion of lubricating (heavy) oil mixed in petrol either deliberately, as in two-stroke motorcycles and autorickshaws, or through leaks into the engine around worn piston rings in older and improperly maintained cars, where it is only partially burnt and is then emitted as smoke with the exhaust gases.

Hydrocarbons in ambient air have been directly linked to adverse effects on human health. Studies of the carcinogenicity of certain classes of hydrocarbons do indicate that some cancers appear to be caused by exposure to polynuclear aromatic hydrocarbons. The major effects of hydrocarbons are indirect. In the presence of oxides of nitrogen and sunlight they produce photochemical oxidants such as ozone.

As hydrocarbons in exhaust emissions are a result of incomplete or inefficient combustion, measures suggested for the reduction of carbon monoxide would also be effective in reducing hydrocarbon emissions. Evaporative losses may be reduced by absorbing the vapours in a suitable medium like activated charcoal, which is later purged through a control valve and burnt in the engine.

Oxides of nitrogen are formed basically by reactions between oxygen and nitrogen contained in the air inducted into the engine. Among the oxides of nitrogen, nitric oxide and nitrogen dioxide are acute irritants; they also suppress the growth of small plants. Suitable control systems for nitrogen oxides are exhaust gas recirculation and catalytic reduction.

Smoke is generally emitted by autorickshaws, two-stroke motorcycles, improperly maintained cars and diesel vehicles. Autorickshaws are probably the worst offenders because their combustion system is very inefficient, producing large amounts of particulates and carbon monoxide. The particulates in rickshaw smoke are much smaller than those in diesel smoke, (as apparent from their blackish compared to bluish diesel smoke) and can thus be more harmful. This problem has been resolved dramatically in some countries such as Thailand by using low-pressure gas as an alternative fuel.

Diesel smoke may be substantially reduced by good engine maintenance, the use of quality fuel, and reasonable operating methods.

Organic lead compounds are added to petrol to prevent premature detonation of fuel. A part of this lead is emitted in the exhaust at various rates depending on the mode of operation. Most lead in exhaust is in the inorganic form, which can act as cumulative poison causing liver and kidney damage, gastro-intestinal problems, mental defects in children, and abnormalities in fertility and pregnancy. Concentrations of airborne lead of between 0.024 and 0.13 milligrams per cubic metre have been measured in Karachi. The obvious method of control for airborne lead is to eliminate its use as an antiknock agent in petrol, which would require some engine modifications.

Chemicals present in vehicular exhaust undergo physical and chemical transformation when released into the atmosphere. Thus the ultimate fate of air pollutants is determined by such transformations which in turn are governed by a number of factors such as the stability of the compounds emitted, the quantities produced and the degree of dilution, temperature, intensity of sunlight, meteorological conditions, etc.

Natural processes can take care of air pollution upto a certain extent. But when this limit is exceeded, the burden on the atmosphere becomes evident by increases in the concentration of pollutants in the ambient air. The limitations of the natural degradation process should be recognised during the town planning stage. Roads with high traffic intensity should be far from residential areas and lined by trees and shrubs, which act as biofilters and barriers to air pollutants.

Preliminary surveys conducted in Karachi and Lahore indicate that air quality in the urban areas of Pakistan is fast deteriorating due to a rapid rate of increase in the number of vehicles, coupled with poor maintenance. The ideal situation would be to improve the public transport system to such an extent that the use of private vehicles is no longer necessary for routine purposes. This would reduce not only pollution but also petrol consumption, resulting in substantial savings in foreign exchange. Additional benefits include fewer accidents on the road and reduction in road maintenance costs. The second best solution, which is more plausible at this stage, is the adoption and strict enforcement of emission standards including regular inspection of motor vehicles to ensure proper maintenance. Maintenance costs are offset by savings in fuel consumption and longer vehicle life. Measures aimed at smoothening the flow pattern can reduce some pollutants like carbon monoxide, because freely moving vehicles produce less of this gas than those which constantly stop and start.

