Address of Welcome
By
Engr. Husnain Ahmad
President
Pakistan Engineering Congress
On
World Water Day March 22, 2010
At
"Mashhaddi Hall" of Pakistan Engineering Congress

Honourable Mr. Shakil Durrani Sahib, Respected Scholars,
Executive Council Members,
Fellow Engineers,
Ladies & Gentlemen !

It is the importance of water in the life of individuals and nations that the United Nations Conference on Environment Development (UNCED) held in Rio de Janerio in 1992 declared 22nd March as "World Water Day". Since then, it is being celebrated the world over. At the occasion of World Water Day, experts on "Water Resources" speak on the Theme & the related issues laid down for that particular year.

The theme for this year is:

"Communicating Water Quality Challenges and Opportunities".

Ladies & Gentlemen !

The Allah Tabarak wa Ta'ala, Himself through numerous verses in the Holy Quran signifies about the crucial role played by "Water" in the socio-economic life of mankind.

"And He is Who created the Heavens and the Earth in six days and His Throne was on water" (Sura Hud).

"He showeth you the lightening for a fear and for a honour sendeth down water from the sky and thereby quincheneth the earth after death" (Sura Rome).

"And have sent down from the raining clouds abounded water thereby to produce gram and gardens of thick foliage" (Sura An Naba i.e. Tidings).

Ladies and Gentlemen !

Let me begin by drawing your kind attention towards the importance of Climate Change on Water Resources:

- Environmental experts have visualized that unless the present levels of **"carbon emissions"** are drastically reduced, there will be earth-shattering 2-degree-celsius increase in global temperatures by 2050. The "Copenhagen" formulations will even if scrupulously implemented would arrest the increase at the most by 1-degree Celsius.

- A second study by sustainability institute of USA reveals that "Copenhagen" proposals will possibly result in 3.9 degree increase in world temperatures by 2100.

- A German study reveals that even if "Copenhagen" proposals are fully implemented, there will be approximately 3.2 degree Celsius increase in temperatures by 2100.

  The UNEP's chief spokesman Nick Nuttal is reported to have said,

  "It becomes increasingly difficult to achieve reduction and increasingly costly if you wait".

The leading greenhouse gas emission polluters & further predictions in their respect are given below:

		Million Metric Tons of CO2		
		2007	**2020**	**2050**
1	**China**	8106	11,292	16,232
2	**U.S.A**	6087	6308	7098
3	**European Union**	4641	4804	6912
4	**India**	1963	3194	5027

Pakistan ranks amongst lowest greenhouse gas emitters on the world (135th), but in terms of impacts and vulnerability it ranks in the top 20 category.

Ladies & Gentlemen !

The repercussions of 2-degree temperature increase are visualized as under:

i. Most parts of Amazon rain forest will stand dried / burnt throwing-out millions of tons of extra dioxide.

ii. Greenland's ice will melt away thereby raising the sea levels by as much as seven (7) meters submerging low lying coastal areas, uprooting millions of people with devastating economic fall-out, altogether disappearance of some of the islands.

iii. Accelerated Himalayan Glaciers melt. The Himalayas Glaciers (12000 to 15000 occupying 500,000 Sq. Km) are receding fast.

- A study involving 1387 selected glaciers reveals 16% reduction in area since 1962. (over a 48-year period).

- Another study including Pindari, Gangotri & Dokriani glaciers show the annual retreat by 5 to 49 meters.

The Himalayan Glaciers are the source of sweet water to Asia's seven (7) river systems including:

- Indus
- Yangtze
- Mekong
- Ganga
- Brahmaputra

A critical study of the data reveals that if stringent measures are not put in force to check the expected temperature increase visualized at 3 to 3.2 degree Celsius by 2100 (next 90 years).Himalayan glaciers would disappear by 2300. However, the crux of the matter is that the catastrophic consequences are manifestly imminent in the shape of:

- Flooding.
- Drastic reduction in river in-flows resulting in food shortages, Famines, Starvation
- Prolonged electricity outages & the consequent falling living standards.

- Agricultural yields would stand drastically reduced in global terms especially creating food shortages, starvation and throwing millions below poverty lines.

In a recent statement Dr. Zafar Adeel who is an eminent scholar and a member of United Nations Think Tank Team on water said:

"The impact of climate change on water resources was quite central for a country like Pakistan. The general public as well as the political & policy leadership needs to be fully aware of the challenges, being imposed on Pakistan due to climate change"

The question is why so and where does Pakistan Stand in Water Availability?

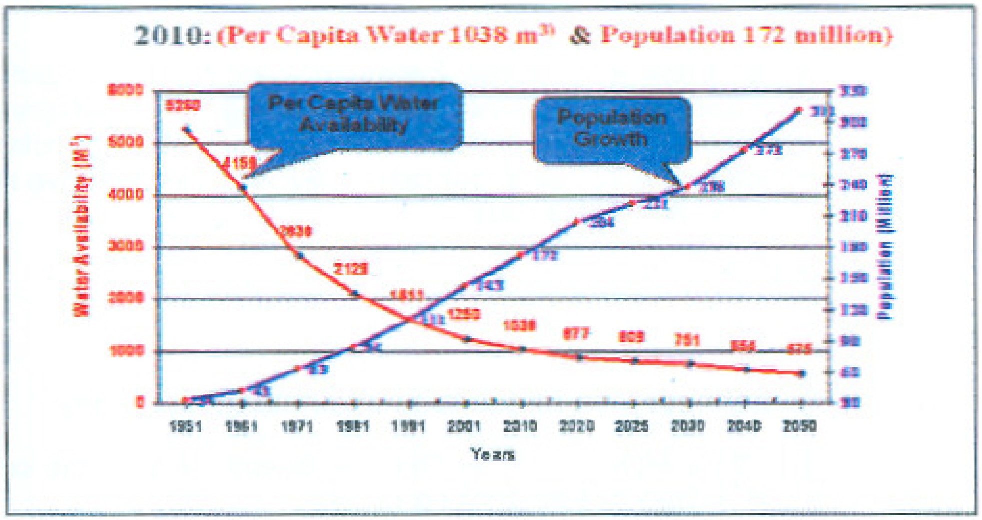
Ladies & Gentlemen !

Please have a look at the table which shows the rapid reduction in per Capita water availability in Pakistan.

