Physicochemical and Bacteriological Analysis of Water used for Drinking Purposes within a Residential University

Sara Ishaque, Zainab Nisar, Sabah Iqbal, Manan Abbas, Imran Hashmi
Institute of Environmental Sciences and Engineering (IESE)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences and Technology (NUST), Islamabad
imranhashmi@iese.nust.edu.pk ; hashmi71@gmail.com

Abstract

This study was carried out to highlight the emerging concerns related to drinking water contamination and to assess mainly the bacteriological quality of drinking water supply within a residential university. A total of sixteen (16) samples were collected from specified sites that included tube wells, underground and overhead reservoirs, filtration plants and electric water filtration coolers. These samples were analyzed for both bacteriological and physicochemical parameters (pH, temperature, turbidity, TDS). The samples had pH ranging from 6.6-7.8 and turbidity ranging from 0.18-0.63 NTU. The results of these parameters are satisfactory since they are within the permissible limits, whereas bacteriological estimation of the samples was accomplished using the standard membrane filtration method. The coliform count for the drinking water samples ranged between 9-287 CFU/100ml. Supply of pure drinking water, which is free from contamination and bacteria, is the fundamental duty of any government or organization. Such a drinking water supply system helps to promote wealth and welfare of publics and economic level. In the present work, the evaluation of drinking water quality status and possible source of contamination of drinking water within the residential university was studied.

Keywords: drinking water, distribution network, coliforms, filtration, contamination

Introduction

A large portion of the population in developing countries suffers from health problems associated with either lack of drinking water or due to the presence of microbiological contamination in water [1]. The risk from the presence of microbial pathogens in drinking water is estimated to be several orders of magnitude greater than the risk from chlorination by-products. Chlorine remaining in the water supply, or added after disinfection, is available to fight against potential contamination in water distribution and storage systems that might enter through leaks and pipe breakages. Residual chlorine concentrations of approximately 0.2-0.3 mg/L are often maintained in distribution systems to serve as a sentinel for the entry of pollution and to prevent the growth of nuisance bacteria and other organisms.

Poor water quality is responsible for the death of an estimated 5 million children in the developing countries [2]. The problem is further aggravated by rapidly increasing population which results in poor water quality management [3]. According to a report by World Health Organization (WHO), 3.575 million people die each year of water related diseases. Almost 884 million people worldwide lack access to safe water supplies; about one in eight people. It is estimated that every 20 seconds a child dies due to water related illness [4- 5]. In Pakistan; despite of the low quality of groundwater and surface-water it is further being deteriorated because of unchecked disposal of untreated municipal and industrial wastes [6]. The Pakistan Council of Research and Water Resources assesses that 40 percent of all reported illnesses are water-related. According to Pakistan National Conservation Strategy (1992) about 40 per cent of communicable diseases like infectious hepatitis, gastroenteritis, diarrhea, typhoid giardiasis, intestinal worms, trachoma and scabies, in Pakistan are water borne and 30 to 40 per cent of the population (served through piped water) is deprived of safety measures. 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 [7].

Thus there is a need to find out where the actual problem lies; whether the water sources are contaminated or lapses occur in the distribution system. Prevention and protection of drinking water exists in documents in Pakistan as National Drinking Water Policy but it has no strategic implementation. So WHO guidelines are not followed [8-9]. Disinfection of potable water is most crucial for ensuring public health. Water disinfected for the duration of 30 minutes at 0.5 mg/L of free residual chlorine at turbidity of less than 1 NTU, accompanying with less than 8 pH , is considered as safe for Drinking [10]. This safety lays its foundations on the absence of Total coliform bacteria or their presence within the permissible limits, also termed as indicator microorganisms. This can be referred to as an indicator of treatment efficiency, *Escherichia coli* of which is most suitable for fecalcontamination [11]. It is found in human and animal faces, sewage and water that come in contact with fecalcontamination. The purpose of this review is not to discuss the indicator concept, but rather to assess water quality currently in use by estimating the bacterial and physicochemical properties of water in its regime.

Materials and Methods

Sampling Sites

Samples were collected from tubewells feeding the water distribution network, underground and overhead reservoirs, filtration plants, consumers end sites including residential colony and hostels of a public university in Islamabad. These water samples were analyzed for four physicochemical properties including pH, temperature, turbidity, TDS and spread plate count as per standard methods [12]. Samples were collected from the sixteen (16) stations as shown in Table 1.