Burning Fuel

Wood (including charcoal) and natural gas are the two main fuels used for home heating and cooking in Pakistan. Electric heating, which is non-polluting, is restricted to a small proportion of the urban population who can either afford to pay the price for this convenience or who do not have to pay at all, as in government offices.

Wood Burning

The environmental effects of wood burning generally fall into two main categories. The first relates to the impact of increased firewood harvesting on forest resources, water pollution, soil erosion, nutrient balances, wildlife habitat, recreational activities, etc.; the second includes the effects of emissions resulting from wood burning. The impact of firewood harvesting has been briefly discussed in relation to deforestation. Since wood is a traditional fuel, not much attention has been given to the possible ill-effects of burning wood on human health. Research studies have identified over one hundred different chemicals and compound groups in wood smoke, including priority pollutants, carcinogenic, citra-toxic, mucus coagulating and co-carcinogenic (cancer initiating or promoting) agents. It also contributes to a number of clinical and subclinical respiratory and non-respiratory effects such as the common cold, chronic and acute bronchitis, pneumonia, emphysema and asthma. In the literature it has been reported that villagers in the highlands of New Guinea, who are constantly exposed to high levels of smoke from fires in small enclosed huts, develop obstructive lung diseases by the time they reach the age of 40.

The problem of wood smoke can be handled either by adopting some basic changes in the design of dwellings or through technological means. The latter option is preferred in industrialized countries where air-tight controlled combustion heaters and cookers are used and wood smoke vented to the exterior through appropriately designed flue systems. In developing countries, stress has been placed on improving the design of conventional appliances so as to increase efficiency and reduce direct exposure to smoke by installing a flue pipe. This is coupled with the kitchen (which is well ventilated) being detached from the living area so as to minimise exposure to smoke.

Combustion of Natural Gas

Natural gas is the most common indigenous fuel in Pakistan. There are large known reserves of this resource in the country which are, however, not unlimited. It is available in most cities of Pakistan and because of its convenience and low cost, is the most popular fuel for heating and cooking.

Natural gas consists of methane and minute quantities of other constituents. Methane is a simple gas which when mixed with adequate quantities of air and provided sufficient combustion time, burns completely to carbon dioxide and water. However, the ideal combustion of natural gas is not achieved in the range of appliances available in the market. Many of the appliances are manufactured in 'garage workshops' and small factories where due attention is not paid to efficiency and safety factors. These factors are neglected in an effort to keep prices down resulting in a large range of appliances which are not only inefficient but potentially dangerous. These inefficient appliances waste the resource and cause air pollution. The flue gas from such appliances contains unburnt methane along with the products of incomplete combustion. When such appliances are located in poorly ventilated kitchens and rooms they can cause headaches, lethargy, inability to concentrate and, in extreme cases, death.

It is important to regulate the gas appliance manufacturing industry. Only licenced manufacturers, whose products have been tested in a laboratory and conform to prescribed standards, should be allowed to sell their appliances. The industry should be encouraged to redesign space heaters (room heaters) so that combustion occurs in an enclosed firebox from where the combustion products, including any unburnt or incompletely burnt gas, is vented directly to the atmosphere, without polluting indoor air. Some safety features must also be specified such as automatic shut-off in the event of any interruption in gas supply.

NOISE POLLUTION

Urban Areas

Noise is described as sound without agreeable musical qualities or an unwanted sound, and is as much of an environmental pollutant as noxious gases and the chemicals and wastes that befoul our air, water, soils and crops. If the noise is loud enough, the ear may suffer temporarily, but if it occurs consistently the damage may become permanent. Noises which are most dangerous are those which are loud, high pitched, pure in tone and long in duration. Sharp, loud impulse noises like gunfire are also very dangerous.

Noise directly affects the ear; it also indirectly affects other parts of the body, specifically the cardiovascular system. It increases the level of artery-clogging cholesterol in the blood and raises blood pressure. Headaches are one common effect. Medical researchers have also indicated that noise has profound effects on unborn children, including developmental malformations. It affects the nerves, emotions, and personality of people working in noisy conditions. A consensus of medical opinion places the danger mark at 85 decibels, above which continuous exposure to noise beyond specified periods of time poses a serious threat to the ears and the rest of the body.

