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Micro-pollutant risks associated with using recycled water

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Abstract

Overwhelming demand of water with the modernization of globe consequences paucity as the total amount of fresh water remains fixed. In this vision, reclaimed water from wastewater instead of disposing it to the environment has become one of the viable options in the integrated water resources management over the few decades. The most common sources of recycled water are treated sewage effluent, stormwater runoff, domestic greywater and industrial wastewater. This water can be used for both agricultural and landscape irrigation, industrial reuse, environmental and recreational uses, groundwater recharge, non-potable purposes such as toilet flushing, indirect or direct potable reuse. Instead a long history of water reuse in different parts of the world, the question of safety and issue of health risks are being hotly debated. The most common human microbial pathogens found in reused water are enteric pathogens such as viruses, bacteria, protozoa and Helminths. Moreover, long term health risks may be associated with chemical contaminants such as pharmaceutically active compounds (PhAC), pesticides, personal care products (PCPs), endocrine disrupting compounds (EDC) and disinfection by-product (DBPs) in reclaimed water. However, this paper discusses about the micro-pollutant risks associated with reclaimed water particularly on agriculture, indirect potable reuse and toilet flushing.

Keywords: Micro-pollutants, Recycled water, Agriculture, Indirect potable reuse, Toilet flushing

1. Introduction

Water is the hub of life and indispensable part of all terrestrial ecosystems (Vo 2007). Growing demand of water with the modernization of the earth consequences paucity as available water remains as a fixed source. Nevertheless, in the scientific community it is believed that knowledge and human ingenuity will ultimately solve water scarcity problems through the efficient improvement of freshwater production (Medeazza 2004). In this vision, recycled water seems very promising. Even in space exploration recycled water has been a challenge. In short term missions water transported and produced abroad the space shuttle can be adequate (Choia, Stathatosb & Dionysioua 2007). But for long duration missions, recycle water is necessary in order to confirm self-sufficiency and sustainability (Choia, Stathatosb & Dionysioua 2007). One of the main goals in the biological and physical research enterprise of the national Aeronautics and Space Administration (NASA) is to improve the conditions of space habitation for extended on-orbit missions (Advanced Life Support Project Plan 2002 cited in Choia, Stathatosb & Dionysioua 2007). Hence acceptance of recycle water is gaining not only in the planet but also in space exploration.

Over the few decades reclaimed water from wastewater instead of disposing it to the environment has become one of the viable options in integrated water resources management (Asano 2005). The most common wastewater considered for recycling water is treated sewage effluent, besides stormwater run-off, domestic greywater and industrial wastewater are used for this purpose as well (Toze 2006a).

It can be applied for both agricultural and landscape irrigation, industrial reuse, environmental and recreational uses, groundwater recharge, non-potable purposes such as toilet flushing, indirect or direct potable reuse. This is undoubtedly reducing dependency on conventional water sources and contributing to sustainable water resources management. It has several advantages (Asano 2005) :

- Conserving high quality water supplies by substituting reclaimed water for applications which doesn't need that quality.
- Augmenting potable water sources and providing alternate source to meet the present and future demand.
- Protecting aquatic ecosystems by reducing the diversion of freshwater, decreasing the quantity of nutrients and other toxic contaminants by entering waterways, ignoring additional water resources via dams and reservoirs with considerable economical and environmental expenditures.
- Complying with environmental regulations and liability by better managing water consumption and wastewater discharges.

Instead a long history of water reuse in different parts of the world, the question of safety and issue of health risks are a matter of controversy. The level of treatment required for each type prior to reuse depends on the opportunity for – and degree of contamination from – faecal material, domestic and industrial chemicals and nutrients, both organic and inorganic (Toze 2006a). The general rule is that the greater the chance of faecal contamination of water, the greater the health risk and hence the greater potential for treatment required. Therefore, sewage effluent is the most contaminated form in regard to others (Toze 2006a).

The most common human microbial pathogens found in water are enteric pathogens such as viruses, bacteria, protozoa and helminths (Toze 2006a). They usually enter the environment in the faeces of infected hosts and can go into water either directly through defecation into water or from run-off from soil and other land surfaces (Toze 2006a).

