# ASSESSMENT OF WATER-QUALITY

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## ABSTRACT

*Water is the most essential component of all living things and it supports the life-process. Without water, it would not have been possible to sustain life on [his planet. The total quantity of water on earth is estimated to be 1.4 trillion cubic meter. Of this, less than 1% water, present in rivers and ground resources is available to meet our requirement. These resources are being contaminated with toxic substances due to ever-increasing environmental pollution. To reduce this contamination, many countries have established standards for the discharge of municipal and industrial waste into water streams.*

*We use water for various purposes and for each purpose we require water of appropriate quality. The quality of water is assessed by evaluating the physical, chemical, biological and radiological characteristics of water. Water for drinking and food preparation must be free from turbidity, colour, odour and objectionable tastes, as well as from disease-causing organisms and inorganic and organic substances, which may produce adverse physiological effects. Such water is referred to as potable water and is produced by treatment of raw water, involving various unit operations. The effectiveness of the treatment-processes is checked by assessing the various parameters of water-quality, which involves sampling and analysis of water and comparison with the National Quality Standards or WHO standards. Water which conforms to these standards is considered safe and palatable for human consumption. Periodic assessment of water is necessary, to ensure the quality of water supplied to the public. This requires proper sampling at specified locations and analysis of water, employing reliable analytical techniques.*

## INTRODUCTION: THE IMPORTANCE OF CLEAN WATER

Water is the most common substance on earth and we use it every day, without giving much thought to its importance and significance. In fact, water is the most essential component of all living things, as it supports the life-processes by providing the essential nutrients to living organisms. Without water, it would not have been possible to sustain life on this planet. About 70 per cent of earth' s surface is covered with water, which helps to regulate the earth's climate, by transporting heat from warmer to colder regions. The total quantity of water in the oceans, inland seas, rivers, lakes, underground reservoirs, ice caps of mountains and in the atmosphere is estimated to be about 1.4 trillion ($1.4 \times 10^{12}$) cubic meters[1]. This quantity has remained the same ever since the formation of the earth. Water changes from one form to another and moves from one place to another, and is used countless times by many persons. All the water we use passes through the "water-cycle" and is used and reused again and again.

Water is unevenly distributed on earth. The oceans and inland seas contain about 97.2%, the ice caps of mountains and glaciers about 2.15%, surface and underground resources about 0.63% and the atmosphere about 0.02-0.05%[1]. Huge amount of water present in oceans and seas can not be used for most purposes, as it contains 35,000 ppm of dissolved impurities. Similarly, brackish water contains 1000-25,000 ppm of dissolved impurities. Since, for most applications, water containing less than 1000 ppm dissolved impurities is required, this water is not suitable for use. Icecaps and glaciers contain significant amount of relatively fresh water but its exploitation is not economical as yet, although the melting of mountain-snow actually recharges the water streams.

This distribution shows that, out of all the available water on earth, less than 3% is fresh water. Even out of this 75% is frozen in the glaciers and icecaps. Thus, less than 1 % of the total water that is present in rivers and



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underground resources, is available to meet our present-day requirements.

The surface and ground water resources are not evenly distributed on the surface of earth and about half of the land has very little or no water at all. This uneven distribution of water is partially responsible for unequal distribution of population in the world. About 5 per cent of the land where lots of fresh water is available contains half of the world population, whereas another half is distributed on the remaining land. The limited availability of water in arid and semi-arid areas adversely affects the productivity and prosperity of people and the quality of life.

The population of the world is growing exponentially and has increased from one billion in 1820 to about 6 billion in 2000[2]. The population-growth in table - 1 shows that it took several thousand years to build up the world population to the one-billion mark, whereas now it is taking less than 15 years to add another billion. At present, the population is increasing at the rate of about 80 million per annum. This rapid growth of population is putting a great stress on all the available resources, including water. At present about 8% of the population is facing shortage of fresh water and, with growing population, this may increase to 25% by the year 2050. It is likely that 48 countries, including Pakistan, will face fresh-water shortage. The population of Pakistan has increased from 33.7 million in 1951 to 140 million in 2000, whereas water-resources have not substantially increased. It is projected that the population will increase to about 250 million by the year 2025. Therefore, careful planning and management of the existing water-resources should be given highest consideration, and the desalination of ocean-water may have to be exploited to add more water resources.