Sampling: Water Samples were collected in sterile glass bottles as per WHO guidelines to determine and validate the mean qualitative parameters of drinking water. Samples were stored in ice box and taken to the laboratory for microbiological and physicochemical assessment, within 20 hrs of sampling.

Table 1: Sampling Stations and their Nomenclature

Sr. No	Location	Detail
1	*L1*	Underground Reservoir 1
2	*L2*	Underground Reservoir 2
3	*L3*	Underground Reservoir 3
4	*T1*	Tube well 1
5	*T2*	Tube well 2
6	*T10*	Tube well 10
7	*CFP 1*	Colony Filtration Plant 1
8	*CWC*	Colony Water Cooler
9	*CFP2*	Colony Filtration Plant 2
10	*BFP*	Barracks Filtration Plant
11	*SFP*	School Filtration Plant
12	*H1FP*	Hostel 1 Filtration Plant
13	*H2WC*	Hostel 2 Water Cooler
14	*H3WC*	Hostel 3 Water Cooler
15	*H4WC*	Hostel 4 Water Cooler
16	*H5FP*	Hostel 5 Filtration Plant

Physicochemical Analysis: Physicochemical analysis of water reflects the cogency of drinking water quality evaluation. It is though vital to check its compliance with the established quality criteria and efficiency for distribution network and filtration facilities. Very basic parameters were evaluated onsite for this purpose, which included temperature, pH (Hach pH meter sension 1), turbidity(Hach 2100) and TDS (Hach meter sension 5).

Results and Discussion

The results of the physico-chemical analysis of drinking water samples collected from different sampling points of the residential university are presented in Table 2. Results show that the treated water meets WHO standard in terms of pH, TDS, conductivity, and turbidity and all lie within the permissible limits.The value of turbidity ranged from 0.18 to 0.63 NTU well within the Highest Desirable Level (HDL) values of WHO i.e. < 1 NTU (Figure 1). Turbidity, defined as the interference of light passage through water by insoluble particles, is an important indicator to determine water quality and often, filtration effectiveness [13 & 14]. Egorov *et al*. [15] has reported that an increase in water turbidity of 0.8 nephelometric turbidity units in Cherepovets, Russia, was associated with a 47% increased risk for diarrhoeal illness. Due to the increased amount of precipitates in the water from corrosion, the amount of particulate matter (and thus turbidity) increases [16].

Temperature observed at the time of collection of water samples ranged from 21.1 to 22.7 °C as shown in table 2 which is above WHO limits of 12°C. Water temperature is crucial for microbiological water quality. Bacterial growth rates, decay of disinfection residual, corrosion rates and even distribution hydraulics are all affected by water temperature [17]. The pH value measured for water samples varies from 6.6 to 7.8 and all the values are well within the WHO permissible limit of 6.5–8.5. These results are in accordance with the earlier study conducted by Hashmi *et al*. [18] in which the pH values varied from 7.02–7.30. Depending on a number of characteristics of the distribution system, pH can be a strong determining factor in the bacterial and chemical quality of water. The pH and temperature profiles are given in Figure 2. Similarly the total dissolved solids (TDS) values of collected samples ranged from 269 to 331 mg/L not exceeding WHO limit of 500 mg/L and conductivity values varying from 484 to 619 µS/cm (Figure 3). These results are also in agreement as reported by Hashmi *et al*. [19]. Total dissolved solids represent the amount of inorganic substances (e.g. iron, salts) that are dissolved in the water. High total dissolved solids (TDS) can reduce the palatability of water or cause health problems if specific constituent elements are at high levels.