Noise is basically an occupational hazard to which workers in some industries are exposed or a big city problem. The worst general source of disturbance in cities is the noise of vehicular traffic. Road traffic in Pakistani cities is considerably noisier than that in most other countries of the developing world. The concentration of vehicles on city roads is one reason but other factors, which are far more important, are the condition of these vehicles and the attitude of the drivers. Private as well as government buses are improperly maintained and very often produce a high level of noise. However, by far the worst offender is the autorickshaw which is ubiquitous in most of our cities.

Driver attitudes in our cities also leave much to be desired. Bus and wagon drivers, especially, are impatient, have no sense of road courtesy, and show scant regard for traffic regulations. During morning and evening rush hours, there is a complete breakdown of discipline on most city roads and chaos prevails. Horns blare frequently and needlessly. There is no concept of 'silent zones', or reduction in the noise level outside schools and hospitals. In this context a vigorous public education programme should be launched. Rule 158 in the Motor Vehicles Rules of 1969 on noise — which states that every motor vehicle shall be so constructed and maintained as not to cause excessive noise when in motion — should be strictly followed.

4. CURRENT AND POTENTIAL INTERACTION WITH COMPETING USERS

Surface water is used for community water supplies and for the disposal of municipal and industrial wastes. Air and land resources are utilised for the same purpose. These resources are also exploited for other activities. Identification of competing users and options for reducing conflicts are described in this section.

SURFACE WATER

Surface water in Pakistan has several beneficial uses. These include the use of water for irrigation, hydroelectric power generation, domestic and industrial supplies, fish rearing, and for the disposal of municipal and industrial wastes. Competition among various users exists in terms of water quantity and quality. The maximum use of water is for agricultural irrigation. During an average year, the canal system in the country delivers 65 million acre-feet (MAF) in the Kharif and 37 MAF in the Rabi season (1). These quantities are considered insufficient for the growing needs of the agriculture sector. Surface water is also used for domestic water supplies — for many small towns and villages, as well as for major cities like Karachi, Hyderabad, Islamabad and Rawalpindi. An estimated 466 mgd of surface water in urban areas and about 14 mgd in rural areas is in use for domestic water supplies (15). The water used for municipal supplies is not available for irrigation. Although water is needed for food production, water for drinking is even more important. About 80% of the amount of water drawn for domestic supplies appears as waste water and can be returned to surface water after treatment. The treated waste water could be safely used for agriculture. Therefore, in case of competition between agriculture and domestic use, the latter should get preference.

Hydroelectric power generation, irrigation and waste water disposal also compete for surface water. Since the assimilative capacity of surface water increases directly with flow, large quantities diverted for irrigation or held for power generation can conflict with water requirements for waste assimilation, particularly for downstream communities. In certain cases, hydroelectric power generation and irrigation can complement waste water disposal. Dams store water during high flows and regulated releases are made during low flow periods to meet agricultural and power generation requirements. Augmentation of low flows increases the assimilative capacity of the river and waste water treatment requirements are reduced. The releases can be adjusted to optimise the overall use of surface water for multiple purposes. The regulated release of waste water in proportion to the flow available in the river can also be beneficial, especially for the discharge of industrial wastes.

Competition also exists among various users with respect to the quality of water. The discharge of waste water can affect the quality of receiving water to the extent of making it unsuitable for subsequent beneficial uses. It limits aesthetic benefits, reduces or eliminates fisheries and results in a quality which is less acceptable for municipal and agricultural use. Since the major use of water in the Indus Basin is for irrigation, water quality suitable for agriculture must be maintained at the point of use. Any other use which makes the water unfit for irrigation must be banned.

LAND

Land is put to various uses — residential, industrial and agricultural — besides providing a means of municipal waste disposal. Land is required for waste water treatment facilities even where waste water is disposed of through surface water. Land requirements vary according to the treatment method and disposal, and market pricing may help in selecting a disposal method which can compete economically with other uses. However, waste disposal is so important from the health point of view that the land needed for treatment plants should receive due consideration.