Year	Population (Millions)	Growth Rate (R)	Total Water Availability		Per Capita Water Availability (M3)
			MCM	MAF	
1951	34	0	178840	144.9	5260
1961	43	2.38	178848	144.9	4159
1971	63	3.89	178815	144.9	2838
1981	84	2.72	178836	144.9	2129
1991	111	2.38	178825	144.9	1611
2001	143	2.60	178780	144.9	1250
2010	172	2.10	178584	144.7	1038
2020	204	1.70	178948	145	877
2025	221	1.60	178880	145	809
2030	238	1.50	178710	144.8	751
2040	273	1.40	178668	144.8	654
2050	311	1.30	178800	144.9	575

In 1951, per capita water availability was 5260 (Cubic Meter) which stands slided to 1038 (Cubic Meter) in 2010 - a very steep and worrisome position. With the country's population increased from 34 million to 172 million and visualized at 311 million by 2050, the country will be a severely water scarce country with per capita water availability reduced to a miserable 575 (Cubic meter) an alarming and distressing scenario indeed.

A diagrammatic presentation would make the position even more glaring for an understanding mind.



- WATER SCARCE COUNTRY AS PER GLOBAL CRITERIA – 1000 M^3/CAPITA
- RAPIDLY INCREASING POPLULATION – 221 MILLION (2025).

What are the reasons behind this entanglement and what is in store for us in future.

The people at the helm of affairs of the country as well as the planners of socio-economic development schemes without any exception have shown apathetic negligence towards building-up of water reservoirs. Almost 3- precious decades have been wasted away in political wranglings about construction of kalabagh Dam, an engineering matter sacrificed at the altar of political egoistic behavior. What is even more incomprehensible is the non-construction of other Dams now belatedly taken-up and which will take 10-16 years to bear fruit.

- Diamer Basha
- Dasu
- Akhori
- Kurram Tangi & Munda

And let me also share the consequential effect in a comparative manner, if no rains occur over a prolonged period. To quote Engr. Mumtaz A. Khan:

- America has water storage enough for a number of years.
- China has 200 days water storage.
- India has water enough for 170 days consumption
- Pakistan has water storage enough for barely 30-days.

A disappointing & an enigmatic situation and in the meantime 35 MAF water is wasted away untapped to the sea.

Decades back world renowned veteran Engineer, Engr. S. S. Kirmani (Late) bluntly told that if proper attention is not given to storage and conservation of water , the country would not have enough water for domestic, agriculture and industrial consumption and now due to our ostrich like attitude, we have come to a dead end & do not find an escape route.

Pakistan Scenario

Ladies & Gentlemen !

Let us now have a bird's eye view of access to water etc in the country:

- Compared to 93% MDG target by 2015 an overall 66% of the country's population has access to safe drinking water.

- 85% people of urban areas have facility of safe drinking water.

- Out of 30,000 villages about 1/3rd villages (55% of the population of these villages) have access to safe drinking water. Remaining population of 20,000 or so villages have no such facility.

- 25% of adults and 40% children are exposed to water-borne diseases.

- Ground water should normally be less exposed to bacteriological contamination than surface water. However, even ground water is becoming un-safe due to leakage of pipes, un-treated municipal wastes (both waste water & solid waste) un-checked use of pesticides, nitrogen, fertilizers, industrial wastes etc.

- Tap water availability position is:
  - 62% Urban
  - 22% Rural (a dismal position)
  - 36% overall

- Studies of selected cases reveal that most of the people (almost 80%) are exposed to use of un-safe drinking water.

- Streams & Rivers have been heavily polluted due to defective, out-dated & inadequate sewage treatment facilities and dumping of chemical, agriculture waste. Even lakes like "Mancher" have been polluted to the brink.

- Due to over-mining of water through tubewells and the declining re-charging of underground water reservoirs, the water table has fallen by 40-50 feet.

Water Quality Scenario

Ladies & Gentlemen !

Water is one of the most precious commodities for sustenance of life. Whilst abundant water is available around us, fresh water resources have depleted at an alarming rate. Changes in weather patterns are adding more challenges to our experts of water resources management. Pakistan is rapidly becoming a water deficient country.

Excessive ground water exploitation (the number of tubewells is touching 1-million mark) by industry and agricultural sectors have forced untreated industrial and municipal waste water into our fresh water resources. Care free attitude towards water by everyday rising population need comprehensive measures and awareness about water re-use and re-circulation. Non-availability of dams is costing us in billions of rupees annually in terms of ground water pumpage for irrigation. India's building of dams is further aggravating our water resources situation. In order to develop sustainably, we must involve U.N in resolving water issues between us and our neighbors. Any further delay would force us into a water war rather than long waited peace that is so overdue.

On one hand we are losing our fresh water resources and on the other hand we are destroying the quality of the available resources by indiscriminate discharge of all kinds of waste water into our rivers, reservoirs and fresh water streams. Most of the hospital beds in our country are occupied by patients of water related diseases (loss of 0.6% to 1.44% GDP). Hepatitus B and C which were almost non-existent have become an every family's affair.

Pakistan is confronted with all kinds of water related problems. Good quality raw water is only available underground which requires energy resources for pumping. Most of the water supply agencies have poorly trained and carefree manpower. Supply networks are old, rather expired, and occasionally crosslinked with sewerage lines. A system of water quality monitoring at the consumer end is totally non-existent. High Arsenic content in ground water in the southern belt is already taking its toll. Experts have reported high Arsenic in Lahore's groundwater. Menace of high nitrates is spreading around most of our rural areas. Shortage of Iodine is spreading Goitar in the outer fringes of Pothohar region. Earthquake of 2005 has modified groundwater quality in most of the earthquake struck areas. Many springs have disappeared. Surface water quality has deteriorated to a very poor level. Water filtration plants installed could have helped improving drinking water quality but very poor maintenance is taking away all the good-work and with the passage of time these filtration plants are becoming sources of biologically polluted water. In fact, such a temporary arrangement was bound to fail. All around the developed world one will hardly find such a solution for supply of safe drinking water to large communities.

The only answer to our safe water supplies is the standard treatment plant involving coagulation, flocculation, sedimentation, filtration and disinfection. Every water treatment facility must be equipped with a trained water quality monitoring team and a decent laboratory. All existing water supply networks must be thoroughly examined for leakage and cross-contamination. Expired lines must be replaced with fresh lines. Good quality, high strength PVC pipes, made up of food grade resin, can be used for supply lines. These pipes have smooth inner surface and offer low head-loss when compared with traditional G.I pipes. Water meters at the cost and security of every household would help returning the cost of such endeavors. In fact, if the cost of medical bills for water related diseases is compared with the cost of these conventional plants and supply networks, the latter will outweigh the former within a period of less than two years.

A clean drinking water for all (CDWA) project launched several years back envisaged setting-up of 6626 filtration plants all over the country. This could have gone a long way, however, only 822 filtration plants have been installed.