Microbiological Analysis

Detection of Coliform and fecal coliform bacteria in drinking water distribution network are indicators of microbiological quality of water being supplied to consumers. Drinking water regulations under the *Final Coliform Rule* require that total coliform-positive drinking water samples be examined for the presence of Escherichia coli or fecal coliforms. Membrane filtration methodwas adopted to evaluate water quality by measuring the total and fecal coliform count [12]. As drinking water can be declared fit for consumptive use if it satisfies the set parameters as per WHO guidelines [9]. The value of colony forming units ranged from 9-287 CFU/ml. Higher counts were obtained at ground water reservoirs, water coolers and filters, whereas lower counts were obtainedat tube wells. The counts obtained for all the collected samples were reported to be unsatisfactory and above the maximum allowable limits set by the National Drinking Water Quality Standards Pakistan and the WHO guidelines. Coliform presence in the water supply indicates that there is a possibility of wastewater intrusion into the system and lower residual chlorine availability. The contamination in the

Table 2: Physiochemical and Microbial Analysis

Sr. No	Location	pH	TDS (mg/l)	Conductivity (µS/cm)	Temp^{o}C	Turbidity (NTU)	CFU/100ml
1	*L1*	7.1	310	583	22.1	0.39	19
2	*L2*	7.2	313	605	22.3	0.309	286
3	*L3*	7.4	331	604	21	0.325	46
4	*T2*	7.3	309	593	21.8	0.23	1
5	*T10*	7.2	313	605	22.3	0.309	284
6	*CFP1*	7.2	319	603	21.9	0.188	9
7	*CWC*	7.1	323	618	21.1	0.19	231
8	*BFP*	7.5	315	573	22.4	0.295	54
9	*CFP2*	7.8	269	484	22.7	0.215	213
10	*H2WC*	6.9	316	595	22	0.63	287
11	*H3WC*	6.8	278	531	22.2	0.213	123
12	*H4WC*	7.1	286	543	22.3	0.21	216
13	*H5FP*	6.7	331	592	22	0.23	102
14	*SFP*	6.8	310	603	21	0.21	102
15	*H1FP*	6.6	308	619	22	0.31	213
16	*T 1*	7	306	490	22	0.33	33

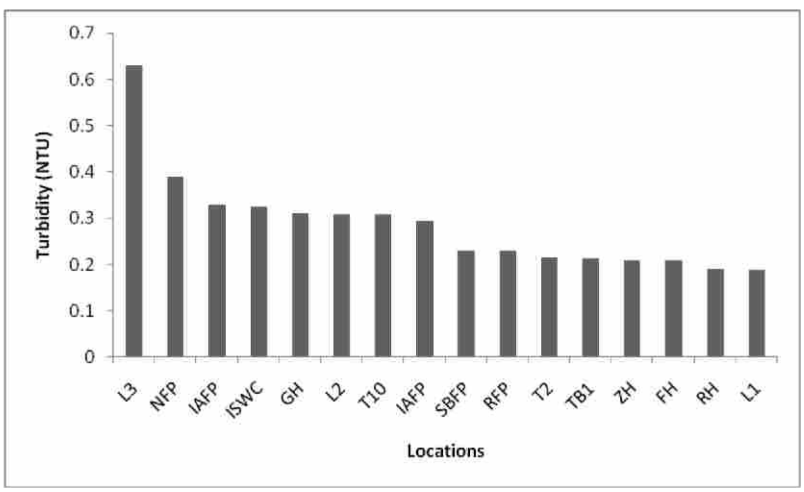

Fig. 1: Turbidity profiles of water samples collected from various sampling stations

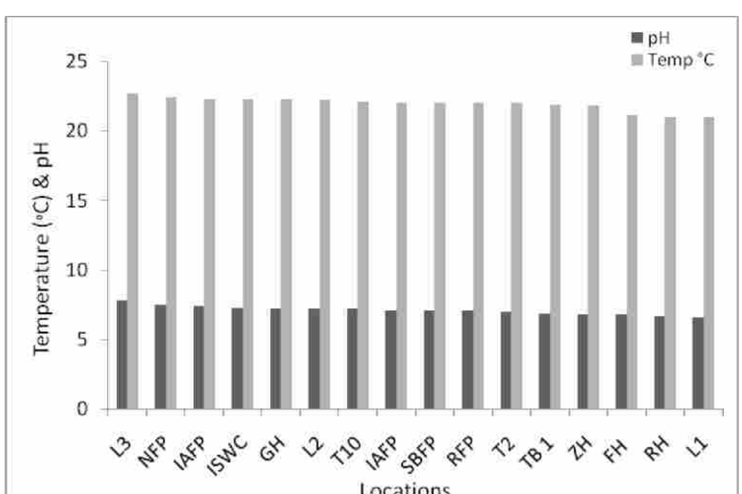

Fig. 2: pH and Temperature profiles of the water samples against sampling sites

samples from the filtration plants and the electric water filtration coolers revealed that the filters are not capable of retaining *Escherichia coli* and UV lamp are nonfunctional.