Competition between land for waste disposal and agriculture can be reduced if waste water is used for growing crops. It is beneficial in three ways: it complements canal water supplies; nutrients such as nitrogen, phosphorus and potash in the sewage stimulate plant growth; and it serves as a method of sewage disposal. Pakistan is short of irrigation water and as such, municipal sewage has its value as a potential resource — in some cities it is being used to water municipal parks and private garderns. On the other hand, there are two kinds of health hazards associated with sewage irrigation: occupational hazards of those employed to work on the land so irrigated and the risk that contaminated products will infect humans or animals through consumption or handling. Such risks depend largely on the type of product. The product may be food for direct human consumption, food for animal consumption or agricultural products put to other uses.

The use of sewage for the production of food for direct human consumption should be discouraged, due to the health risks involved. Untreated waste waters contain pathogens and if these are not removed by treatment processes, will reach the fields and, ultimately, the crops. The survival time of pathogens on crops can be about 15 days, and viable pathogens have a chance of infecting those who handle or eat the crop. The health risks associated with the use of sewage for pasture or fodder crops are relatively small. When sewage is used for tree cultivation for timber production, for the cultivation of commercial crops such as cotton, and for the control of desertification, health hazards are further reduced although farm workers can still be at risk. To protect the health of workers, sewage treated through waste stabilization ponds should be used. The options of waste water treatment and crop restriction can be combined to reduce health risks and get maximum benefits from the reuse of sewage.

On-site excreta disposal facilities such as bucket latrines, pit latrines and septic tanks use land as the receptor. The prevention of soil contamination and groundwater pollution are important considerations in such systems. Pathogens move into the soil by liquid being leached or rainwater. The extent of bacterial pollution depends on several factors, among which porosity of the soil is most important. In areas where there are pit latrines and soakage wells, there will be the risk of pathogens reaching the groundwater. In addition, elevated nitrate levels may also occur in the groundwater. Strict vigilance is required in areas where groundwater is the source of the community's water supply. If groundwater quality monitoring demonstrates significant groundwater pollution, the excreta disposal system should be changed.

AIR

Air is finite and limited by the troposphere boundary layer. As human activity increases, increasing amounts of pollutants are being discharged into a fixed quantity of air.

In cities, human activities and high population densities lead to air pollution. When considering pollution levels, it is useful to think of the city as enclosed in a 'bubble' with a fixed amount of available air. Within the 'bubble', sources of air pollution include motor vehicles, industries, heating and cooking appliances and burning of trash. To ensure that the available air does not get polluted to a point where it starts to have an adverse effect on a significant portion of the human population, it is essential to have a viable pollution control strategy. For this purpose, ambient air quality standards that define the maximum permissible limits, at source, of common pollutants are needed; these are generally based on what can be practically achieved. Regular monitoring of ambient air as well as of pollution sources is required to ensure strict compliance.

In the absence of any proper air quality monitoring programmes, as in Pakistan, it is important to adopt at least minimal controls on an ad hoc basis. Such measures could include placing new industries with air pollution potential outside city limits; encouraging the use of air pollution control equipment in new industries by providing financial incentives, such as tax rebates; banning trash burning; mandatory inspection of public as well as private transport vehicles (buses, wagons and rickshaws) at least twice a year; and educating the public about the causes and dangers of air pollution. At the same time the Environmental Protection Agencies should monitor the pollution level in the provinces and develop sound air quality management programmes.

5. ACHIEVING SUSTAINABLE USE

In Pakistan, the realization of the necessity for sustainable use of natural resources can best be described as poor at various levels of society. Recently, some awareness of the importance of a clean environment has been discerned in the problem areas of municipal water supply, waste water treatment and disposal, air pollution and solid waste management. Slow progress or the lack of progress in certain areas can be attributed to economic, technical, cultural, social and administrative factors.

EDUCATION

The process of integrating environmental concerns into formal education has been a gradual one. Environmental engineering, for example, has undergone an evolutionary process guided by the needs of the time. In most situations, sanitary engineers played the traditional role of providing water supply and waste water disposal systems. Sanitary engineering later became part of the broader field of public health engineering. With industrialization, the need for pollution control technology in industrial waste management began to be felt. Therefore the areas of municipal water supplies, waste water treatment and disposal, water and air pollution control and solid waste management are now among the essential courses which need to be incorporated into traditional programmes of undergraduate and postgraduate degrees.