In Pakistan the availability of surface and ground water is much less than the daily per capita requirement, which will further aggravate with the rapid population growth. The per capita water availability has declined from 5100 $m^3$/a in 1950 to about 1200 $m^3$/a in 2000 which may soon fall below 1000 $m^3$/a. Average annual water availability in Pakistan based on seventy years data is mentioned in table - 2[3]. We use both surface and ground water for drinking and other purposes. The quality of drinking water in most areas is sub-standard as it contains many impurities. The problem of the availability of good quality drinking water is more pronounced in coastal areas as the groundwater in these areas contains high amount of dissolved salts.

## SOURCES OF WATER-POLLUTION

Water, during its passage through rivers and through the ground, acquires various types of dissolved and suspended impurities. In addition to this, the ever-increasing environmental pollution, due to various activities of man, is contaminating the water resources with toxic substances. The main sources of water-pollution are sewage, industrial, agricultural and chemical wastes. The large-scale use of insecticides, pesticides and other agrochemicals is gradually contaminating the water- resources with toxic chemicals. Effluents from many industries are discharged into rivers and canals, without proper treatment to conform to the regulatory requirement. Similarly, untreated municipal effluents are dumped into water-bodies. Table - 3 shows the quantity of sewage generated, along with the population in 10 major cities[4]. Most of this sewage is discharged into water-bodies without any treatment, which causes water pollution.

The pollution of water in river Ravi in Lahore and Nullah Lehi in Rawalpindi / Islamabad was studies in April 2000 by JIAC, in collaboration with Pak.EPA, by measuring the following parameters[5]:

| | |
|---|---|
| Parameters Measured at site | Flow rate, Temperature, Conductivity, pH , Dissolved Oxygen , Odour , Colour and Turbidity |
| Parameters Measured in Lab | BOD , COD , TSS , T-N , O & G , E – Coli As , Cu , Cr , Cd , Pb and Zn |

The comparison of these parameters with those of Japanese river-water indicates high pollution in river Ravi and Nallah Lehi. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD), which are the main indicators of biological and chemical pollution, were found to be much higher (BOD>100 ppm, COD>50 ppm) in most of the samples.

The level of water-pollution due to the release of effluents from various industries in Korangi site area, Karachi, was investigated by Ali and Jilani[6]. The parameters studied include pH,

total suspended solids, total dissolved solids, BOD , COD , grease & oil and heavy metals. The data regarding five different types of industries, along with NEQS, is tabulated in table 4, which indicates that the amounts of pollutants discharged are much higher than the permissible levels.

The indiscriminate release of municipal and industrial waste is polluting the water with toxic chemicals and microorganisms that can cause various diseases. These pollutants must be removed by appropriate treatment before the water is supplied to the public. The pollution of water-resources has become a serious problem and requires serious attention. It is necessary to properly regulate the discharge of municipal and industrial wastewater into rivers and canals. In order to reduce the contamination of surface and ground-water resources, many countries have established National Environmental Quality Standards (NEQS) for the discharge of municipal and industrial waste into water-resources. The Government of Pakistan in 1993 has also established NEQS for the release of municipal and liquid industrial effluents, which are not properly enforced[7].

## POTABLE WATER

We use water for drinking and food preparation and for domestic, industrial, commercial and agricultural purposes. For each purpose, we require water of appropriate quality, which is suitable for that particular use. The desirable characteristics of water vary with its intended use. Thus, the quality of water that is good for one purpose may not be good for another. From the user's point of view, the term "water-quality" is used to define those biological, chemical, physical, and radiological characteristics by which he evaluates the acceptability of the water. In may parts of the world, the people first look at the water in a glass to see if it is crystal clear, then taste it to check if it is palatable. If the water is agreeable in these qualities they assume that it is good-quality water. Water for drinking and food-preparation must be aesthetically acceptable, that is, it should be free from apparent turbidity, colour and odor and from any objectionable taste. Further, it must not contain organisms capable of causing disease, nor should it contain minerals and organic substances which may produce adverse physiological effects[8]. Such water is termed as "potable water".

## TREATMENT OF WATER

Potable water is produced by treatment of raw water, involving various operations in water-treatment plants. In many part of the world the availability of potable water is limited, due to lack of appropriate treatment plants and financial constrains. The unit operations involved in the production of potable water include Aeration, Coagulation and Flocculation, Sedimentation, Chlorination and other Disinfections Process, and Filtration[9].

### Aeration

Aeration is a process, in which air is thoroughly mixed with water to remove or decrease the concentration of substances, which produce unpleasant taste and odor, such as hydrogen sulphide and some organic compounds. It also helps in reducing the concentration of carbon dioxide and oxidation of iron and manganese. However, many of the taste and odour-producing compounds from industrial wastes and those released by disintegration of organisms are not highly volatile and can not be removed by aeration alone.

