Government of Pakistan

Pakistan Environmental Protection Agency

(Ministry of Environment)

National Standards for Drinking Water Quality (NSDWG)

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In Collaboration with:

- **Ministry of Health**
- **World Health Organization**
- **UNICEF**

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SUMMARY

Improving the quality of water for purposes of drinking, domestic consumption, personal hygiene and certain medical situations has always been among the top priority goals of the Government of Pakistan. The *Guidelines and Criteria for Quality Drinking-Water* published by World Health Organisation (WHO) (1996, 2004) have made it possible to review, evaluate and further improve the quality of water in Pakistan against these standards. Two workshops were organized to finalize drinking water quality standards on November 6-8 and 13-15, 2006 at Islamabad under the auspices of Health Services Academy, Ministry of Health, Government of Pakistan in collaboration with WHO. Representatives from all major agencies, provinces and stakeholders, including Pakistan Standards Quality Control Authority (PSQCA), from throughout Pakistan were invited to participate in these workshops. A team of five members was assigned the responsibility to compile the report based on the recommendations generated during these workshops. This report includes finalized standards for quality drinking water in Pakistan stated in accordance with WHO criteria and guidelines. Current situational analyses are also presented along with recommendations for legislation and implementation of action to continue improving the quality of water in Pakistan.

This report is compiled based on the information provided by the subgroups of participants that were formed for more focused discussion and intense work on the topic that was assigned to them. I express my sincere thanks to each team leader and every member of each team for the dedication and commitment with which they worked hard during the entire workshop. My special thanks are to all the guest speakers for the contribution of their expertise and time. Dr. Ejaz Ahmad Khan, National Program Manager (EH), deserve special thanks for the hard work before, during and after the workshops and imparting his best expertise to achieve this great mile stone.

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INTRODUCTION

In Pakistan, there are several potential sources to contaminate drinking water. Bacteriological contamination of drinking water has been reported to be one of the most serious problems throughout the country in rural as well as urban areas (Abid & Jamil, 2005; Kahlown, Tahir, & Sheikh, 2004; Jehangir, 2002; Sun-OK, Shin-Ho, Nasir, & Noor-us-Saba, 2001). Such contamination is attributed to leakage of pipes, pollution from sewerage pipes due to problem within the distribution system, intermittent water supply, and shallow water tables due to human activities. A second strong source for ground water contamination in irrigated and industrial areas is chemical pollution from toxic substances from the industrial effluents, textile dyes, pesticides, nitrogenous fertilizers, arsenic and other chemicals (Tahir,1989; Tahir & Bhatti,1994; Din, Hussain, Naila, Shabbir, Rana, Anwar, Saeed, & Zumra, 1997; Tahir, Chandio, Abdullah, & Rashid,1998; Sajjad & Rahim,1998; Hussain & Mateen, 1998; Sial & Mehmood,1999; Latif, Akram, & Altaf,1999; Chandio,1999; and Tahir, 2000). In addition, excessive monsoon rains, floods, herbicides, fungicides, untreated municipal waste, sewage breakdowns, and coastal water pollution due to waste discharges and oil spills are extremely hazardous for drinking water. For the sake of public health, it is absolutely essential to establish drinking water quality standards and criteria that are chemically balanced and medically safe.

General public, in Pakistan, use subjective quality criteria like brackish, foul smelling, bad tasting, turbid or coloured water to determine that it is not suitable for drinking. The agencies responsible for monitoring of water quality perform periodic checks of the basic water parameters against certain recommended standards. In order to ensure that consumers throughout the country are receiving quality water, research-based standards and guidelines for quality drinking water must be available to monitoring agencies. In 1999, Hashmi & Shahab advocated for the strong need to establish standards and guidelines for quality drinking water. In 2002, the Pakistan Standards Institute compiled the preliminary standards for quality drinking water. In 2004, Pakistan Council of Research in Water Resources prepared a report related to water quality in Pakistan with recommendations for establishing standards. Johri (2005) from WHO office proposed a framework of action for improving the quality of drinking water in Pakistan. In March 2005, Health Services Academy, the Ministry of Health, Government of Pakistan in collaboration with World Health Organisation (WHO) sponsored, organised and conducted a 4-day workshop in Islamabad. The purpose of this workshop was to review current standards implemented in Pakistan for quality control of drinking water and update these standards in accordance with the quality standards of WHO.

The workshop was designed to seek input of experts from all important federal, provincial and private agencies. In addition to WHO and Pakistan Ministry of Health staff, 33 representatives from the following programs participated in the workshop: United Nations Development Program, UNICEF, Pakistan Environmental Protection Agency, PSQCA, Pakistan Council for Research in Water Resources, PINSTECH/Pakistan Atomic Energy Commission, Pakistan Council of Scientific and Industrial Research, Institute of Environmental Science and Engineering, Pakistan Standard Quality Control Authority Development Centre, Environmental Protection Agency-Sindh, Liaquat University of Medical and Health Sciences, Social Security Hospital, Lahore Engineering University, and Pakistan Medical and Dental Council.

Through a combination of lectures, discussions, intense work Sessions, and utilization of reading literature provided by WHO and Ministry of Health, quality standards for drinking water in Pakistan were finalized. During all sessions, a careful attention was given to the following considerations: (1) All modifications in standards remain in correspondence with the social, cultural, geological, economic, technical and other significant conditions specific to the regional areas. (2) A review of existing national research-based data related to drinking water quality should be conducted. (3) The work done by individual experts and by specialists from different agencies throughout the country should be coordinated and utilized in the finalization of standards. (4) In addition to WHO guidelines and standards, USEPA standards, Malaysian standards, and Indian water quality standards were to be utilized for further benefits. (5) The standards must have a long range positive impact on human health in Pakistan. (6) Recommendations should be made based on the finalized standards for future plans of action.