University Education

To highlight the impact of various engineering activities on the environment, all undergraduate programmes should address basic environmental issues relating to their field of activity. There is also a need to develop interdisciplinary post-graduate programmes to offer balanced training in the scientific, engineering, social and economic aspects of environmental protection and management.

Continuing Education

The most common and urgent need for continuing education is that of the non-specialist engineer, whose job now includes handling environmental problems. Additionally, many engineers may have entered the profession at a time when interaction between engineering work and the environment was considered less important than is the case now. In the years ahead, many of these men will continue to dominate engineering activity. They will be working in environmental management, with or without formal training for such a role. Their work will have a direct impact on the environment. Continuing education can increase their awareness of environmental issues as well as their competence, so that they can foresee problems, rather than react defensively when secondary effects become apparent. The need for increasing environmental awareness among practising engineers is thus urgent. Professional engineering societies, training institutions and employers can play an important role in continuing education by organising in-service training courses, seminars and lectures on specific aspects of the environment for their engineering personnel.

General Awareness

In addition to continuing education for specialists, it is necessary to emphasise three important areas which relate to the creation of general awareness and appreciation of the environment in society. The first of these is some form of education at the school level. This will help instill a concern for the environment in the minds of the coming generations. The second area relates to the effort directed at the group consisting of people holding important positions in government, politics, the business sector and other fields. This could take the form of lectures especially organised for such groups. The third area relates to the use of media to promote and spread the message of environmental preservation. Television, radio and national newspapers are formidable tools which could be used to greater effect in this effort.

TECHNOLOGY

Appropriate technology, the use of local manpower and materials, and the avoidance of unnecessary sophistication and automation can contribute to the sustainable use of the environment with regard to municipal water supplies, waste water disposal, air and water pollution, and solid waste management.

Appropriate Technology

Appropriate technology is often mistakenly assumed to mean simple or 'low' technology. The key requirement for appropriate technology is that it be selected in the light of local circumstances, with particular attention to the human, material and financial resources available for installation, operation and maintenance (13). The type of technology selected should be such that it serves reliably and economically, under local conditions, over a long period of time. It should not be directly copied from a very different situation. The degree of automation must also take into account the lower cost of locally available labour. In Pakistan, labour-intensive methods can be many times lower in cost — there is a 30-fold disparity in many situations (14) — than automated devices. In addition, equipment for mechanization and automation must generally be manufactured in the industrialised world, so that spare parts and maintenance skills must also be imported, usually at high cost with long delays.

Local Resources and Skills

Mechanization and automation may be appropriate when the task to be carried out cannot be readily performed by labour, no matter how low-cost. For example, the pumping of water in large quantities is a mechanical process, not easily replaced by labour. On the other hand, the introduction of automatic filter washing, in a water treatment plant, to save labour hardly seems appropriate. The automation required for automatic filter washing is quite complex, and its purchase and maintenance, even if it could be suitably maintained in Pakistan, would be very expensive. An operator could readily wash a filter on the basis of head loss or a time schedule. Precise timing is not required. If a simple and labour intensive option is so clearly preferable, why are so many examples of sophisticated technology to be seen in Pakistan? High technology is often the only technology familiar to most engineers, whether local or expatriate. They are therefore unable to identify themselves with practices that appear 'backward'. That the technology is not appropriate does not appear to matter. It may be pointed out that London's water supply, drawn from the Thames River, is treated through slow sand-filter plants, some of which have been built over the last few years, despite the fact that this represents the oldest technology in water treatment — it was chosen since it was the most appropriate. In Pakistan, on the other hand, failure to use the latest technology may be attributed to ignorance, so every attempt is made to become up-to-date. Turnkey arrangements with highly complex provisions for push-button operations and the option for operation from a control room are mistakenly considered desirable.