### Coagulation and Flocculation

Surface waters contain dissolved inorganic and organic materials, suspended inorganic matter and biological substances, such as bacteria and plankton. Inorganic matter present in the form of finely divided particles, or as colloidal particles, is the main cause of turbidity, whereas organic compounds are generally the cause of unpleasant taste, odor and colour. Some colloidal metallic hydroxides may also produce colour. The size of the fine particles producing turbidity may range from molecular dimension to 50$\mu$m or larger. Particles greater than 1$\mu$m in diameter are generally referred as silt and settle down on standing under gravity. However particles smaller than 1$\mu$m, classified as colloid, remain suspended for a very long time, as their surface area to mass ratio is very large. The removal of colloidal material requires the use of procedures, which agglomerate the small particles into larger aggregates. Certain chemical agents called coagulants, such as salts of aluminium and iron, are used for this purpose. The addition of a chemical to a colloidal dispersion causes the destabilization of particles by reduction of forces that tend to keep the particles apart. The chemical should be rapidly mixed and uniformly dispersed in

water to increase the particle-to-particle interaction. The entire process occurs in a very short time and initially results in particles of submicroscopic in size. This process is called Coagulation. These particles then gradually agglomerate to form larger aggregates by chemical bridging or physical enmeshment mechanism. This process is termed as Flocculation.

The coagulation and flocculation processes are sensitive to many variables such as pH, coagulant concentration, presence of anions, etc. The mechanism for the removal of particles by metal coagulants and polymers involves neutralization of electrical charges, compaction of electrical double-layer, adsorption and bridging and mechanical enmeshment. These processes are involved in varying degrees in coagulation flocculation system.

**Sedimentation**

The solids in their natural form, such as silt or modified form by coagulation and chemical precipitation, settle down under the effect of gravity. Initially the particles with density greater than that of water begin to settle with accelerated velocity, until the resistance of the liquid equals the effective weight of the particle. Thereafter, settling-velocity remains constant and depends upon the size, shape and density of the particles as well as the density and viscosity of the water. The separation of coagulated or suspended matter from water under the influence of gravity is known as sedimentation.

**Disinfection**

Surface and ground-waters generally contain microorganisms, which cause diseases such as typhoid, cholera, dysentery, etc. Many epidemics have been attributed to waterborne diseases, especially in developing countries. In Pakistan, about 25% of all the reported diseases and 30% of all the deaths are attributed to the use of contaminated water. Therefore potable water should be free from disease- producing organisms, in addition to its physical and chemical qualities. The destruction of harmful and other objectionable organisms can be achieved by disinfection of water, which kills the disease-producing organisms. Disinfection-processes may include one or a combination of both physical and chemical treatment, such as filtration, reverse osmosis, boiling, irradiation with ultraviolet light, metal ion treatment, chlorination and treatment with surface- active chemicals. Except for chlorine and some of its compounds, most of these disinfectants have one or more serious limitations. Therefore chlorine and its compounds are used for municipal potable water treatment. The quality of disinfected water is checked by counting the number of coliform bacteria E.Coli employing multiple tube fermentation or membrane filter technique. According to WHO and EPA good quality water should not have more than one bacterium per 100 ml. Water containing more than 10 bacteria considered as contaminated.

**Taste and Odour**

Many organic and inorganic substances, though present in small quantities impart objectionable taste and odour to water. Generally inorganic compounds such as metal ions in concentration of few ppm impart taste to water whereas organic materials and hydrogen sulphide are mainly responsible for imparting odour to water. Most of the odorous substances present in water are removed by aeration, coagulation and flocculation, sedimentation, filtration and chlorination. The remaining substances are removed by treatment with activated carbon, which is considered to be the best treatment procedure for odour and taste control.

**Filtration**

Water purification involves the removal of suspended silt, clay, colloids and microorganisms including algae, bacteria, and viruses. Most of the suspended particles and other impurities are removed by coagulation, flocculation, and sedimentation processes. The remaining particles are removed by passing the water through a filtering unit. The filtering unit may consist of a thin porous layer of filter aid deposited by flow on a support or a bed of granular non-porous material held in place by the force of gravity. The filters are generally classified into four categories depending upon the type of filter media used and quantitative rate of filtration. These include slow-sand filter, rapid sand filter, high rate rapid-sand filter and diatomite filter. Rapid sand filter consisting of a bed of sand about 30 inches thick on top of a bed of gravel are commonly used for filtration of water.