Coliform countsvs. Turbidity

A relationship between colony forming units and turbidity is shown in Figure 4 where seventy nine percent of the variation in total coliform concentration is accounted for presence of turbidity in drinking water. Turbidity and coliform count are moderately correlated to each other. When the turbidity of water increases coliform count also increases. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa [20]. The particles which contribute to turbidity provide nutrients and shelter for microbes reducing their exposure to attack by disinfectants. Microbial attachment to particulate material or inert substances in water systems has been documented by several investigators [21-22] and can aid in the survival of microbes [23].

Coliform countsvs. Total Dissolved Solids (TDS)

Thelinear regression value between colony forming units and TDS is less then 70% which shows a weak relationship. The TDS of collected samples were all less the 500mg/ and little variations between stations has been observed (Figure 5).

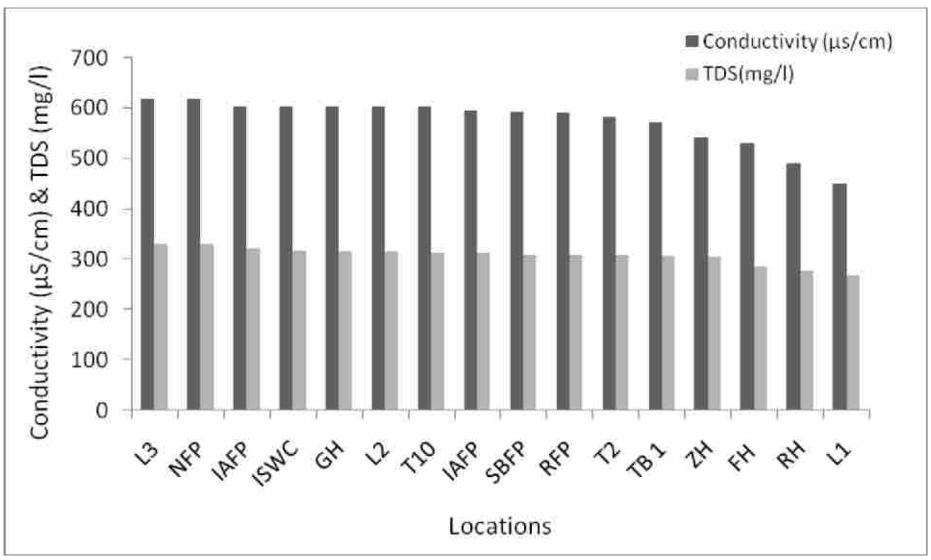

Fig. 3: Conductivity (µS/cm) and TDS (mg/l) profiles of the water samples collected from various sites

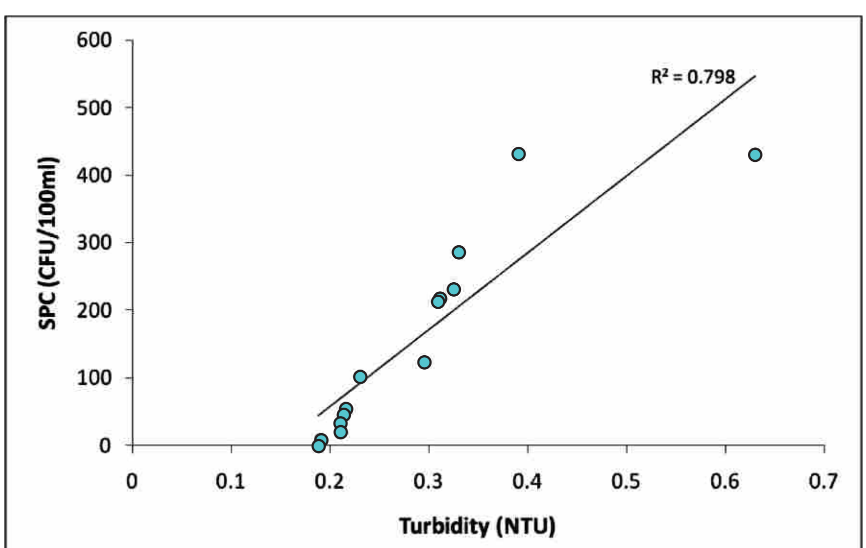

Fig. 4: Linear Correlation between colony forming unit per 100 ml of sample and turbidity