The greatest need in the environmental health engineering field is to increase the number of people served. Not only does the use of inappropriate technology divert funds away from higher priority needs, but investment in this type of technology becomes a heavy liability. Sophisticated facilities are often allowed to fall into disrepair and ultimately into disuse. Some waste water treatment facilities such as trickling filters and activated sludge plants installed at great cost are obvious examples of such wastage. Their presence is a constant reminder that we must opt for simple technology which is low-cost and labour-intensive rather than automation-oriented. Waste stabilization ponds must, therefore, be given their due place in water pollution control programmes. Similarly, air pollution control, industrial effluent and solid waste management programmes should take due cognizance of these guiding principles.

RESEARCH

Research in natural resource conservation must be in a systematic manner. To be effective, it is important to carry out baseline surveys, monitoring programmes, project evaluation and plant performance studies in the areas of water supply and waste water engineering, water and air pollution control and solid waste management. For example, in the area of developing community water supplies, traditionally there has been an emphasis on the design and construction of new works. The financial constraints of recent years will soon lead to a change in priorities so that an increasing number of projects will aim at improving the effectiveness of existing facilities, enhancing management skills and upgrading technical staff. This will help in prolonging the life and improving the operation and maintenance of existing facilities through institutional strengthening, rehabilitation and training. The role of research in this and other areas related to the environment would be to investigate and identify the technological option most suitable for local conditions, and to improve on those already in use.

Baseline Surveys and Monitoring Programmes

Research has been done in the area of environmental conservation and protection. Now, however, it is necessary to evolve a systematic and comprehensive plan at the national level, to help collect and compile information on the existing state of the environment. This would include initiating monitoring programmes for natural water sources; municipal and industrial effluents; ambient air quality studies; and the collection and compilation of data on solid wastes in major urban centres. Such investigations can take the form of regular baseline surveys or monitoring programmes.

Databases

This information can help generate databases, useful when deciding on the parameters of environmental engineering projects e.g., demand projections for municipal water supplies, pollution loads in the case of waste water treatment plants, and ambient air quality in the case of air pollution control.

The lack of an adequate database is acutely felt, for instance, in designing water supply systems. The demand for water in a particular situation depends on local conditions such as climate, traditional water use practices and the level of service provided (stand-pipe, yard-tap or house connection). In our country, the engineer is almost always faced with having to guess at present and future demand, without knowing how much more water will actually be used when the level of service is upgraded. The engineer generally designs a system to meet an overestimated future demand. But the cost of undertaking a water demand survey is far less than the additional cost of building an overdesigned system. All that is needed is foresight and the allocation of funds for the demand survey during the project preparation phase. The same can be said for demographic information, where the target population is exaggerated and the system is overambitious. Similarly, there is seldom adequate information on leakage/wastage from piped water systems.

Project Evaluation and Plant Performance Studies

With the exception of community water supplies and municipal sewer systems, projects have rarely been built to protect the environment. Even when such projects are undertaken there is little evaluation, despite the need for documentation which could provide feedback for future projects. It is indeed unfortunate that performance data relating to existing waste water treatment plants, constructed at great cost in major urban centres, is not to be found in the engineering literature in the country. Evaluation of the beneficial impact of these facilities on the environment, on the well-being of the population, and their socio-economic status is rare. Government departments, organizations and industrialists all have an obligation to arrange, organise, compile and disseminate information on these aspects. For this purpose there should not be any hesitation, particularly on the part of the industrialist, to commit resources in terms of both finance and manpower.

ADMINISTRATION AND LEGISLATION

In order to establish a firm foundation for an environmental conservation strategy, it is important to formulate plans and policies at the organization and department level. This could be achieved by the creation of environmental planning and control organizations. With the promulgation of the Pakistan Environmental Protection Ordinance of 1983, a legislative basis has become available "to provide for the control of population and preservation of [the] living environment" in Pakistan. The ordinance has fulfilled a long standing need for provision of an administrative and legislative basis for environmental conservation in the country. It provides for the establishment of a powerful Pakistan Environmental Protection Council (chaired by the prime minister), as well as Environmental Protection Agencies at the Federal level and in each of the four provinces. The council, in association with the agencies, shall establish a comprehensive national policy for environmental conservation, ensure integration of environmental considerations into national development plans, as well as ensure enforcement of the environmental quality control standards (which have started to be framed). A provincial Environmental

Protection Agency (EPA) was established in the Punjab in July 1987, while the Sindh EPA came into being in 1989.