Virus:

Enteric viruses have low-dose infectivity (the ingestion of as few as 10 viral particles or less), long-term survival in the environment, monitoring difficulties and limited extent of removal and inactivation that usually occurs in conventional wastewater treatment (Asano 2005). They are the smallest of the pathogens found in water and this parasites force the host cell to produce multiple copies of the virus (Toze 2006a). Only human faecal contamination of water needs to be considered as a risk for viral infection of human (Toze 2006b).

Bacteria:

Bacteria are one of the most common microbial pathogens found in recycled waters. Many of the bacterial pathogens are enteric in origin, yet bacterial pathogens which cause non-enteric illness (e.g., *Legionella* spp., *Mycobacterium* spp., and *Leptospira*) are also detected in wastewaters (Toze 2006a). Bacterial pathogens are metabolically active micro-organisms and are capable of self-replication in the environment (Toze 2006b). The majority of pathogenic enteric bacteria require ingestion of a high dose of cells to be ingested to cause infection (usually $>10^6$ cells), although *Shigella dysenteriae* and *Campylobacter jejuni* have been required the ingestion of as few as 100 cells to cause infection in susceptible hosts (Toze 2006a).

Protozoa:

Like the enteric viruses, all human protozoan pathogens are significantly more infectious than most enteric bacterial pathogens (Toze 2006a). Enteric protozoan pathogens are unicellular eucaryotes which are obligate parasites and outside of an infected host they persist as dormant stages known as cysts or oocysts (Toze 2006b).

Helminths:

Helminths (nematodes and tape worms) are common intestinal parasites which are transmitted through the faecal–oral route and have a simple life-cycle with no intermediate hosts (Toze 1997 cited in Toze 2006b).

Moreover, recent studies in environmental toxicology and pharmacology have suggested that long term health risks may be associated with chemical contaminants such as pharmaceutically active compounds (PhAC), pesticides, personal care products (PCPs), endocrine disrupting compounds (EDC) and disinfection by-product (DBPs) in reclaimed water (Asano 2005). The origin of PhACs and EDCs are either from industrial and domestic sources and hence can be detected in a wide range in recycled water (Toze 2006a). These are present in treated recycled water at very low concentration (usually in the range of ng/l) and require ingestion of high doses over longer period to affect clinically (Toze 2006a).

Endocrine disrupting chemicals:

Certain synthetic and natural compounds that could mimic natural hormones in the endocrine systems of animals are now collectively known as endocrine-disrupting compounds (EDCs) and have been linked to a variety of adverse effects in both humans and wildlife (Snyder et al. 2003). Known and suspected EDCs that can be found in wastewaters and the environment include the estradiol compounds commonly found in the contraceptive pill, phytoestrogens, pesticides, industrial chemicals such as Bisphenol A and Nonyl Phenol, and heavy metals (Lintelmann et al. 2003 cited in Toze 2006a). Many of these substances are resistant to conventional wastewater treatment and may persist in the environment for some time (Jiméneza 2006).

Pharmaceutically active compounds:

The majority of PhACs detected in environmental waters and waste waters are drugs used for a variety of therapeutic uses both for humans and animals which include analgesics such as Ibuprofen, caffeine, antiepiletics, cholesterol reducing drugs such as atorvastatin (common brand name Lipitor), antibiotics and antidepressants (Toze 2006b).

Heavy metals:

When the source of recycled water is industrial waste then the influence of heavy metals needs to be considered in case of specially irrigation that could pose health risk (Toze 2006b). Some examples of heavy metals are iron, cobalt, copper, manganese, molybdenum, zinc, so on.

Overall effects on health and environment by micro pollutants related to agriculture, indirect potable use & toilet flushing are discussed underneath.

2. Agriculture

Wastewater (even raw wastewater, typical numbers of excreted organisms in raw wastewater for irrigation are given in table-1) is generally used for irrigation in developing countries because of shortage of water, availability of wastewater and boosting up productivity due to its fertilizing properties (Jiméneza 2006). Moreover, it is known that one-tenth or more of the world's population consumes crops irrigated with wastewater (Jiméneza 2006). In contrast, such un-controlled wastewater consequences detrimental health effects to humans and cattle for presence of pathogens and toxicity to plants and reduction of soil productivity due to existence of some substances (Jiméneza 2006).