These standards include review of the available literature and proposed guidelines and standards for Pakistan and is prepared by a team of four members form Ministry of Health and National University of Science and Technology. The team members are working on different aspects of water quality and provision of safe water to the population of Pakistan. The Ministry of Health is playing its due role in the overall effort of the Government of Pakistan in provision of safe drinking water to the entire population of the country as a safeguard against water borne diseases. The valuable partnership of WHO is deeply appreciated.

Standards for Quality Drinking Water in Pakistan

PROPERTIES /PARAMETERS	STANDARD VALUES FOR PAKISTAN	WHO STANDARDS	REMARKS
Bacterial			
All water intended for drinking (e.Coli or Thermotolerant Coliform bacteria)	Must not be detectable in any 100 ml sample	Must not be detectable in any 100 ml sample	Most Asian countries also follow WHO standards
Treated water entering the distribution system (E.Coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample	Must not be detectable in any 100 ml sample	Most Asian countries also follow WHO standards
Treated water in the distribution system (E.coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample In case of large supplies, where sufficient samples are examined, must not be present in 95% of the samples taken throughout any 12-month period.	Must not be detectable in any 100 ml sample In case of large supplies, where sufficient samples are examined, must not be present in 95% of the samples taken throughout any 12-month period.	Most Asian countries also follow WHO standards
Physical			
Colour	≤15 TCU	≤15 TCU	
Taste	Non objectionable/Acceptable	Non objectionable/Acceptable	

PROPERTIES /PARAMETERS	STANDARD VALUES FOR PAKISTAN	WHO STANDARDS	REMARKS
Odour	Non objectionable/Acceptable	Non objectionable/Acceptable	
Turbidity	‹ 5 NTU	‹ 5 NTU	
Total hardness as $CaCO_3$	< 500 mg/l	---	
TDS	‹ 1000	‹ 1000	
pH	6.5 – 8.5	6.5 – 8.5	
Chemical			
Essential Inorganic	***mg/Litre***	***mg/Litre***	
Aluminium (Al) mg/1	≤0.2	0.2	
Antimony (Sb)	≤0.005 (P)	0.02	
Arsenic (As)	≤ 0.05 (P)	0.01	Standard for Pakistan similar to most Asian developing countries
Barium (Ba)	0.7	0.7	
Boron (B)	0.3	0.3	
Cadmium (Cd)	0.01	0.003	Standard for Pakistan similar to most Asian developing countries
Chloride (Cl)	<250	250	
Chromium (Cr)	≤0.05	0.05	
Copper (Cu)	2	2	
Toxic Inorganic	***mg/Litre***	***mg/Litre***	
Cyanide (CN)	≤0.05	0.07	Standard for Pakistan similar to Asian developing countries

PROPERTIES /PARAMETERS	STANDARD VALUES FOR PAKISTAN	WHO STANDARDS	REMARKS
Fluoride (F)*	≤1.5	1.5	
Lead (Pb)	≤0.05	0.01	Standard for Pakistan similar to most Asian developing countries
Manganese (Mn)	≤ 0.5	0.5	
Mercury (Hg)	≤0.001	0.001	
Nickel (Ni)	≤0.02	0.02	
Nitrate (NO_3)*	≤50	50	
Nitrite (NO_2)*	≤3 (P)	3	
Selenium (Se)	0.01(P)	0.01	
Residual chlorine	0.2-0.5 at consumer end 0.5-1.5 at source	--	
Zinc (Zn)	5.0	3	Standard for Pakistan similar to most Asian developing countries
* indicates priority health related inorganic constituents which need regular monitoring.			
Organic			
Pesticides mg/L		PSQCA No. 4639-2004, Page No. 4 Table No. 3 Serial No. 20- 58 may be consulted.***	Annex II
Phenolic compounds (as Phenols) mg/L		≤ 0.002	
Polynuclear aromatic hydrocarbons (as PAH) g/L		0.01 (By GC/MS method)	

PROPERTIES /PARAMETERS	**STANDARD VALUES FOR PAKISTAN**	**WHO STANDARDS**	**REMARKS**
Radioactive			
Alpha Emitters bq/L or pCi	0.1	0.1	
Beta emitters	1	1	

*** PSQCA: Pakistan Standards Quality Control Authority.

PHYSICAL PARAMETERS

COLOUR OF WATER

WHO STANDARD: Colour is detectable in a glass of water above 15 True Colour Units (TCU). Levels of colour below 15 TCU are acceptable to consumers. *No health-based guideline value is proposed for colour in drinking water*.

PAKISTAN STANDARD: (1) Colour parameter ≤ 15 TCU/Hazen Units.

Colour of water is one of the most important and conveniently observed indicators of its quality. The highest quality drinking water should be colourless. Potential inorganic, organic and bacteriological contributors of colour to natural water are: (1) inorganic constituents such as dissolved iron; (2) dissolved organic substances like humic or fulvic acids, organics from anthropogenic sources such as dyes; and (3) suspended particulate matter such as plant debris, phytoplankton and zooplankton. Some of these contributors may be harmless but others are definitely harmful.

Suspended organic matter may itself be harmless but may harbour bacteria and viral contaminants. Trihalomethanes (THM's) that are generated in the post filtration disinfection stage of water treatment are considered carcinogenic. Organic materials pass through coagulation and filtration and are exposed to chlorine acting as a disinfectant. Humic materials which give a tea like appearance to water are an ideal example of compounds which may serve as THM precursors. Presence of colour in water may, therefore, indicate the presence of organics and if organics are there and the water has been subjected to chlorination, the chances of the existence of THM's are considerable.

Traditionally, the colours of liquids, including drinking water are classified according to the Alpha/Hazen/Pt-Co colour scale. One alpha, hazen or Pt-Co colour unit is produced by a solution having a concentration of 1mg/L of Platinum.

To determine that a sample of water has no colour, a visible light (400 – 850 nm) is passed through it. If there is little or no attenuation, it implies an absence of light absorption, reflection, or refraction (the three main mechanisms that give colour to an object).