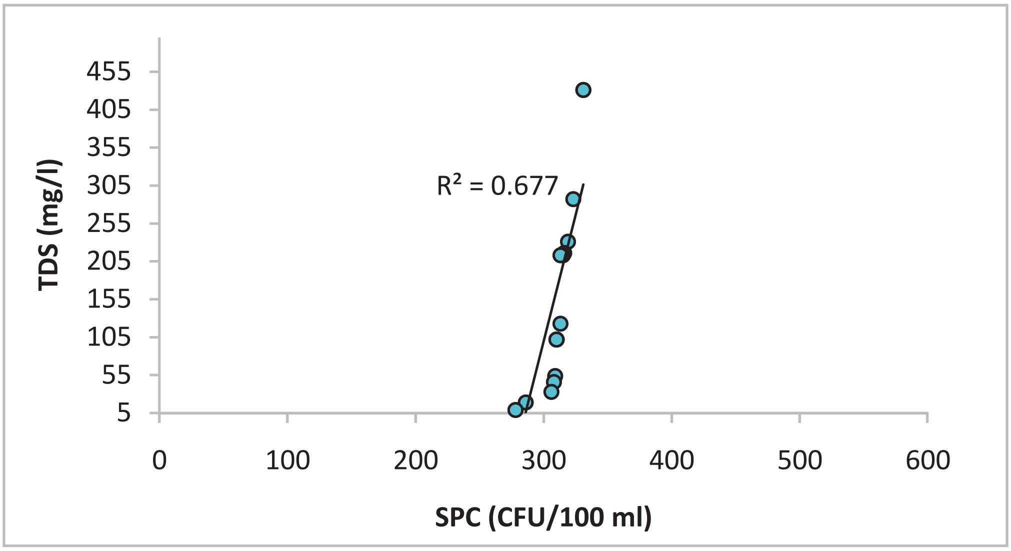

Fig. 5: Linear Correlation between colony forming units per 100 ml of sample and total dissolved solids

Conclusions

The physico-chemical parameters were within the WHO standards. The microbiological analysis revealed that coliform count of the samples is significantly high ranging between 9-287 CFU/100ml. The water samples collected from tubewells were less contaminated as compared to the storage reservoir samples which showed high coliform counts. Water samples from the filtration plants and electric water filtration coolers also had high coliform counts, thus the filters installed are highly inefficient. Regular monitoring of chlorineand inspection of filters and UV installed at filter plants is essential to ensure the availability of safe drinking water to the people.

Recommendations

- It is recommended that distribution network be inspected and maintained regularly.
- Inspection of storage reservoirs for slime development and their regular maintenance is required
- Preferable solution for more efficient removal of coliforms is Reverse Osmosis and UV disinfection.
- Titanium dioxide (TiO_2) photo catalysis is a possible alternative/complementary drinking water treatment method [24].
- Research shows that Antimicrobial nanomaterial's can be used for water disinfection and microbial control [25].

Acknowledgments

We are thankful for the Undergraduate Environmental Engineering Research Project Grant awarded to us by the Institute of Environmental Science and Engineering (IESE), School of Civil and Environmental Engineering (SCEE), National University of Sciences and Technology (NUST), Islamabad.We are also grateful for the COMSTECH-TWAS Research Grant No: 10-213 RG/ENG/AS_C-UNESCO for the accomplishment of project activities.