Role of Subsidies and Incentives

Water supply and sanitation services have been increasing gradually in major urban centres and towns. Due to the lack of political will, a corresponding rise in charges has not materialised. Thus, present services are heavily subsidised, leaving the water agencies in debt. These agencies are unable to operate efficiently and maintain delivery systems. The deeper in debt the agency falls, the more dependent it becomes on government subsidies. A loss of freedom is the price paid for government bailouts, and municipal agencies have become increasingly subject to political priorities and interventions. Ultimately, water agencies function as de facto government departments, and are caught in the downward spiral of not being able to collect adequate revenue, attract high-calibre motivated staff or provide efficient service. The way out of this vicious circle is to provide water and sanitation services which the community can afford and pay for. This would ensure long-term operation and maintenance on an efficient basis. Similarly, incentives can play a significant role in the control of environmental pollution in respect of municipalities and industries.

6. CONCLUSIONS

The conclusions are:

1. The discharge of untreated municipal wastes into water bodies and dumping on land has created serious pollution problems. The provision of safe drinking water and adequate sanitation facilities need to be extended to a much larger section of the population, especially in rural areas, to protect public health.
2. The increased use of chemicals to enhance agricultural production is a potential source of chemical pollution of surface and groundwater. To reduce pesticide pollution, biological control measures along with judicious chemical applications need to be investigated.
3. Effective measures are needed to protect water supply sources from chemical and faecal pollution. The use of slow sand filters should be encouraged in rural water supply schemes as they remove pathogens most efficiently.
4. Waste disposal methods that incorporate resource recovery should be encouraged. The use of municipal waste water for irrigation, after adequate treatment through waste stabilization ponds, needs to be promoted. This would supplement irrigation water, provide nutrients for plant growth, and reduce the pollution load on surface water.
5. The use of composting as a means of resource recovery and solid waste disposal should be encouraged, as it conserves nutrients and kills pathogens.
6. The use of a stream classification system should be made for the optimal use of surface water.
7. Enforcement of legislative measures is needed to control air and noise pollution problems from motor vehicles in urban areas. Adequate town planning measures for smooth urban traffic flow patterns are also needed to control automobile exhaust pollution.
8. The mass media should be used to promote general awareness and appreciation of the environment. Besides formal education, there is also the need for continuing education for professionals.
9. There is a need to initiate monitoring programmes for water sources and air, to build an adequate environmental database. Research should be undertaken to identify and develop appropriate technology to control pollution and promote resource recovery.
10. Government agencies and autonomous bodies involved in water supply, sanitation and pollution control should commit manpower and financial resources to applied research, project evaluation and plant performance studies.

11. The process of evolving environmental quality control standards should receive due consideration by the concerned government agencies.

12. National planning must take into account the environmental dimensions of development projects, for effective implementation of a National Conservation Strategy.

ANNEXURES

TABLE 1

WATER SUPPLY AND SANITATION COVERAGE

PROVINCE	COVERAGE			
	Urban Water Supply	Urban Sewerage and Sanitation	Rural Water Supply	Rural Sanitation
	(per cent)			
Punjab	56.41	33.44	14.86	1.64
Sindh	70.02	45.09	9.68	0.84
NWFP	45.33	8.67	17.14	—
Balochistan	90.00	2.00	11.35	—
FATA	—	—	11.03	0.04
Overall	**61.12**	**34.91**	**13.96**	**1.11**

Source: Shah, A.A. 1984. Progress made in Drinking Water Supply and Sanitation Sector in Pakistan and Sectoral Position in Development Plans. In *Proceedings of the National Conference on Drinking Water Supply and Sanitation, 16-19 November 1981*. Islamabad: Ministry of Planning and Development, Government of Pakistan.