By comparison with colour of solutions having different concentration of platinum and hence colours, one can determine the colour units of drinking water. It is practically observed that below 15 Hazen, colour of water in a clear glass container may not be detectable. Most drinking water standards, the world over therefore require that the colour parameter may not exceed 15 Hazen.

THE MICROBIAL STANDARDS FOR DRINKING WATER

Total coliform bacteria are a collection of relatively harmless micro organisms that live in large numbers in the digestive systems and intestines of human beings and warm- and cold-blooded animals. These micro organisms aid in the digestion of food and can be found in humans and animals wastes. Soil and decaying vegetable can also be a source of the coliform bacteria. Some coliform bacteria known as faecal coliforms are only present in faecal material. The most common member of this group being Escherichia coli (abbreviated as *E. coli*) in the Family *Enterobacteriaceae* named *Escherichia* (Genus) *coli* (Species). These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the faecal material of warm-blooded animals. Approximately 0.1% of the total bacteria within an adult's intestines are represented by *E. coli*. Although, in a newborn infant's intestines *E. coli*, along with lactobacilli and enterococci represent the most abundant bacterial flora.

There are other disease causing bacteria, or viruses present in human waste. If such a waste finds its way to a water source it would contaminate it and such waters would definitely become a vector for that particular disease. Some of the most common, microbes linked to drinking water contaminated by human waste and associated diseases are:

- ***Compylobacter*** species are believed to cause 5-14% of cases of diarrhoea worldwide. The most commonly isolated species of Campylobacter is *C. jejuni*, an organism that causes gastroenteritis. In developing countries the illness occurs primarily in the children under 2 years of age. There is a high association between use of un-chlorinated water and campylobacter infection. In a safe drinking water, there should be no such organisms.
- ***Vibrio cholerae***, is the causative organism of cholera. However, *Vibrio cholerae 01* spreads through food/water borne route and through the street vendors. The disease causes massive diarrhoea, dehydration and electrolyte imbalance.

- ***Shigella sonnei*** and other related *Shigella* strains are often responsible for the diarrhoeal diseases (shigellosis) that occur under adverse conditions. Once infected with *Shigella*, the patient develops diarrhoea, fever, and stomach cramps starting a day or two after the exposure to the bacterium. The diarrhoea is often bloody. Untreated surface or even well water may result in shigellosis in the areas where unhygienic conditions prevail.

- ***Escherichia coli*** can cause a variety of syndromes and is notoriously responsible for diarrhoeal episodes, most common being the "*Traveller's diarrhoea*". Water and food are the common vehicles of the transmission of the *E coli*.

- ***Giardiasis***, a diarrhoeal illness, is caused by ***Giardia lamblia***. *Giardia* is a microscopic parasite that inhabits in the intestine of humans and animals. The parasite is passed in the stool of an infected person or animal.

- ***Hepatitis A*** and ***E*** are the waterborne viral illnesses that are the most common ones to occur as an outbreak in a defined population. The water borne hepatitis epidemics are common.

Coliforms are also present in the soil and plant material. If a water supply is found to contain coliform bacteria it may be contaminated by sewage or manure, and there is a risk of exposure to water-borne disease. In particular, the presence of faecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the faecal material of human beings animals. Water supplies must be tested for faecal coliform bacteria.

According to WHO guidelines, the *E coli* and *faecal coliform* bacteria **must not be** detectable in any 100 ml sample of all water intended for drinking.

TASTE AND ODOUR

WHO STANDARD: Non-objectionable/Acceptable

PAKISTAN STANDARD: Non-objectionable/Acceptable

Tastes and odours in water supplies can generally be attributed to two different causative elements: the actions of human beings upon the aquatic environment and natural forces within the environment occasionally affecting each other.

Actinomycetes (bacteria) and algae are two important groups of organisms that produce taste and odour related toxins in drinking water. Actinomycetes are mould like bacteria that produce strong smelling chemicals with earthy and mouldy odours. Actinomycetes and other bacteria can grow as biofilms on the inner surfaces of pipes in the distribution system and cause odours in the household water. Many organisms impart taste and odour to the aquatic environment due to their defence mechanism by releasing repellents and other organic compounds to even kill their predators. These compounds are naturally very obnoxious.

In heavily polluted waters, say near the effluent outlets, or where there are high nutrient levels from domestic, agricultural or industrial fertilizers, excessive plant and algal growth can degrade the water quality and are a very visible cause of the taste and odour problem. During the death of this material, bacterial action can produce a variety of unpleasant odours (putrid, sulphurous, sharp, rancid, methane, etc.). These can be particularly intense where the decay occurs under the oxygen depleted anaerobic conditions. Diatoms which are very common in surface waters, and high numbers of these algae can also result in strong source-water odour. Diatoms store polyunsaturated fatty acids (PUFAs) in their cells, and a process similar to the one that is the cause of the development of rancid odours in foods containing saturated fatty acids such as fish and vegetable oil etc. works here whereby the fatty acids in diatoms are broken down by cell enzymes into odorous compounds.

As far as the human cause of taste and odours in drinking water is concerned, probably the most common cause of consumer complaints is chlorination in the water treatment plant. When low dosages of chlorine are added to water that contains phenols, chlorophenol compounds are formed and impart an objectionable medicinal taste to the water. In general, however, the medicinal odours frequently encountered in treated waters, originally contaminated by industrial wastes, may be due to a variety of other chlorinated organic compounds.

. Because of the various combinations of inorganic and organic compounds that cause tastes and odours in water supplies, no simple treatment is cost effective for all taste and odours but generally some form of oxidation is usually effective and potassium permanganate and chlorine dioxide are commonly used.