Availability and Quality of Water in Punjab

Ladies and Gentlemen !

Punjab can be divided into four major zones on the basis of drinking water quality:

a) Sweet zones
b) Brackish zones
c) Barani zones
d) Mixed (brackish / barani) zones

The quality of underground water depends on geo-formation of the zone and is generally manifested in terms of Total Dissolved Solids (TDS).

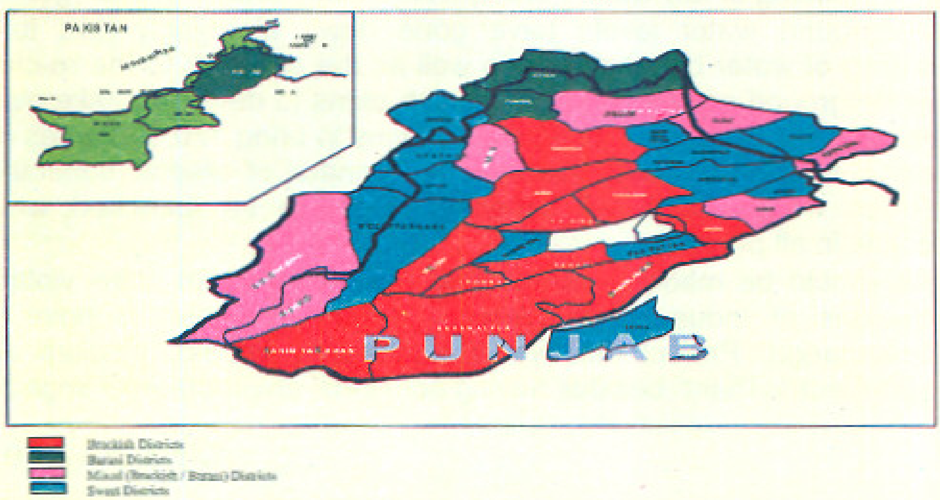
- Predominantly Water Scarce Barani Districts 3 Nos
- Predominantly Brackish Districts 11
- Sweet Water Districts 13
- Mixed (Brackish Barani) Districts 7

34 Nos

The below given table and diagram will make the matters all the more clear:

Predominantly Water Scarce Barani Districts	Predominantly Brackish Districts	Sweet Districts	Mixed (Brackish/ Barani) Districts
Rawalpindi	Faisalabad	Lahore	D.G. Khan
Attock	T.T. Singh	Sheikhupura/Nankana	Rajanpur
Chakwal	Multan	Gujranwala	Khushab
	Jhang	Sialkot	Jhelum
	Lodhran	Hafizabad	Gujrat
	Bahawalpur	M.B. Din	Narowal
	R.Y. Khan	Bhakkar	Kasur
	Okara	Pakpattan	
	Sargodha	Mianwali	
	Bahawalnagar	Layyah	
	Vehari	Muzaffargarh	
		Khanewal	
		Sahiwal	

Ground Water Quality in Punjab



Recommendations:

- There is no substitute of big dams for conservation of water & these need to be completed in record time.
- Presently drinking water availability is about 4.5 MAF. If MDG goals are to be met and drinking water made available to the urban and rural population, water supply would have to be augmented by additional 4-MAF.
- Small Dams (no substitute for big dams irrespective of the numbers built) need to be constructed. In POTHOHAR Plateau 15. Such dams were built (another 5-dams nearing completion). It has created 91746 AFT water storage bringing about 29760 acres of culturable commanded area. It is heartening that small dams are being constructed in all provinces.
- Responsibility of supplying drinking water rests with Tehsil Municipal Administration (TMA's). However, these need to be technically & financially empowered (presently highly deficient).
- Direct supply of water from the ground through tubewells is open to serious health hazards. It should be through "overhead" water tanks and supplied after chlorination & treatment.
- Fiscal measures are required to be undertaken to ensure assured supply of safe drinking water in adequate quantities and at a price that at least covers the cost.
- For conservation of water metered supply should be resorted to in all cases.
- Experts have suggested adoption of the following measures to avoid wasteful use of water:
    i. Hotel industry be encouraged to install ultra-low flow toilets.
    ii. High efficiency washing machines be introduced.
    iii. Planting of low water / drought resistant plants in lawns / gardens.
- Underground water levels have gone down alarmingly due to over-pumping of water by tubewells as well as the set-back to the re-charging of underground aquifer. Govt. of Punjab plans to develop a lake over 500 acres of dried-up bed of sutleg river. It aims to bring 120,000 acres of land under-cultivation besides checking the menace of arsenic substances & brackish water. Such like schemes ought to be launched wherever possible in all provinces.
- India should be made to realize that Pakistan will not allow violation of Provisions of Indus Basin Treaty – 1960. The case in point is the "Kishanganga" Project that would significantly impact "Neelum Jhelum Hydro-Electric Plant" besides having additional environmental impacts.

PAKISTAN ZINDABAD

Inaugural Address
By
Mr. Shakil Durrani
Chairman
Water and Power Development Authority
On
World Water Day March 22, 2010
At
"Mashhaddi Hall" of Pakistan Engineering Congress

President Pakistan Engineering Congress, Distinguished Guests, Participants, Ladies and Gentlemen!

Assalam-o-Alaikum !

1. I deem it an honour and a duty to deliver the inaugural address to this concerned gathering on the occasion of World Water Day being celebrated with the theme "Communicating Water Quality Challenges and Opportunities" organized by Pakistan Engineering Congress in collaboration with WAPDA.
Let me begin with a cliche.

2. Water has a pivotal position in all development activities for its enormous importance in food security, livelihood, environment, economics, power generation and in fact life itself. However, the quality of water whether for use in agriculture, municipalities, drinking, household and in industry acts like a quality multiplier. So it is not only the quantity but the utility which determines the levels a society or a country reaches. This can be appreciated from the fact that out of total available water on the earth, only about 3 percent is directly usable. And of the fresh water, 69 percent is locked up in ice caps and glaciers primarily in Antarctica and Greenlands, 30 percent is stored in ground water reservoirs and only a tiny quantity is available in fresh water lakes, rivers and streams.

3. The water situation in our country as you are aware, is facing both quantity and quality issues. The water availability at the time of independence was 5260 cubic meter (M^3) per capita which has reduced to 1,038 M^3 in the year 2010 and will further reduce to 809 M^3 in 2025. Soon we would be a water starved and not just a water stressed country. Despite these critical shortages, we in Pakistan remain extravagant in its use. Our biggest concern should be the surface irrigation with very low efficiencies and considerable waste. Our farmers are unaware of the benefits of modern irrigation techniques and the responsibility for this primarily lies with Government. Similarly our standards for drinking water and increasingly of irrigation water as well leaves much to be desired.