TABLE 2

INTERNATIONAL WATER SUPPLY AND SANITATION DECADE, 1981-90: PAKISTAN'S TARGETS

PROVINCE	POPULATION				WATER SUPPLY						SANITATION					
					URBAN			RURAL			URBAN			RURAL		
	Urban 1980 (Million)	Rural 1980 (Million)	Urban 1990 (Million)	Rural 1990 (Million)	Population Coverage 1981 (%)	Proposed Population Coverage 1990 (%)	Finance Required (Rs. Million)	Population Coverage 1981 (%)	Proposed Population Coverage 1990 (%)	Finance Required (Rs. Million)	Population Coverage 1981 (%)	Proposed Population Coverage 1990 (%)	Finance Required (Rs. Million)	Population Coverage 1981 (%)	Proposed Population Coverage 1990 (%)	Finance Required (Rs. Million)
Punjab (including Islamabad)	12.78	33.8	19.7	42.04	60	100	4,228	18	60	1,510	43	58	1,050	2	14	502
Sindh	7.78	9.92	11.97	12.33	83	100	2,208	13	81	500	49	66	900	1	15	180
NWFP	1.62	8.46	2.23	10.32	51	100	453	22	66	1,250	10	38	100	—	10	103
Balochistan	0.54	2.39	0.84	2.97	87	100	170	13	47	166	7	29	40	—	10	29
Azad Kashmir	0.22	1.69	0.33	2.10	50	100	66	20	95	250	9	18	8	—	8	16
Northern Areas	0.09	0.45	0.13	0.55	45	100	38	20	100	69	11	23	4	—	11	6
FATA	0.021	2.91	0.36	3.62	50	100	10	9	75	370	10	19	1	—	10	36
Total	**29.05**	**59.62**	**35.56**	**73.93**	**68**	**100**	**7,173**	**17.27**	**66**	**4,115**	**42**	**58.5**	**2,103**	**1.3**	**12.80**	**872**

Source: Shah, 1984.

TABLE 3

COMPOSITION OF HUMAN WASTE

CONSTITUENT		FAECES	URINE
		(per cent of dry weight)	
Calcium	(CaO)	4.5	4.5 - 6.0
Carbon		44 - 55	11 - 17
Nitrogen		5.0 - 7.0	15 - 19
Phosphorus	(P_2O_5)	3.0 - 5.4	2.5 - 5.0
Potassium	(K_2O)	1.0 - 2.5	3.0 - 4.5

Source: Feachem, R.G., D.J. Brodley, H. Garelick, and D. Mara. 1983. *Sanitation and Diseases: Health Aspects of Excreta and Wastewater Management.* New York: John Wiley and Sons.

TABLE 4

SELF-PURIFICATION RATIO

NATURE OF RECEIVING WATER	SELF-PURIFICATION RATIO AT 20°C
Sluggish streams	1.0 - 1.5
Large streams of low velocity	1.5 - 2.0
Large streams of moderate velocity	2.0 - 3.0
Swift streams	3.0 - 5.0

Source: Fair, G.M., J.C.Geyer, and D.A. Okun. 1968. *Water and Wastewater Engineering Vol. 2*. New York: John Wiley and Sons.

TABLE 5

APPROXIMATE ASSIMILATIVE CAPACITY AT MINIMUM FLOW

RIVER	MINIMUM FLOW	APPROXIMATE ASSIMILATIVE CAPACITY
	(cubic feet per second)	(in terms of persons)
Indus below Chashma	2,265	1,500,000
Indus below Guddu	1,770	1,150,000
Indus below Sukkur	76	50,000
Jhelum at railway bridge, Jhelum	1,796	1,170,000
Jhelum at Khushab bridge	345	224,000
Chenab at Alexandria bridge	117	76,000
Chenab below Khanki	202	130,000
Chenab at river bridge, Jhang	1,153	750,000
Ravi at Shahdara	400	260,000
Sutlej below Suleimanki	96	60,000

Source: Planning and Development Division, 1987. *Development of Optimal Standards of Quality for Disposal of Sewage. HRH/IL Joint Venture.* Lahore: Government of Pakistan.

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