Levels of taste- or odour-causing contaminants are quantified in a gross manner through threshold odour or taste tests. The water to be examined is diluted with taste- and odour-free water in a series of dilutions and presented in order of highest to lowest dilution to a panel of selected persons. The sample average at which odours or tastes are just detected determines the threshold number according to the following formula:

$$Threshold\ Number = \frac{A + B}{A}$$

Here 'A' is the volume of the sample tested and 'B' is the volume of pure water (which is totally free from any taste and odour) used for dilution. Thus, if a 100-mL sample is diluted with 100 mL of odour free water and odour is just detectable in the resultant sample, the Threshold Odour Number (TON) is 2.

Ideally the drinking water should have a TON value of 1 (no dilution required and B has a value of zero!) In practice however, a specific TON may have to be fixed with a certain statistical spread. In a country like Pakistan, it may be difficult to go through this exercise and the subjective parameter of consumer satisfaction may have to be relied upon. Thus if the drinking water is generally acceptable to the community being served, with other parameters meeting the standards, it should be considered to be acceptable.

TURBIDITY

WHO STANDARD: Ideally median turbidity should be below 5 Nephlometric Turbidity Units (NTU).

PAKISTAN STANDARD: Below 5 NTU.

Turbidity (muddy aspect) in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and other microscopic organisms. The particles that cause turbidity in water range in size from colloidal dimensions (approximately 10 nm) to diameters of the order of 0.1 mm.

Originally, turbidity was measured in terms of a Jackson turbidity unit (JTU). In this case the height of the turbid water column, sufficient to make invisible a standard candle flame, when observed vertically, gave a measure of the turbidity of the water sample; obviously, the longer the column the lower the turbidity and vice versa. A column of 21.5 cm was assigned a value of 100 JTU. The Jackson candle turbidimeter turbidity measuring equipment) is applicable only to turbidity values greater than 25 JTU and, as such, has limited applicability to the monitoring of drinking water.

The current method of choice for turbidity measurement, the world over, is the nephelometric method. In this method the intensity of light scattered at 90° to the path of the incident light is measured. Suspensions of formazin polymer have generally been adopted as the primary turbidity reference standard. Commercially prepared suspensions of polymeric beads are also available for this purpose. A suspension of formazin formed by the reaction of hydrazine sulphate (50 mg/L) with hexamethylenetetramine (500 mg/L) has a defined turbidity of 40 NTU.

Standard nephelometers are able to respond to changes of about 0.02 NTU at turbidity values below 1 NTU and the practical lower limit of the standard nephelometric method, therefore, is about 0.1 NTU.

Levels of turbidity in raw water can range from less than 1 to over 1000 NTU and control of turbidity in public drinking water supplies is important for both health and aesthetic reasons. Excessive turbidity makes the treated water not pleasing to look at. It can also interfere with disinfection processes and the maintenance of chlorine residual. In fact chlorination of water containing turbidity, due to organic matter, can produce carcinogenic trihalomethanes.

The removal of turbidity is achieved by filtration and, by a combination of coagulation, sedimentation and filtration. Filtration is carried out through sand beds or other single-, dual- or mixed-media granular filters. This treatment process is capable of producing water with a turbidity of 1 NTU or less. Following filtration, turbidity in a water treatment plant may be affected by a number of mechanisms, such as post-flocculation of coagulants, oxidation of dissolved metals, bacterial and other growths, resuspension of deposited materials or pipe corrosion etc. Because of the ease of analysis and relative inexpensiveness of the equipment, it is a very useful tool to assess the drinking water quality, in general and of monitoring the treatment processes and the public water delivery systems, in particular.

The relationship between high turbidity, in both raw and filtered water, and taste and odour is well known. As shall be seen later, algal growths, actinomycetes and their breakdown products contribute to taste and odour problems. A positive correlation between serious epidemics of infectious diseases and increased turbidity has been recorded.

Particulate materials in water are usually not in themselves potential hazards, but they may have indirect effects. The concentrations of heavy metal ions and biocides are usually much higher in suspended solids than in water. The adsorption capacity of suspended particulates can lead to the entrapment of undesirable compounds and pesticides like DDT, and Herbicides such as 2; 4-D, paraquat and diquat have shown twenty fold increase in solubility in waters with raised turbidity values. When such contaminated particles enter the stomach, through drinking water, the release of the pollutants could occur, with possible deleterious effects.

Similarly, the presence of turbidity can have significant effects on both the microbiological quality of drinking water and the detection of bacteria and viruses in the water. Microbial growth in water is most extensive on the surfaces of naturally occurring particles and inside flocs formed during coagulation.

For many countries the value of 5 NTU has been set as the allowable limit for drinking water at the point of consumption. In Pakistan, health issues related to infected water are of critical importance and the turbidity being an easily measurable parameter, even down to 0.1 NTU, should be used as a strong indicator for screening of the potable water. In fact this committee feels that, in absence of any other information, the turbidity value in combination with a negative faecal coliform result could serve as the deciding factor for declaring a water fit for drinking or not. In view of this it is proposed, that a value of 1 NTU may be adopted as the drinking water standard for Pakistan.

pH OF DRINKING WATER

*WHO STANDARDS**:** Most raw waters lie in the pH range of 6.5 to 8.5.*

*PAKISTAN STANDARD**:** pH range from 6.5 to 8.5.*

No health based guideline value is proposed for pH, but it is one of the most important operational water quality parameters. The pH of a solution is the negative logarithm of the molar hydrogen ion concentration which indicates its acidic character. pH= - log [H+]. It is a measure of acid-base equilibrium in natural water. An increased concentration of carbon dioxide will lower the pH and vice-versa.

Careful attention to pH control is necessary at all stages of water treatment and distribution system to ensure satisfactory water clarification and disinfection and also to minimize the corrosion of water mains and pipes in household water systems. If this is not done, contamination of the drinking water may result manifesting itself in the form of taste, odour and appearance changes. At pH less than 7, for example, corrosion of water pipes may be accelerated releasing metals into the water; this may be a cause of concern if the concentration of such metals exceeds the permissible limits.