4. Pakistan has 75 million acres (MA) of land suitable for agriculture. However, by making the additional water available through more storages and high efficiency irrigation system, nearly 20 million acre of additional land can be brought under cultivation.

5. Another aspect which needs attention at the national level is the water which escapes to sea and is more than the requisite amount. Between the period 1976-2009 average annual flows below Kotri have been 31.5 MAF. The flows during the last 10 – 15 years have often been lower. What is heartening is the realization that we have the land and the water potential not only to feed us but to generate surpluses as well.

Ladies & Gentlemen !

6. In the years ahead we need to concentrate upon the following five priorities for balanced growth and equity:

i) Development of additional reservoirs.

ii) Increasing irrigation water efficiency through modern irrigation modes like drip and sprinkler system.

iii) Ensuring provision of clean drinking water.

iv) Treatment of saline water for use in agriculture and fishery.

v) Recycling of urban and industrial waste water for different uses.

7. These five priorities could be achieved efficiently if only we cost our irrigation and drinking water economically. Currently, for instance only about 25% of O&M charges for irrigation water are actually recovered as Abiana. This recovery does not include the capital costs of the storages and channels. No wonder we are so profligate. For providing drinking water to the disadvantaged sections, an element of intervention by the State in the form of subsidies would be required for some time. For the rest of the population and especially for the large farmer it is important that the real cost of water is recovered from them.

8. As far as increasing storage is concerned, I would also like to mention that after the creation of Pakistan, only 3 Mega water storage reservoirs – Mangla, Tarbela and Chashma have been constructed. Their storage capacity has been reduced by 28% due to siltation. The daily silt deposit in Tarbela is nearly half a million tons. With this reduction in storage capacity, it was felt necessary to start construction of new storage reservoirs. In this regard WAPDA has been executing many projects for the development of surface water resources on fast track basis. These include the Mangla Dam Raising (3 MAF) and Gomal Zam (0.89 MAF). The big one at Diamer Basha Dam (6.4 MAF), Kurram Tangi Dam

(nearly 1.0 MAF) and some other projects are currently in various stages of planning and implementation. Diamer Basha Dam Inshallah shall be started early next year. A dozen Small and Medium Dams are also in different stages of planning and implementation in all the four provinces with potential of storing 2.5 MAF and will be completed by 2013. Studies for storages and other sites are also underway by WAPDA.

9. Wastage in irrigation needs rectification by adopting high efficiency irrigation systems like drip and sprinkler irrigation. In drip irrigation, there could be a saving of upto 50% of irrigation water and also a concomitant reduction in the use of fertilizer. The initial costs are high at about Rs.50,000 to Rs.70,000 per acre but then water is even more valuable. In any case the costs can be recovered in a few years. The flood irrigation system requires 3,470 M^3 of water per crop acre whereas drip irrigation system requires 1,590 M^3 of water per crop acre and sprinkler requires 1,690 M^3 of water per crop acre. Drip can save 1,880 M^3 of water, whereas, sprinkler can save 1,780 M^3 of water per crop acre. A comparison of flood and drip irrigation is shown in the slides. By adopting high efficiency irrigation system, the additional area can be brought under cultivation with the saved water.

10. The water channels pollution is frequently associated with the disposal of untreated effluents from municipal, industrial and agricultural wastes. The natural streams are always considered as an easy way to dispose off many kinds of effluents. The psychology behind this practice is that the wastes are washed away and are not visible at dumping sites. Besides this, indiscriminate pumping of groundwater is causing over mining which is enhancing salt water intrusion and polluting the groundwater.

11. WAPDA is presently undertaking a study for treatment of saline water of the RBOD-I. Our consultants would soon submit the initial recommendations for treating water for a pilot project of 40 cusecs. The costs are doubtlessly high but their long term benefits are more alluring. Imagine, if we can save 10 MAF of saline and polluted water and use this for agricultural purposes. This adds a Tarbela Dam equivalent reservoir for us.

Ladies & Gentlemen !

12. We have no more time for sterile discussions and debates; now is the time to act. Planned usage of available resources and developing a time bound action plan are central to our survival. Organizing and engaging local communities to help themselves through practical schemes and creating awareness among masses about the precious resource scarcity is need of the day. For managing water scarcity, WAPDA is recommending adoption of high efficiency irrigation system in both public and private sectors. Each province needs to earmark at

least 10,000 acres next year for drip and sprinkler irrigation through PSDP as pilot project in collaboration with private sector. Credit facilities for such innovative programmes are urgently required. Distinguished individuals like yourselves and organizations like the Pakistan Engineering Congress could act as agents of change in this regard.

13. In the end, I would like to thank Pakistan Engineering Congress, WAPDA and representatives from other organizations for their participation and commitment to the goal of the World Water Day. We should not just be observing the World Water Day as a one-off event but move forward to celebrating it in the years ahead through achieving our objectives. Your contributions would certainly be helpful in better understanding the water quality problems; its magnitude and solution. I would suggest that the recommendations of the seminar should be sent to all the federal and provincial institutions dealing with water.