REFERENCES

1. F.X.R Van Leeuwen, “Safe drinking water: the toxicologist's approach”, Journal of Food and Chemical Toxicology, Vol. 38, No. 1, 2000, pp. 51-58.
2. S. Haydar, M. Arshad and J.A. Aziz, “Evaluation of Drinking Water Quality in Urban Areas of Pakistan: A Case Study of Southern Lahore”, Pakistan Journal of Engineering and Applied Sciences, Vol. 5, 2009, pp. 16-23.
3. G.H. Huang and J. Xia, “Barriers to sustainable water-quality management”,Journal of Environmental Management, Vol. 61, No.1, 2001, pp. 1-23.
4. World Health Organization, “Safer Water, Better Health: Costs, benefits, and sustainability of interventions to protect and promote health”, 2008.
5. World Health Organization, “Disease Outbreaks News”, World Health Organization Communicable Disease Surveillance and Response (CSR), 2013.
6. PCRWR, Pakistan Council of Research in Water Resources, “National Water Quality Monitoring Programme Report”,2007.
7. UNDP, Pakistan National Human Development Report, “Water Crisis”, Karachi, Vol.7, 2003, pp. 103.
8. World Health Organization, “Guidelines for drinking-water quality”, Geneva, 3rded, vol. 1, 2004, pp. 143-220.
9. World Health Organization, “Guidelines for drinking-water quality”, Geneva, 2nd ed, Vol. 2, 1996, pp. 991.
10. World Health Organization, “Guidelines forDrinking Water Quality”, Geneva, 2nded, Vol.1, 1984.
11. N.J. Ashbolt, W.O.K. Grabow and M. Snozzi,“Indicators of microbial water quality”, L. Fewtrell, J. Bartram, eds., Water quality—Guidelines, standards and health: Assessment of risk andrisk management for water-related

infectious disease WHO water series, London: IWA Publishing, 2001, pp. 289–315.

12. APHA, American Public Health Association, “Standard Methods for the Examination of Water and Wastewater”, Washington, D.C., 20thed, 2005.
13. M.J. Hammer and M.J.J. Hammer, “Water and Wastewater Technology”, P.H. Upper Saddle River, 4 ed., New Jersey, 2001.
14. US Environmental Protection Agency, “National Primary Drinking Water Standards”, Washington, D.C., 2003.
15. A. Egorov, T. Ford, A. Tereschenko, N. Drizhd, I. Segedevich and V. Fourman, “Deterioration of drinking water quality in the distribution system and gastrointestinal morbidity in a Russian city”, International Journal of Environmental Health Research, Vol. 12, No.3, 2002, pp. 221–233.
16. T. Juhna and M. Klavins, “Water-quality changes in Latvia and Riga 1980-2000: possibilities and problems”, Ambio, Vol. 30, No. 4-5, 2001, pp. 306–314.
17. M.W. LeChevallier, N.J. Welch and D.B. Smith, “Full-scale studies of factors related to coliform regrowth in drinking water”, Applied Environmental Microbiology, Vol. 62, No. 7, 1996, pp. 2201–2211.
18. H. Imran, F. Shaukat and Q. Sara, “Incidence of fecal contamination within a public drinking water supply in RattaAmral, Rawalpindi”,Desalination and Water Treatment, Vol. 11, No. 1-3, 2009, pp. 124-131.
19. H. Imran, Q. Sara and F. Shaukat, “Microbiological quality of drinking water in urban communities, Rawalpindi, Pakistan”, Desalination and Water Treatment, Vol. 41, 2012, pp. 240-248.
20. K.C. Marshall, “Interfaces in Microbial Ecology”, Harvard University Press, Cambridge, MA, 1976.
21. B. H. Olson, H. F. Ridgway and E. G. Means, “Bacterial colonization of mortar-lined and galvanized iron water distribution mains”, Proceedings of National Conference on AWWA, Denver, CO, 1981.
22. D.S. Herson, D.R. Marshall and H.T. Victoreen, “Bacterial persistence in the distribution system”,Journal of American Water Works Association, Vol. 76, 1984, pp. 309-22.
23. NAS, National Academy of Sciences, National Research Council: Drinking Water and Health, National Academy Press, Washington, D.C., Vol. 2, 1980.
24. P.S.M. Dunlop, J.A. Byrne, N. Manga and B.R. Eggins, “The photo catalytic removal of bacterial pollutants from drinking water”, Journal of Photochemistry and Photobiology A: Chemistry, Vol. 148, No. 1-3, 2002, pp.355–363.
25. L. Qilin, M. Shaily, Y.L. Delina, B. Lena, V.L. Michael, L. Dong and J.J.A. Pedro, “Antimicrobial nanomaterials for water disinfection and microbial control: Potential applications and implications”, Water Research, Vol. 42, No. 18, 2008, pp. 4591–4602.