The direct effects of exposure of humans and animals to extreme pH values (below 4 or above 10) for extended periods of time may result in irritation to the eye, skin and mucous membranes. In sensitive individuals gastrointestinal irritation may also occur, however, occasional pH changes may not have any direct impact on water consumers.

CHEMICAL PARAMETERS

Aluminium (Al)

Aluminium is the most abundant metallic element and constitutes about 8% of the Earth's crust. Aluminium is iatrogenically introduced in drinking water through the treatment process. The high concentration have been linked to the development of Alzheimer Disease (WHO , EHC document, 1997). However the population attributable risk could not be calculated, but it is imperative to be on the safe side. Following good standard operating procedures, concentrations of aluminium of 0.1mg/l or less are achievable in large water treatment facilities. Problem may arise among the small facilities (serving less than 10,000 people), in attaining the desired level due to the small size of the p[ant that could provide little buffering for fluctuation in operation. Other limitations rest in the availability of resources and capacity to tackle with the specific operational problems. For such small facilities, 0.2 mg/l (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*) or less is a practicable level for aluminium for the deliverable water. Same is applicable for adaptation for Pakistan i.e. less than 0.2 mg/l.

Antimony (Sb)

The daily oral uptake of antimony appears to be significantly higher than exposure by other routes. The common source of antimony in drinking water appears to be dissolution from metal plumbing and fittings. It appears that antimony leached from antimony containing materials would be in the form of the antimony (V) oxo-anion, which is less toxic form. Antimony trioxide is genotoxic due to its low bioavailability. Potassium antimony tartrate is most soluble form of antimony. The chronic exposure to it may not be associated with an additional carcinogenic risk (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*). For Pakistan , in order to cautiously contribute towards reducing the burden of chronic diseases, a provisional value of less than or equal to 0.005 mg/l is set as standard.

Arsenic (As)

Arsenic is a metal-like substance found in small amounts in nature. Drinking water containing high levels of arsenic may cause health problems. There are two main ways arsenic can get into the drinking water. Mineral deposits in some areas naturally contain high levels of arsenic. Groundwater flowing through these deposits can dissolve arsenic from the minerals. This can increase the amount of arsenic in to the well water. Arsenic has no smell or taste, so it is not possible to tell that the drinking water contains arsenic or not unless it is tested in the lab. Adverse health effects of arsenic depend on the type and amount of arsenic that has entered the body, the length of exposure time and the response of the exposed body. Unborn babies, young children, people with long-term illnesses and elderly people are at greatest risk due to arsenic exposure.

Studies in other countries have shown that drinking water containing elevated levels of arsenic can cause the thickening and discoloration of the skin. Sometimes these changes can lead to skin cancer, which may be curable if discovered early. Numbness in the hands and feet and digestive problems such as stomach pain, nausea, vomiting, and diarrhoea can also occur due to the elevated levels of arsenic. Some recent investigations in the Punjab and Sindh provinces show elevated concentrations of arsenic in drinking water. Keeping this in view the value for the standard for Pakistan has been set at less than or equal to 0.05 mg/l. This also conforms with most of the developing countries in Asia.

Barium (Ba)

Barium is normally found as a trace element both in igneous and sedimentary rocks. It is also used in various industrial applications. Food is considered to be the primary source of intake for the non-occupationally exposed population. There is no evidence that barium is carcinogenic or mutagenic but the toxicological end-point of greatest concern to humans appears to be its potential to cause hypertension (*WHO, Guidelines for Drinking Water Quality, third edition,* *2004*). Its value has been proposed to be 0.7 mg/l for Pakistan in confirmation with WHO guidelines.

Boron (B)

Boron in surface water is frequently a consequence of the discharge of treated sewage effluent. It is also naturally found in the edible plants and general population obtains it through the food intake. Conventional treatment processes do not take Boron out and the special procedures should be adopted to remove Boron from the drinking water. The methods such as ion exchange and reverse osmosis may enable the substantial reduction. These processes are expensive too. Blending with low-boron supplies may be the only economical method to reduce boron concentration in waters where these concentrations are very high (*WHO, Guidelines for Drinking Water Quality, third edition, 2004)*. The value for Boron for Pakistan is 0.3mg/l in confirmation with WHO guidelines.

Cadmium (Cd)

Now-a-days Cadmium compounds are widely used in the batteries. There is a vast use of Cadmium in the steel and plastic industry. It is released to the environment through the wastewater and diffuse pollution is caused by contamination from fertilizers. The drinking water may get contaminated by impurities in the zinc of galvanized pipes and solders and some metal fittings. Food is daily source of exposure to Cadmium. Smoking is a significant additional source of cadmium exposure (*WHO, Guidelines for Drinking Water Quality, third edition, 2004)*. Cadmium accumulates primarily in the kidneys and has a long biological half-life of 10-35 years, in humans. For Pakistan a value of 0.01 would be appropriate, which is in accordance with the standards for most developing nations in Asia.

Chloride (Cl)

Chloride in drinking water comes from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source for humans comes from the edible salt. The high dose of chloride may result in detectable taste at 250mg/l but no health-based guideline value is proposed (*WHO, Guidelines for Drinking Water Quality, third edition, 2004).* However, less that 250 mg/l would suffice as a Pakistani standard for Chloride.

Chromium (Cr)

The toxicological database fro chromium carries uncertainties. Total chromium concentrations in drinking water are usually less than 2µg/litre, although the concentration as high as 120µg/litre has been reported. In some epidemiological studies, an association has been found between exposure to chromium (VI) by the inhalation route and lung cancer. The cautious guideline for chromium has been proposed that is 0.05 mg/l in drinking water (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*).

Copper (Cu)

Copper concentrations in the drinking water vary widely. Along with the manufacturing of the commercial appliances, it is also used as the copper sulphate pentahydrate for the control of algae. Copper concentration in the treated water often increases during distribution, particularly in the systems where an acidic pH exists or in the presence of high-carbonate waters with an alkaline pH. The guidelines are derived on the basis to be protective against the gastrointestinal effects of copper (*WHO, Guidelines for Drinking Water Quality, third edition, 2004)*.