Thank you and Allah Hafiz

PAKISTAN ZINDABAD

PREVALENCE OF *ESCHERICHIA COLI* WITHIN PUBLIC DRINKING WATER SUPPLY IN 1-8 SECTOR, ISLAMABAD

By

Sajida Rasheed, Imran Hashmi* and Sara Qaiser

Abstract

Insufficient treatment of surface waters for the drinking water supply, malfunctioning of sewage collection systems, and defective water distribution pipelines have led to contamination of potable water by fecal *coliform* and other pathogenic bacteria. Sector I-8 of Islamabad was monitored for the physicochemical parameters as well as biological contamination to track the microbial contamination and residual chlorine throughout the water distribution network. Samples were collected from source, underground tank and end point users, i-e., houses were analysed for total chlorine, free chlorine residual, chloramines, *total coliforms, fecal coli forms,* total dissolved solids (TDS) and turbidity. The value of total chlorine was estimated to be 0.13 mg/L; free chlorine was 0.09 mg/L, monochloramine of 0.04 mg/L and dichloramines of 0.03 mg/L. From the analysis result it is clear that the temperature of the water samples tested varied from 25.8 to 26.7 at *Station # 4* and *3*. The values of pH fluctuated from7.10 to 7.62 at *Station # 1* and *4* respectively. The value of TDS was lowest at *Station # 4* with values ranging from 332 to 354 mg/l with mean value of 339 mg/L while maximum value was obtained at *Station # 6* with mean value of 368 mg/l. Conductivity values were found varying in between 683 to 749 µS/cm at *Station # 4* and *6*. All the parameters were within WHO standards of drinking water quality. Highest value of turbidity was obtained at *Station # 2* with mean value of 1.27 NTU while lowest value was observed at over head tank at I-8 with mean value of 0.34. The value of total chlorine varied from 0.05 mg/L at *Station # 3* to 0.13 at *Station # 1*. Free chlorine residual was also detected in the system with average values varying from 0.02 mg/L at *Station # 3* to 0.09 at *Station # 1*. Microbial analysis of drinking water samples revealed that fecal contamination at *Station # 3* with MPN /100mL of 16.1, at *Station # 5* and *7* MPN/100 mL was 6.9 and at *Station # 8* MPN/100ml was 5.1. While at the rest of the stations MPN/100 ml was <1.1. The maximum SPC counts were observed at *Station # 3* with values ranging from 81 to 370 CFU/mL with average value of 267 CFU/mL. At the rest of the stations SPC counts were below countable range. So from the analysis it revealed that water sample from *Station # 3* was highly contaminated. The water samples collected were also analyzed for TOC. The analysis results were alarming as high amount of TOC was observed at all of the sampling stations which were above standards of treated drinking water i.e., above 2 mg/L. The values were found to be ranging from 7.67 to 22.57 mg/L. The main water supply had a TOC value of 11.22 mg/L. The routine monitoring of the water distribution network is strongly recommended for provision of safe and clean potable water to public.

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Keywords: *Escherichia coli*, Chlorination, Chlorine residual, Coliform, Microbial counts, Monitoring, Drinking water.

1. Introduction

Protection of public health from pathogenic contamination in drinking water infrastructure is a critical component in the operation of a community drinking water system (Helbling and Van Briesen, 2008). Reported pathways of accidental pathogenic contamination in the distribution system include cross-connections with non potable water sources (Liang et al., 2006) and intrusions via waterline materials that are aged and structurally compromised

The occurrence of *coliform* bacteria in otherwise high quality drinking water has been a nemesis to the drinking water industry (Le Chevallier et al., 1988). Transmission of pathogens with drinking water is a widespread problem, which affects not only the countries with low hygienic standards but the industrialized countries as well (Schoenen, 2002). *Escherichia coli*, a member of *coliform* bacteria, is a commensal bacterium of the intestinal tract of humans and various animal species. Among the many harmless strains, pathogenic isolates exist; and such strains can be harmful, especially for children (Balmer *et al.*, 2007). Their presence in drinking water clearly shows fecal contamination (Ram *et al.*, 2009) and indicates a possible contamination of enteric pathogens (Min & Baeumner, 2002). Clinical manifestations range from asymptomatic excretion, through mild non-bloody diarrhea to hemorrhagic colitis and severe complications as hemolytic uremic syndrome (HUS) with acute renal failure, sometimes resulting in death (Schets *et al.*, 2005).

Waterborne outbreaks associated with consumption of faecally contaminated drinking water (Licence *et al.*, 2001) and recreation in or consumption of surface water contaminated with faeces have both been reported. Drinking water from private water supplies is often only partially treated or is used untreated. Particularly in rural areas and in periods with heavy rainfall, insufficient protection of wells can lead to contamination. Contamination originating in distribution systems is of particular concern because their spatial distribution could result in widespread contaminant propagation and affect the health of large, dispersed populations.

Chlorination is the predominant disinfection method applied in water and waste water treatment due to its low cost, ease of application, and ability to inactivate a wide variety of pathogenic microorganisms (Donnermaire and Blatchey, 2003). The effectiveness of chlorine as a germicide is a result of chlorine's powerful oxidizing action. Its addition to drinking water has greatly reduced risk of waterborne diseases. I addition, protection of public health from pathogenic contamination in the distribution system is provided by the maintenance of a disinfectant residual and chlorine has its residual effect in the form of chloramines. Chlorine residuals of drinking water have long been recognized as an excellent indicator for studying water quality in the distribution network (Lienyao *et al.*, 2004). For more than a century, the safety of drinking water supplies has been greatly improved by chlorine treatment. When properly designed and operated, the process is well-developed, inexpensive, and efficient (Shang and Blatchey, 2001). Due to these properties, chlorine will remain the most commonly used drinking water disinfectant.

Beside the microbial threat in drinking water, Total organic carbon (TOC) is another issue which should be paid attention. TOC is the amount of carbon bound in an organic compound and is often used as a non-specific indicator of water quality. TOC in source waters comes from decaying natural organic matter (NOM) especially humic acid, fulvic acid, amines, urea and from synthetic sources like detergents, pesticides and fertilizers etc. Some of the contaminants may not be completely removed by treatment processes; therefore, they could become a problem for drinking water sources. The recently issued *Disinfectants and Disinfection By-Products Rule* by the US Environmental Protection Agency specifies maximum total organic carbon levels of 2 mg/L in treated water and 4 mg/L in source water to ensure acceptable levels of disinfection byproducts. TOC value of drinking water supply with chlorination is 4 mg/L (EPD, 2001).

It is important to know the organic content in a waterway because if there is a considerably high content of organic carbon compound in the water to be processed, Trihalomethane (THMs) will develop as a result of chlorine reaction with organic carbon. But the maintenance of chlorine residue is needed at all points in the distribution system supplied with chlorine as disinfectant (Kitazawa, 2006). A quantitative assessment of the risks associated with pathogenic intrusions has shown that protection of public health by maintenance of a disinfectant residual may be insufficient (Helbling and Van Briesen, 2008) leading to regrowth of microbes or their accidental intrusion in the pipelines.

In Pakistan chlorination is practiced at most of the filtration plant as the only mean of water disinfection, and it is supplied to the public using plastic pipes via distribution network. But there is no planned regular monitoring program to assess the water quality of the surface and groundwater bodies, at the treatment plants or in the distribution system except at few major water treatment plants (WB-CWRAS, 2005) which allows episodes of serious bacteriological contamination to go undetected. Pakistan has one of the highest child mortality rates in Asia. It is estimated that water related diseases cause annual national income losses of USD 380-883 million – or approximately 0.6-1.44 percent of GDP (UNDP, 2003).

So The objective of this work was to evaluate the efficacy of free chlorine to inactivate the microbes in drinking water distribution network and bacterial contamination events in drinking water distribution systems and to evaluate their inter ralationships along side with other variables like TDS, turbidity and electrical conductivity etc.