Table 1
Typical numbers of excreted organisms in raw wastewater
(Kamizoulis 2008, p.155)

Organism	Numbers in wastewater (per L)
Bacteria	
Thermotolerant coliforms	10^8-10^{10}
Campylobacter jejuni	10-10^4
Salmonella spp.	1-10^5
Shigella spp.	10-10^4
Vibrio cholerae	10^2-10^5
Intestinal helminthes	
Ascaris lumbricoides	1-10^3
Ancylostoma/Necator	1-10^3
Trichuris trichiura	1-10^2
Protozoa	
Crytosporidium parvum	1-10^4
Entamoeba histolytica	1-10^2
Giardia intestinalis	10^2-10^5
Viruses	
Enteric viruses	10^5-10^6
Rotavirus	10^2-10^5

There is obviously a risk of disease transmission through the use of untreated wastewater for vegetable irrigation. In Mexico, the irrigation of vegetable crops with domestic wastewater showed that the highest bacterial contamination was observed in leafy vegetables such as lettuce (37,000 total coliforms/100g and 3600 fecal coliforms/100g) and spinach (8700 total coliforms/100g; 2400 fecal coliforms/ 100g) (Bitton 2005). Moreover, vegetable crops are highly contaminated with *Salmonella*, Entamoeba histolytica (Ercolani 1976, Kowal 1982, Pude et al. 1984 cited in Bitton 2005), *Cryptosporidium* oocysts and Giardia cysts, following irrigation with raw wastewater (Armon et al. 2002 cited in Bitton 2005). Furthermore, outbreaks of diseases like cholera have been associated with wastewater irrigation of vegetables and infections and disease outbreaks caused by parasites can also be linked to this practice (Bitton 2005). For instance, in Chile, the consumption of such raw vegetables was found to be linked with the transmission of *Helicobacter pylori* (Hopkins et al. 1993 cited in Bitton 2005). However, parasitic protozoa found on wastewater irrigated vegetable surfaces don't have any evidence of related disease transmission (Kamizoulis 2008). Additionally, toxic organics generally have a larger size and high molecular weight which are not absorbed by the plants (Pahren et al. 1979 cited in Jiméneza 2006) but some present in the wastewater can remain in fruits and leaves by direct contact (Jiméneza 2006). Study of Rosas et al. (cited in Bitton 2005) reveals that the common rinsing of vegetables with tap water does not reduce the indicator organisms to safe levels.

Microbial pollution also depends on types of irrigation applied and type of crops (Jiméneza 2006). For instance, compared to sprinkler irrigation, surface and subsurface drip irrigation were found to reduce vegetable contamination with *Cryptosporidium* oocysts or *Giardia* cysts (Armon et al. 2002 cited in Bitton 2005). Moreover, outdoors experiments showed a limited penetration of poliovirus into tomato plants when using this irrigation method (Oron et al. 1995 cited in Bitton 2005). Another study by Armon et al. (cited in Jiméneza 2006) is that Zucchini spray-irrigated with poor quality wastewater accumulated higher levels of *Cryptosporidium* oocysts (160–20,000 oocysts/kg) on the surface than other types of crops. Besides the irrigation system, Zucchini has hairy, sticky surfaces and grows close to the ground and thus may concentrate certain types of pathogens on its surface (Jiméneza 2006).

Even soil can be affected with micro-organisms such as bacteria, virus and they eventually contaminate crops. For instance, the concentration of parasite eggs in soil may be high and may reach levels of 6000–12,000 viable eggs/m^2/year and may persist (especially those of Ascaris) for years (5–7 years or more) (Bitton 2005). However, in a study by Aiello, Cirelli & Consoli (2007) reveals the effects of reclaimed urban wastewater for irrigation on tomato fruit quality and hydrological soil behaviour that wastewater application resulted in increased microbial contamination (*Escherichia coli*, Faecal *Streptococci*) on soil surface but increased tomato yield. Another study shows that the poliovirus was detected in the leaves of the plant only when the roots were damaged or cut and the soil was inoculated with poliovirus (Lee, Lesikar & Waller 2003). In addition to that, they also inform that possibility of translocation of pathogens through roots, trees or vines to the edible portion of crops is very low and the health risk associated with eating these crops is negligible. However, it is found from another study that irrigation of food crops that are eaten raw should be restricted (Bitton 2005).