## QUALITY ASSURANCE

The production of potable water involves a number of processes to remove physical, chemical and biological impurities. The

effectiveness of these treatment- processes is checked by analyzing the final product to assess the various parameters of water quality. The treated water should conform to the National Quality Standards (NQS) established by The Government for water-quality. In countries where NQS are not established, WHO water quality Standards[10] may be used, which are given in table - V. Periodic assessment of water is necessary to ensure the quality of water supplied to the public. This requires collection of representative samples from selected locations and measurement of various physical, chemical and biological parameters. The sampling should be done carefully, to avoid contamination and the concentrations of the substances should not change during storage as a result of chemical, physical and biological processes in the samples. Various parameters of these samples can be measured employing suitable analytical techniques available in Handbooks[11,12]. In order to get reliable data, it is necessary to determine the accuracy and precision of each technique by analyzing a Standard Reference Material. Water, which conforms to the National Quality Standards, is considered safe and palatable for human consumption and can be used in any desirable amount without any adverse effects on health.

## CONCLUSION

- The requirement of water is increasing, with ever-increasing population; as such per-capita availability is decreasing.
- Underground water-resources are depleting due to drought conditions and heavy municipal pumping and private abstraction of water.
- Proper attention is not being given to water-quality and the data regarding water-quality is not readily available.
- Microbial contamination in water is common in many areas, due to cross-
- contamination between water and sewerage lines, poor maintenance, unreliable
- and irregular chlorination, which result in frequent outbreak of waterborne diseases.
- The release of untreated municipal and industrial effluents into water-bodies is adversely affecting the quality of water.

## RECOMMENDATIONS

- To meet our future water-requirements, it is necessary to formulate and implement a National Policy for water-resources management.
- NEQS for the release of municipal and industrial effluents should be enforced, to prevent the pollution of water-bodies.
- Sewage-treatment plants should be installed in all major cities.
- National guidelines or standards for drinking-water quality be formulated.
- A program of regular monitoring of water-quality be formulated and implemented.
- Environmental Data-bank be established in EPA. Data regarding water-quality from various sources may be collected, evaluated and stored for future reference.
- A program for training of personnel in analytical methodologies be prepared by EPA. It should include sampling procedures, measurement techniques, quality control and quality assurance of data, data analysis and its co-relation.

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**Table-1**

(a) POPULATION OF THE WORLD (BILLION)

| Year | 1650 | 1750 | 1850 | 1900 | 1950 | 1980 | 1994 | 2000 |
|---|---|---|---|---|---|---|---|---|
| Population | 0.55 | 0.752 | 1.175 | 1.6 | 2.564 | 4.478 | 5.642 | 6.1 |

(b) POPULATION OF PAKISTAN (MILLION)

| Year | 1951 | 1961 | 1972 | 1982 | 1993 | 1998 |
|---|---|---|---|---|---|---|
| Population | 33.74 | 42.88 | 65.31 | 87.75 | 122.8 | 136.2 |

**Table-2: Average Annual Water-Availability In Pakistan**

| Source | Volume of Water ($bm^3$) | | |
|---|---|---|---|
| | Summer | Winter | Total |
| Water in Indus river system at rim stations | 140 | 33 | 173 |
| Direct precipitation | 40 | 9 | 49 |
| Total Available | 180 | 42 | 222 |
| 10% evaporation loss from surface water | 18 | 4 | 22 |
| Seepage losses from irrigation system | 36 | 8 | 44 |
| Water released downstream of Kotri | 6 | 6 | 12 |
| Water available to users | 120 | 24 | 144 |
| Groundwater supply | 13 | 40 | 53 |
| Total at required points | 133 | 64 | 197 |

*Note: High: 230 $bm^3$ in 1959 - 60 , Low: 124 $bm^3$ in 1974 - 75*

**Table-3: Water And Sewage Quantities In Major Urban Centres**

| No | Cities | Population 1998 (Million) | Water Supply (mgd) | Sewage (mgd) |
|---|---|---|---|---|
| 1 | Islamabad | 0.525 | 42 | 33 |
| 2 | Karachi | 9.27 | 556 | 445 |
| 3 | Lahore | 5.064 | 405 | 324 |
| 4 | Faisalabad | 1.978 | 99 | 80 |
| 5 | Multan | 1.183 | 60 | 48 |
| 6 | Hyderabad | 1.152 | 58 | 47 |
| 7 | Gujranwala | 1.125 | 57 | 46 |
| 8 | Peshawar | 0.988 | 60 | 48 |
| 9 | Quetta | 0.561 | 23 | 18 |
| 10 | Sargodha | 0.456 | 19 | 15 |