2. Material and Methods

2.1 On field analysis of parameters:

On field, samples were analyzed for temperature and pH (Hach pH meter sension 1), turbidity (Hach 2100) and TDS and electrical conductivity by Hach meter (sension 5).

2.2 Parameters analyzed in Laboratory:

Microbial and chemical analysis of drinking water was conducted by using following test in laboratory.

2.2.1 Biological Parameters

1. MPN (Most probable Number)

The *total coliform* and *fecal coliform* counts were determined by the MPN procedure given in Standard Methods for the Examination of Water and Waste water (APHA, 2005) using lauryl tryptose broth (LTB) for the presumptive test and brilliant green lactose broth (BGLB) for confirmation.

To meet the quality standards of the U.S. Environment Protection Agency (US-EPA, 1978) recommended use of the fermentation technique with 10 replicate tubes was performed; each containing 10 ml. Sample was poured in LTB tubes and incubated at 35 ± 0.5°C. Production of an acidic reaction or gas in the tubes within 48 ± 3h constitutes a positive result. The positive tubes were shifted to BGLB and incubated at 35 ± 0.5°C. Formation of gas in any amount in the BGLB tube at any time within 48 ± 3h constitutes a positive confirmed phase. The positive tubes show the presence of *coliform*. For confirmation of *fecal coliform*, the positive BGLB tubes were shifted to EC medium and incubated for 35 ± 0.5°C for 48 ± 3h.Here if gas is produced; it is a positive test for *fecal coliform*.

2. Standard Plate Count-SPC

Standard plate counts (SPC) were also determined as per Standard Methods (APHA, 2005). It is a procedure for estimating the number of live heterotrophic bacteria in water. This test can provide useful information about water quality and supporting data on the significance of *coliform* test results. The SPC is useful in evaluating the efficiency of various treatment processes for both drinking water and swimming pools purposes, and for checking the quality of finished water in a distribution system.

The Pour Plate technique is used on any type of liquefied sample for the enumeration of bacteria. Conditions vary depending upon the type(s) of bacteria being enumerated. Agar is prepared according to standard manufacturer's instruction and then held at 44 - 46°C in molten state in a water bath. Serial dilutions of the sample are prepared (using 0.1 % peptone water) so that following incubation, one of the dilutions will yield growth of 30 - 300 colonies (the ideal counting range) on the agar plate.1.0 ml of the sample or dilution is transferred to a sterile, empty Petri dish. Approximately 15 mL of agar medium is poured into the Petri dish containing the sample. The sample and agar are mixed thoroughly by rotating the plate several times, clockwise, then counterclockwise. When the media has solidified, the plates are inverted and incubated at, 37°C ± 0.5°C for 48 - 72 ± 2 hour.

2.2.2 Chemical parameters:

1. DPD Ferrous Titrimetric Method

Chemical analysis for chlorine residual, free chlorine, monochloramine and dichloramines was carried out using DPD Ferrous Titrimetric method (APHA, 2005). For the detection of free chlorine, 5 ml of phosphate buffer and DPD were placed in a flask with 100 ml sample; development of red color was titrated against standard ferrous ammonium sulfate (FAS). Observation was recorded as soon as the color discharges giving value of free chlorine. For determination of monochloramine 0.5 g KI was added to the above sample and was titrated against FAS. The volume of FAS used gives monochloramine in mg/l. For dichloramines 1 g KI was added in the above sample and similar procedure was repeated after 2 minutes standing at room temperature. Similarly for total chlorine 5 ml of phosphate buffer and DPD was placed in a flask with 100 ml sample along with 1.5 mg KI and was noted after two minutes standing in dark.

2. TOC analysis

The drinking water samples collected were analyzed by TOC analyzer multi win N/C 30. The determination of the inorganic carbon occurs by injection of the sample into phosphoric acid. The resulting carbon dioxide is degassed from phosphoric acid with the aid of carrier gas and quantified with NDIR, according to the TC determination. The CO2 detector measures the concentration of the CO2 gas generated in the oxidation chamber. This component is critical for precise analytical results, since it directly correlates to the organic carbon content of the analyzed water.

3. Results and Discussion

The aim and objective of the study was to evaluate the efficacy of free chlorine to inactivate the microbes in drinking water distribution network and bacterial contamination events in drinking water distribution systems and to evaluate their inter relationships along side with other variables like TDS, turbidity and electrical conductivity etc.

Sampling was conducted in I-8 sector during August and September, 2008. There are two overhead tanks and a water filtration plant in the community which is supplying water to the public. The water at the over head tank was analyzed microbially and chemically to assess the status of drinking water. The analysis revealed that the water is safe for drinking with value of pH 7.10, TDS of 354 mg/L, conductivity of about 714 µS/cm and turbidity of 1.10 NTU. The value of total chlorine was estimated to be 0.13 mg/l; free chlorine was 0.09 mg/l, monochloramine of 0.04 mg/L and dichloramines of 0.03 mg/L. There was no evidence of fecal contamination in water sample collected from over head tank in all three days of sampling.

From the analysis result it is clear that the temperature of the water samples tested varied from 25.8 to 26.7 °C at *Station # 4* and *3*. Water temperature is crucial for microbiological water quality. The increase in temperature enhances the disinfection efficiency of chlorine, i.e., pathogen inactivation effectiveness increases as water temperature rises. These results are inline with the study conducted by Bailey & Thompson, (1995) who found out that higher coliform counts were associated with higher water temperatures in the distribution system. It has been observed, that when water temperatures rise above 15°C, the growth of colonizing bacteria in the distribution system increases markedly (LeChevallier *et al.*, 1991; LeChevallier *et al.*, 1996; Geldreich, 1996).

Chlorination is also effected by pH. In aqueous solutions with pH 7.0 to 8.5, HOCl reacts rapidly with ammonia to form inorganic chloramines (termed combined chlorine) (US-EPA, 1999).The values of pH fluctuated from7.10 to 7.62 at *Station # 1* and *4* respectively.

The United States Environmental Protection Agency (US-EPA, 1978) recommends treatment when TDS concentrations exceed 500 mg/L, or 500 parts per million (ppm). The TDS concentration is considered a Secondary Drinking Water Standard, which means that it is not a health hazard. However water with a high TDS concentration may indicate elevated levels of ions that do pose a health concern, such as aluminum, arsenic, copper, lead, nitrate and others. These results are also in agreement as reported by Farooq *et al.*, (2008). The value of TDS was lowest at *Station # 4* with values ranging from 332 to 354 mg/L with mean value of 339 mg/L while maximum value was obtained at *Station # 6* with mean value of 368 mg/L.