Cyanide (CN)

The cyanide is occasionally found in the drinking water, especially among the developing countries. Cyanide has acute toxic effects. Undesired effects on thyroid gland and the nervous system were observed in some populations as a consequence of the long-term consumption of inadequately processed cassava containing high levels of cyanide (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*). Pakistan needs to have a closer watch over the values of Cyanide levels in the drinking water being served to the masses on account of its acute toxicity, as also true for the microbiological contamination. In this proviso, a value of less than or equal to 0.05 is set as standards for Cyanide in drinking water for Pakistan keeping in view what other Asian countries are also following and on expert inputs.

Fluoride (F)

Fluoride is present in the Earth's crust and forms a part of number of minerals. The exposure of the human population depends upon the geographical location of the inhabitants. Daily consumption is from food mainly, and less from the drinking water and toothpastes. In some northern areas of Pakistan it is found high amounts in the run off water that is consumed by the people living over there and has led to the discoloration of the teeth (dental fluorosis). Epidemiological evidence shows that fluoride primarily affects the skeletal tissue (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*). A few recent incidences of fluoride in drinking water resulting into skeletal deformation (.e.g. among in children in Lahore, Manga Mandi), pose strict monitoring of fluoride in drinking water and value for Pakistan has been tightened than the WHO's one i.e. less than or equal to 1.5 mg/l.

Iodine

Iodine, as iodide , occurs normally in water. Iodine is also used for the water treatment in the emergency situations. Iodine is an essential element in the synthesis of thyroid hormone. Lack of iodine in drinking water and food, leads to the thyroid diseases. However, some recent studies from China also suggest that an excess of iodine in drinking water my also lead to thyroid diseases (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*).

Lead

Lead is used in lead-acid batteries, solders and alloys. The organolead compounds tetraethyl and tetramethyl lead have also been used as anti knock and lubricating agents in petrol. This use is now in a decline and the exposure from the air is declining but source from drinking water constitutes the major proportion. Lead is a general toxicant and accumulates in the skeleton. The placental (vertical) transmission in humans occurs as early as 12^{th} week of gestation. Young children absorb 4-5 times as compared to the adults. Lead is toxic to both central and peripheral nervous systems. The cross sectional epidemiological studies have shown that there is statistically significant associations between blood lead levels of 30µg/dl and more and intelligence quotient deficits of about four points in children. Results from prospective (longitudinal) epidemiological studies suggest that prenatal exposure to lead may have early effects on mental development that do not persist to the age of 4 years. This has been supported through the research on primates that the significant behavioural and cognitive effects were observed following postnatal exposure resulting in blood lead levels ranging from 11 to 33µg/dl (*WHO, Guidelines for Drinking Water Quality, third edition, 2004)*. Most of the lead in drinking water arises from the plumbing systems in the buildings. The measures to control the corrosion may reduce the amount of lead in drinking water. Considering drastic effects of Lead, for Pakistan the value has been set at less than or equal to 0.05 mg/l. This also is in agreement with values followed by most of the Asian developing countries.

Manganese

Manganese is naturally occurring, one of the most abundant metals in the Earth's crust. Usually it occurs along with iron. It levels in fresh water ranges from 1 to 200µg/litre. Higher levels in aerobic waters are usually associated with industrial pollution. Manganese is an essential trace element too. 20% of TDI allocation to the drinking water is required usually fro an adult of weight of 60 kg which consumes 2litres/day of drinking water. The high amounts may also result in the discoloration of drinking water and become objectionable for the consumer (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*). The value for Pakistan is proposed to be less than or equal to the WHO's one.

Mercury

Mercury is used in electrolyte production of chlorine and also used in gold mining. It is used in the thermometers and their spill can cause exposure to mercury. Mercury in uncontaminated drinking water is thought to be in the form of Hg^{2+}. Food is main source of mercury in non-occupationally exposed population. The mean dietary intake of mercury in various countries ranges from 2 to 20µg/day per person (*WHO, Guidelines for Drinking Water Quality, third edition, 2004)*. The value for Pakistan is proposed to be less than or equal to the WHO's one.

Nickel

A metal usually used for making alloys and producing stainless steel. Normally water is minor contributor to the total daily oral intake but if there is heavy pollution or use of certain types of kettles, of non-resistant materials in wells or of water that has come in contact with nickel- or chromium-plated taps, the nickel contribution from water may become significant to the total daily oral intake. There is lack of data and evidence that the oral intake of Nickel might lead to cancer. However, the inhalation may lead to risk of developing cancers among humans (*WHO, Guidelines for Drinking Water Quality, third edition, 2004).*

Nitrate and Nitrite

Nitrate is mainly used in inorganic fertilizers and nitrite is used in food preservatives. The nitrate concentrations normally remain low in ground and surface water but can reach to high limits as a result of run off or leaching from the agricultural land. The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, also known as "blue –baby syndrome". The nitrate is reduced to nitrite in the stomach of the baby and it oxidizes the haemoglobin (Hb) to methaemoglobin (metHb) that is unable to transport oxygen within the body. The methaemoglobinaemia causes cyanosis and ultimately leads to asphyxia, if left untreated. The normal metHb levels in infants under 3 months of age are less than 3%. The consequences manifest themselves when the concentrations reach 10% or more. Nitrate and nitrite in drinking water is the main source and also where there is relatively high intake in relation to body weight (*WHO, Guidelines for Drinking Water Quality, third edition, 2004*).

Selenium

Selenium, like magnesium, is an essential trace element. Foods like cereals, meat and fish are principal source of selenium. The recommended daily intake for humans is 1µg/kg of body weight for adults. Selenium compounds have been shown to be genotoxic in *in vitro* systems with metabolic activation, but not in humans (*WHO, Guidelines for Drinking Water Quality, third edition, 2004).* However, in humans, the toxic effects of long-term selenium exposure are manifested in nails, hair and liver. Different studies have give data on such effects with daily intakes ranging from 0.24 mg/day to 0.7mg/day.