**Table-4: Pollution Levels (Mg/L) of Effluents From Various Industries in Korangi Site Area Karachi.**

| Industries ▸ / Parameters ▾ | Pharmaceutical | Tannery | Silk Mill | Paper Mill | Beverages | NEQS |
|---|---|---|---|---|---|---|
| pH | 5.2 | 9.0 | 11.8 | 3.9 | 13.0 | 37,417.0 |
| TSS | 848.0 | 450.0 | 466.0 | 2,648.0 | 68.0 | 150.0 |
| TDS | 530.0 | 6,818.0 | 5,280.0 | 12,146.0 | 18,244.0 | 3,500.0 |
| BOD | 1,364.0 | 7,620.0 | 6,010.0 | 54,696.0 | 18,724.0 | 80.0 |
| COD | 3,000.0 | 12,000.0 | 4,000.0 | 34,000.0 | 2,000.0 | 150.0 |
| Grease & Oil | 158.0 | 909.0 | 618.0 | 10,644.0 | 163.0 | 10.0 |
| Cd | 6.0 | 889.0 | 14.0 | 917.0 | 20.0 | 0.1 |
| Cr | 1,052.0 | 1,600.0 | 100.0 | 400.0 | 400.0 | 1.0 |
| Cu | 129.0 | 240.0 | 200.0 | 3,942.0 | 107.0 | 1.0 |
| Pb | 75.0 | 1,000.0 | 117.0 | 1,083.0 | 780.0 | 0.5 |
| Ni | 100.0 | 800.0 | 300.0 | 2,000.0 | 364.0 | 1.0 |
| Zn | 812.0 | 1,333.0 | 724.0 | 1,217.0 | 4,386.0 | 5.0 |

| Table-5. Quality-Criteria For Domestic Water-Supplies | | |
|---|---|---|
| **Parameter** | **Level** | |
| | **Permissible** | **Desirable** |
| Color (Cobalt-Platinum scale) | 75 units | < 10 Units |
| Odor | Virtually absent | Virtually absent |
| Taste | Virtually absent | Virtually absent |
| Turbidity | Virtually absent | Virtually absent |
| | Inorganic Chemicals | |
| pH | 6.0-8.5 | 6.0-8.5 |
| Alkalinity ($CaCO_3$) | 30-500 mg/liter | 30-500 mg/liter |
| Ammonia | 0.5 mg/liter | <0.01 mg/liter |
| Arsenic | 0.05 mg/liter | Absent |
| Barium | 1.0 mg/liter | Absent |
| Boron | 1.0 mg/liter | Absent |
| Cadmium | 0.01 mg/liter | Absent |
| Chlorides | 250 mg/liter | < 25 mg/liter |
| Hexavalent Chromium | 0.05 mg/liter | Absent |
| Copper | 1.0 mg/liter | Virtually absent |
| Cyanide | 0.01 mg/liter | Absent |
| Dissolved Oxygen | >4.0 mg/liter | Air Saturated |
| Fluorides | 0.8-1.7 mg/liter | 1.0 mg/liter |
| Iron(filterable) | < 0.3 mg/liter | Virtually absent |
| Lead | < 0.05 mg/liter | Absent |
| Manganese | < 0.05 mg/liter | Absent |
| Nitrates + Nitrites | < 10 mg/liter | Virtually absent |
| Phosphorus | 10-50μg/liter | 10μg/liter |
| Selenium | 0.01 mg/liter | Absent |
| Silver | 0.05 mg/liter | Absent |
| Sulfate | 250 mg/liter | < 50 mg/liter |
| Sulfides | 0.01 mg/liter | Absent |
| Total Dissolved Solids(TDS) | 500 mg/liter | < 200 mg/liter |
| Zinc | 1.5 mg/liter | Virtually absent |
| | Organic Chemicals | |
| Carbon - Chloroform extract | | < 0.04 mg/liter |
| Methylene blue active substances | 0.017 mg/liter | Virtually absent |
| Chlordane | 0.003 mg/liter | Virtually absent |
| DDT | 0.042 mg/liter | Virtually absent |
| Dieldrin | 0.017 mg/liter | Virtually absent |
| Endrin | 0.001 mg/liter | Virtually absent |
| Heptachlor | 0.018 mg/liter | Virtually absent |
| Heptachlor epoxide | 0.018 mg/liter | Virtually absent |
| Lindane | 0.056 mg/liter | Virtually absent |
| Methoxychlor | 0.035 mg/liter | Virtually absent |
| Organic phosphate | 0.1 mg/liter | Virtually absent |
| Taxophane | 0.005 mg/liter | Virtually absent |