Conductivity values were found varying in between 683 to 749 µS/cm at *Station # 4* and *6*. All the parameters are within WHO standards of drinking water quality. As the concentration of dissolved salts (usually salts of sodium, calcium and magnesium, bicarbonate, chloride, and sulfate) increases in water, electrical conductivity increases (Kelin *et al*., 2005).

The microbiological quality of drinking water can be significantly affected by turbidity. Highest value of turbidity was obtained at *Station # 2* with mean value of 1.27 NTU while lowest value was observed at over head tank at I-8 with mean value of 0.34 (Figure 1). Similar results were also reported by National Water Quality Program, (PCRWR, 2005). On the other hand, Heterotrophic plate count (HPC) increases with parallel increase in turbidity as reported earlier by Snead, 1980. Similarly, Chlorine (as hypochlorous acid) reacts readily with organic matter containing unsaturated bonds, phenolic groups and nitrogen groups, giving rise to taste- and odor-producing compounds and trihalomethanes (THMs). Hence, waters with high turbidity from organic sources may give rise to a substantial chlorine demand and so is unavailable to kill pathogens (Crump, 2004). This could result in reductions in the free chlorine residual in distribution systems as protection against possible recontamination.

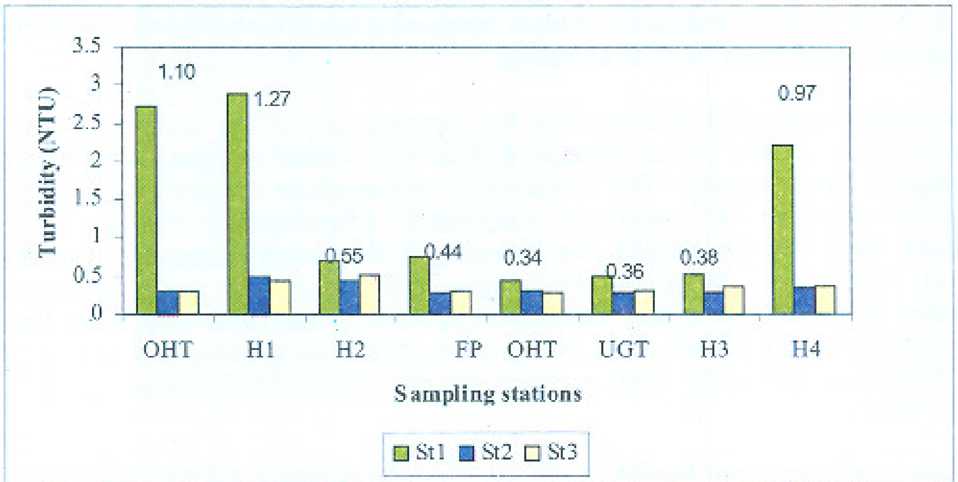

Figure 1: Values of Turbidity obtained at different sampling stations of sector I-8

The value of total residual chlorine varied from 0.05 mg/L at *Station # 3* to 0.13 at *Station # 1*. Free chlorine residual was also detected in the system with average values varying from 0.02 mg/l at *Station # 3* to 0.09 at *Station # 1*(Figure 2). Minimum level of monochloramine available at consumer end was detected at *Station # 3* with mean value of 0.01mg/L and maximum level was obtained at *Station # 6* with mean of 0.08 mg/L. Values of dichloramines ranged from 0.17 to 0.06 mg/L at *Station # 3* and *6*.

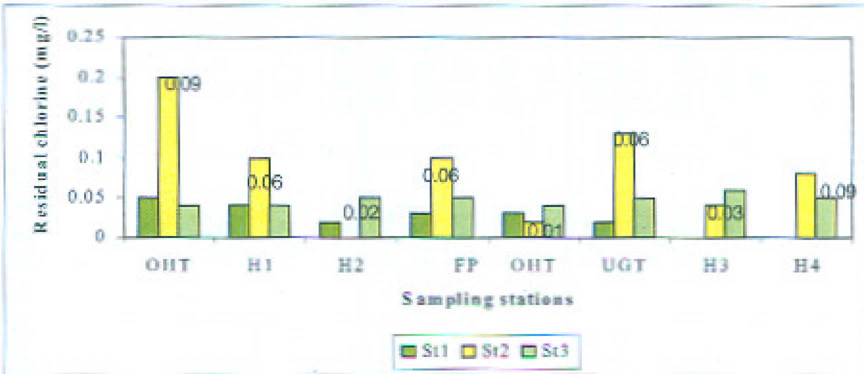

Figure 2: Values of Residual chlorine obtained at different sampling stations of Sector I-8.

Most probable number (MPN) test was conducted to determine the presence of *total coliform* and *fecal coliform* in drinking water samples. Microbial analysis of drinking water samples revealed that fecal contamination was detected at *Station # 3* with MPN /100mL of 16.1, at *Station # 5*and *7* MPN/100 mL was 6.9 and at *Station # 8* MPN/100ml was 5.1. While at the rest of the stations MPN/100 ml was <1.1 indicating that there was no presence of *fecal coliform* (Figure 3).

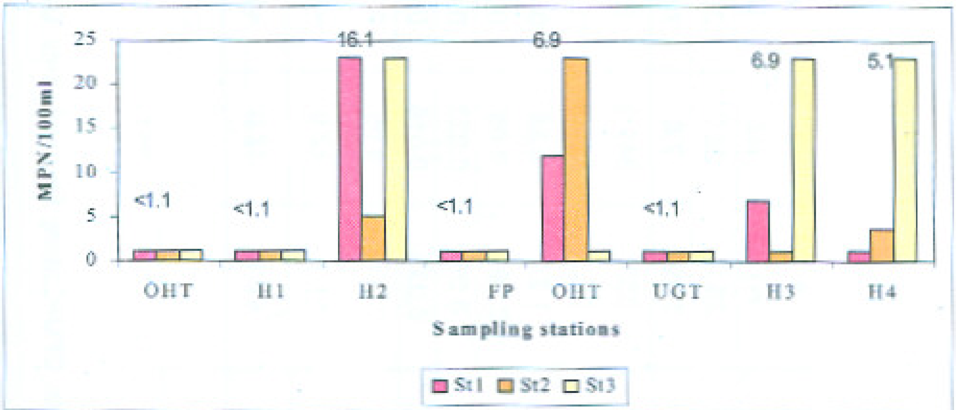

Figure 3: Values of *fecal coliform* count obtained at different sampling stations of sector I-8

The standard plate count (SPC) is considered by some scientists to be a better indicator of potable water quality than the coliform index (Geldreich, 1972).The viable count was measured by the SPC. The maximum SPC counts were observed at *Station # 3* with values ranging from 81 to 370 CU/mL with average value of 267 CFU/ml. At the rest of the stations SPC counts were below countable range. These results are in line with the study conducted by Le Chevallier *et al.*, (1980). So from the analysis it revealed that water sample from *Station # 3* was highly contaminated, this may be due to cross contamination of water supply line with sewage water and unhygienic condition of under ground storage tank (Figure 4). The cumulative values of all the parameters are given in Table-1.