Total Dissolved Solids (TDS)

The inorganic salts (magnesium, calcium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter comprise TDS. Concentrations of TDS in water vary too much extent due to the variability in the geographical locations. There is no reliable data available on the health effects of the TDS in drinking water (*WHO, Guidelines for Drinking Water Quality, third edition, 2004).*

Zinc

Zinc, like magnesium and selenium, is also an essential trace element. It is found in all foods and potable water. The levels of zinc in surface and ground water normally do not exceed 0.01mg/litre and0.05mg/litre, respectively. Concentration in tap water may increase due to dissolution from the pipes. The daily requirement for an adult man is 15-20mg/day. A value 5 mg/l may be appropriate for Pakistan although up to 3 mg/l is usually acceptable for consumption for consumers (*WHO, Guidelines for Drinking Water Quality, third edition, 2004).* This value takes into account what is being followed at the regional level i.e. most Asian countries.

A number of metallic and ionic species existing in water, beyond keratin limits can be the cause of serious health issues. For any water to qualify as potable, these constituents must be below the specified limits. Metals in water are determined with the standard atomic spectroscopy (atomic absorption, flame emission, plasma emission) techniques.

RADIOACTIVE MATERIALS

Radionuclides are radioactive atoms that disintegrate to smaller atomic mass atoms, releasing energy in the process. The energy is primarily released in one of the three forms:

1. Alpha particles consisting of the helium nuclei with two protons and two neutrons and thus bearing a charge of +2
2. Beta radiation, consisting of electrons hence carrying a charge of -1
3. Gamma radiation which has a true electromagnetic character and hence travel with the speed of light (electromagnetic radiation)

Due to the difference in their constitution, the three types of radiation have different health effects on humans. Alpha particle travel at moderate speed but due to their size and charge, if ingested, could be very damaging. Beta particles which travel very fast, near to the speed of light but their smaller size make them less damaging. Gamma radiation has tremendous penetrating power but is less lethal at lower doses normally to be encountered in drinking water.

Radioactivity in water can be natural or man-made. Naturally occurring radioactivity comes from elements in the earth's crust or from cosmic ray bombardment in the atmosphere and is not of critical importance in most instances. Radionuclides whose origin can be linked with human activity may be generated from sources such as mining of ores, nuclear fuel processing, power stations, and radiopharmaceuticals, etc.

Evidence exists from experiments on human beings and animals that radiation exposure at low to doses may increase the long-term incidence of cancer. Animal studies give definite clue that the rate of genetic abnormalities increase with radiation exposure and acute health effects of radiation include reduced blood cell counts.

The 'Bq' is the standard international unit for radioactivity. The limits for drinking water are indicated both as bq or pCi (10^{-12} Ci). A gross alpha test is the first step in determining the level of radioactivity in drinking water. This test serves as a preliminary screening device and determines whether additional testing is required. In order to extend the safety margin it is advisable to take the gross beta measurements as well. Consequently, both standards are frequently quoted in the literature for many drinking water standards. It is important to fix the upper limit for these parameters as 0.1 Bq/L and 1.0 pCi/L respectively for Alpha and Beta emitters..

POLYNUCLEAR AROMATIC HYDROCARBONS (PAH'S)

Polynuclear Aromatic Hydrocarbons **(**PAH's) are a class of organic compounds containing two or more fused aromatic rings of carbon and hydrogen atoms of which benzo[a]pyrene (BaP) is an important representative. Studies involving inhalation and skin exposure have generated clear evidence that mixtures of PAHs are carcinogenic to humans.

Most PAHs enter the environment via the atmosphere from a variety of combustion processes. Owing to their low solubility in water and high affinity for particulate matter, they are not usually found dissolved in water in significant concentrations. PAH levels in uncontaminated groundwater are usually in the range of 0 – 5 ng/litre. In highly turbid waters however, the solubility may increase many fold due to absorption. On the particulate matter concentrations in contaminated groundwater may exceed 10 mg/liter. The main source of PAH contamination in drinking-water is usually the coal-tar coating of drinking-water distribution pipes that are used to protect the pipes from corrosion The presence of significant concentrations of BaP in drinking-water in the absence of very high concentrations of fluoranthene indicates the presence of coal-tar particles, which may arise from seriously deteriorating coal-tar pipe linings. Typical concentration range for sum of selected PAHs in drinking-water is from about 1 ng/litre to 11 mg/liter.

Although the contribution of PAHs from drinking water may be insignificant as compared to inhalation and food ingestion in order to underscore the importance of keeping our water as pure as possible it is necessary that a very stringent limit may be imposed. The detection limit of the compounds by the standard by GC/MS technique is 0.01 mg/liter which may form a very good base for defining the maximum permissible limits in drinking water. It is recommended therefore that the concentration of PAHs in drinking water may NOT exceed the detection limit of GC/MS.

PESTICIDES, HERBICIDES, FUNGICIDES, ETC.

The number of these chemical, in use in Pakistan is so large (Annex A & B), and every day new chemicals are continuously added so that it is difficult, in fact impossible, to identify specific limits for each single one of these. It is recommended therefore that wherever the presence of any particular compound is thought to exist, the water should be analysed, specifically for it and, declared fit for drinking only if the concentration is found to be below the detection limit of the analytical technique under the standard method for each.

RECOMMENDATIONS FOR FUTURE PLANS OF ACTION TO ENHANCE AND MAINTAIN STANDARDS OF QUALITY DRINKING WATER

1. Preventive measures must be taken at all levels to prevent water contamination.

2. Protection of water sources should be the first line of defence.

3. All water distributing agencies must be supplied copies of the finalized standards.

4. Water treatment plants and water distribution systems must work in collaboration with each other to effectively implement quality standards for drinking water.