Table 1: Mean value of Microbial and Chemical Analysis of Water Samples Collected from Residential area of I-8 during July & August 08*

Water Parameters	Station Numbers							
	1	2	3	4	5	6	7	8.
Station Name	**UGT**	**H1**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**
Temp in °C	25.6	26.2	26.7	25.8	26.13	5.8	25.76	20.06
pH	7.10	7.26	7.6	7.62	7.41	7.24	7.56	7.21
TDS (mg/l)	354	353	343.3	339	362.3	368	363	357
Conductivity(µS/cm)	714	718	689.6	683.6	737	749	739	726
Turbidity (NTU)	1.10	1.27	0.55	0.45	0.34	0.36	0.38	0.97
Total Chlorine (ppm)	0.13	0.093	0.05	0.27	0.06	0.12	0.12	0.06
Free chlorine	0.09	0.06	0.023	0.06	0.03	0.06	0.033	0.043
Monochloramine	0.04	0.033	0.016	0.02	0.023	0.05	0.07	0.06
Dichloramines	0.03	0.006	0.05	0.05	0.04	0.06	0.046	0.053
Total Coliform (MPN index/100ml)	<1.1	<1.1	12.0	<1.1	9.2	<1.1	6.9	5.1
Fecal Coliform (MPN index/100ml)	<1.1	<1.1	12.0	<1.1	9.2	<1.1	6.9	5.1
Range 95% Probability	0-3.0	0-3.0	4.3-27.1	0-3.0	3.1-21.1	0-3.0	2.1-16.8	1.3-13.4
CFU /ml	5	12	267	2	36.3	0	3	2

NTU=Nephlometric turbidity units, **CFU**=Colony Forming Units, **UGT**=Underground tank, **H (1, 2, 3, 4, 5, 6,7)** = Consumer houses

* Based on mean of three replicates (Dated: 20/08/08, 02/09/08, 11/09/08)

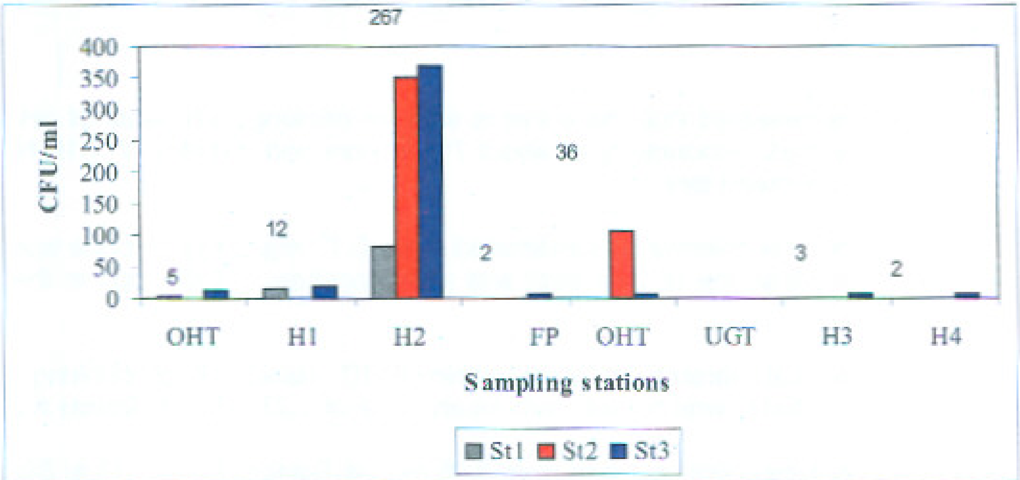

Figure 4: Values of SPC counts obtained at different sampling stations of sector I-8

The water samples collected were also analyzed for TOC. The analysis results were alarming as high amount of TOC was observed at all of the sampling stations which were above standards of treated drinking water i.e., above 2 mg/L. The values were found to be ranging from 7.67 to 22.57 mg/L. The main water supply had a TOC value of 11.22 mg/l. These are in line with the study conducted by Wallace *et al.*, (2002) (Figure 5). According to their study, TOC monitoring is required monthly for one source water and one treated water sample. If the TOC levels of the source water average less than 2mg/L^{-1} C for two consecutive years, or the treated water average is less than 1mgL^{-1} C

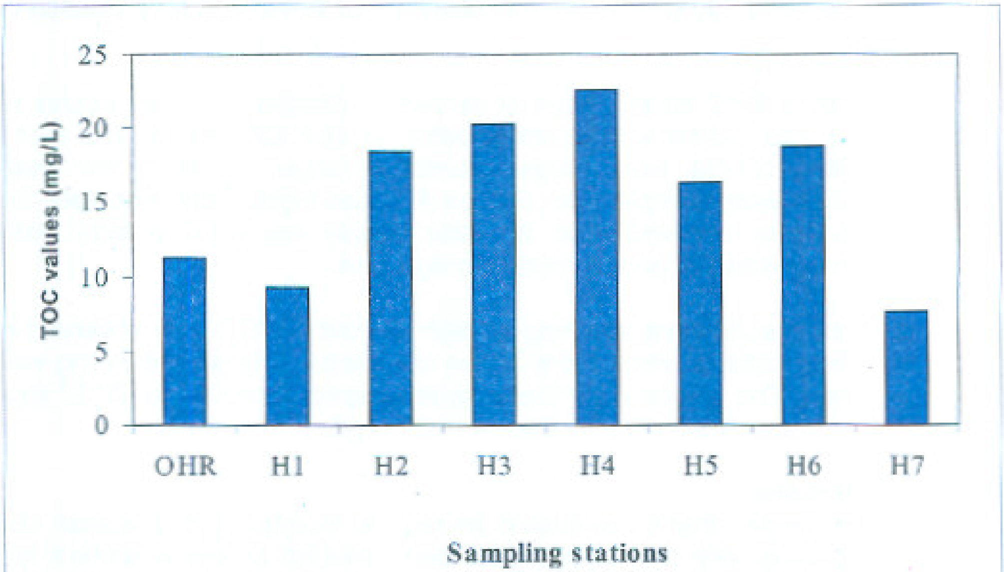

Figure 5: Average values of TOC obtained at different sampling stations of sector I-8