5. Sampling plans should be devised for raw and finished water. All samples of water should be accompanied by complete and accurate identification and descriptive data.

6. Standard methods for the examination of water (ASTM, ISO, etc.) should not only be specified, but also be prepared under local conditions and made available to the working professionals to obtain reliable data.

7. Cost effective methodology should be designed for monitoring and surveillance of water quality.

8. All critical parameters should be monitored.

9. Scarce resources should not be wasted for monitoring constituents of minor importance.

10. All personnel responsible for monitoring the quality of water should be educated and provided in-service training on a regular basis.
11. A critical and objective review of existing national research data on the quality of drinking water should be conducted on a regular basis.
12. Extensive resources should be devoted to upgrade existing water distribution infrastructure.
13. The cleanliness of water reservoirs/tanks of users must be mandatory.
14. Public awareness of their responsibility towards establishment and maintenance of drinking water quality standards. In this view **low cost measures to be applied at a household level** (use of lemon juice, SODIS and chlorination etc.) should be applied.
15. Standard quality water must be supplied equitably to all consumers at reasonably affordable cost keeping the concerns of equity and equality as of prime importance.
16. Precautions must be taken against elements that create and elevate fear in general public to promote sale of bottled water. Irrational advertisement and use of bottled drinking water must be discouraged.
17. Increase coverage of water supply and water treatment facilities.
18. Prime importance should be given to the issue of **quantity of water** over quality where water is scarce such as in Baluchistan and efforts to improve availability and accessibility to the quality water should be made. Windmills can be an option to draw ground water for consumers on affordable prices. Public campaigns to save water should be initiated.
19. In any **disaster**, the water resources and sources along with the quality of drinking water become compromised. Pakistan has recently experienced such situation in NWFP and AJ&K. **Emergency preparedness and response** mechanism demand minimum standards set for quality of drinking water in such situations. For Pakistan mass chlorination in addition to preserving the water sources is proposed in emergency situations along with educating the displaced populations about how to use the low cost measures for decontamination of available water.

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<u>Annex-I</u>

Implementation/Enforcement

A. Service Provider

Activity	WHO	Output	Timeline	Benefit/ Risk
1. Clarification of responsibility for Service Provider (which agency? WASA, MC, PHED, TMA, Development Authority??)	Federal and Provincial Govt.	Uniform Implementation Policy with clear responsibility	3-6 months	Improved Service Delivery as per revised water quality standards
2. Financial Constraints - Increased sector allocation - Sustainable financial mechanism for O&M (recovery cost through metering and public awareness supported by legislative measures)	Federal and Provincial Govt and Public Private Partnership	Increased capacity of the service providers	3-4 months	Reliable Safe Drinking water supply and increased coverage
3. Capacity Development - Diagnostic Surveys of all water supply water systems (already initiated by PCRWR), - HR capacity development on water supply especially on water quality issues for the implementation of revised guidelines and standards - Establishing regular water quality monitoring system including lab established and staff training, with logistic support for monitoring work - Development and implementation of Water Safety Plans based on risk assessment and management mechanism with clear accountable process, - Provision of required chemicals such as chlorine and alums etc	Provincial and Federal Government (LG/Nazim, PHED supported by PCRWR (MoS&T), MoH and MoEn)	Improved service delivery capacity	2 years (continuous Process)	Safe Drinking Water for general public
4. Rehabilitation/Expansion of existing water supply systems including replacement of old/damaged/rusted pipe networks including separation of water network from sewage lines.				
5..Establishment of Emergency Response				

Activity	WHO	Output	Timeline	Benefit/ Risk
Mechanism at different level				
6. Advocacy and Coordination Mechanism for all Stakeholders				
7. Information Management/Public Health Awareness				
Risks: - Political Interference - Delay in decision making - Lack of collaboration/coordination - Lack of financial resources				

Implementation/Enforcement

B. Regulator(Independent monitoring and feedback mechanism by third party)

Activity	WHO	Output	Timeline	Benefit/ Risk
Establishment of Independent Regulatory Authority for Water Supply at different level - Capacity development including training, equipments, human and financial resources etc. - Enhancement of existing water laboratories and establishment of new water labs - Management Information System on Water and Sanitation Sector - Periodic water quality monitoring as per WHO guidelines/Pakistan Standards - Feedback to the Service Providers - Technical Support to Service Provider to improve the water quality	MoST(PCRWR)/MoH.	Independent Sustainable Water Quality Monitoring Mechanism	1-2 years	Contribute to Safe Drinking Water
Risks: - Political Interference - Delay in decision making - Lack of collaboration/coordination - Lack of financial resources				

Implementation/Enforcement

C. Policy Maker/legal framework

Activity	WHO	Output	Timeline	Benefit/ Risk
1. Finalization of Safe Drinking Water Policy (in progress by MoEn)	Ministry of Environment	Revised policy	6 month	
2. Inaction of Safe Drinking Water Act at Federal Level after approval of the drinking water supported by provincial and district level legislation/bye laws The Safe Drinking Water Act must include**:** 1. Accountability of service providers for provision of safe water to the public, 2. Legal protection to minimize the risk of water contamination from unsafe disposal of human, agricultural and industrial wastes, **3.** Penalty for contamination of water sources, illegal connection, misuse of water through **Empowering Service Providers.** 4. Legal protection of recovery of bills and disconnection of water connections. 5. Prevention of excessive water abstraction of ground water **6. Water rights(bottled water issue?)** **Public Awareness Campaign of the law**	Ministry of Environment with with support from MoH, M of Law/ National Reconstruction Bureau Provincial governments and District Govt./TMAs MoST(PCRWR)/ MoH.	Legislative Framework with clear cut roles and responsibilities and accountability.	1 years	Effective Implementation to ensure safe water.

Risks:

- Political Interference
- Delay in decision making
- Lack of collaboration/coordination
- Lack of financial resources