Direct vulnerable group from wastewater irrigation is the farmers and their families. Wastewater contains a variety of excreted organisms and type and concentration depend on the background levels of diseases in the community (Jiméneza 2006). Many pathogens can survive long periods of time in soil or on crop surfaces and thus transmitted to humans and animals (Jiméneza 2006). Most environmentally resistance pathogens that cause main health risk are helminth (parasitic worm) eggs (WHO 1989 cited in Jiméneza 2006). Moreover, helminthiasis are common diseases infested with parasitic worms include the round worm (*Ascarislumbricoides*), the hook worm (*Ancylostoma duodenale* or *Necator americanus*), and the whip worm (*Trichuris trichiura*) (Toze 2006a) and affected populations are 25-33% in the developing countries, less than 1.5% in developed countries, even 90% in regions with poverty and poor sanitary condition (Jiméneza 2006). It mostly affected children under 15 years with problems of pleasing growth and/or impaired fitness (Jiméneza 2006) and approximately 1.5 million of these children can't be cured even after treatment (Silva et al. 1997 cited in Jiméneza 2006). For instance, in Mexico, farmers and their children who worked in fields irrigated with untreated sewage effluent have been observed to have a greater prevalence of round worm infection than the general population (Peasey et al. 2000 cited in Toze 2006b). Besides, other diseases associated with the use of wastewater are cholera, typhoid, shigellosis, gastric ulcers caused by *Helicobacter pylori*, giardiasis, amebiasis, and spoon-shaped nails (Blumenthal and Peasey 2002 cited in Jiméneza 2006). Even the human immunodeficiency virus (HIV) that causes the acquired immunodeficiency syndrome (AIDS) could be transmitted via a waterborne route, but the survival rate was significantly less than poliovirus survival under similar conditions (Lee, Lesikar & Waller 2003). Similarly, there are several protozoan pathogens that have been isolated from wastewater and recycled water sources, among them most commonly detected are *Entamoeba histolytica,Giardia intestinalis* and *Cryptosporidiumparvum* (Toze 2006a). Infection from all three of these protozoan pathogens can occur after consumption of food or water contaminated with the (oo)cysts or through person to person contact (Toze 2006b). The main reservoir for *C. parvum* and *G. intestinalis*is man, but several domestic and wild animals have been observed to be potential reservoirs for these parasites (e.g., cattle can become infected with *C parvum* and then cause infection in humans due to contact with infected bovine faeces) (Toze 2006a). *Cryptosporidium*, *Giardia*, and *Entamoeba* are all observed to have the potential to cause infection with less than 10 (oo)cysts (Toze 2006a). In addition, *Cryptosporidium* is the most significant cause of waterborne disease in United States (Rose et al. 1999). It is of particular concern because of three reasons: the (oo)cysts is extremely resistance to disinfection, can't be killed with routine water disinfection procedures, the disease is not treatable and the risk of mortality ranges between 50% and 85% in the immunocompromised population (Rose et al. 1999). However, generally female households supplement labor input of crops. Thus pathogens can be transformed by female households to other members of the family if basic standards of hygiene are not maintained during household activities such as cooking (Van der Hoek et al. 2002 cited in Jiméneza 2006).

Cattle can be infected by some protozoan if they are survived in crops irrigated by wastewater (Jiméneza 2006). There is strong evidence from the study of Shuval et al. (cited in Jiméneza 2006) that the cattle grazing on the fields irrigated with raw wastewater or drinking from raw wastewater can be severely infected by Taenia, causing cysticerosis. Moreover, limited evidences show that people who consume meat of cattle grazing on wastewater irrigated field or fed crops from such fields can be transmitted by beef tapeworm (*Taenia saginata*) (Jiméneza 2006).

The uptake of the chemicals from the wastewater irrigation to food grown in the soil is an important exposure route for human risk assessment. Among chemical compounds in wastewater, heavy metals and trace organics that can present potential health risks to humans, animals, and agricultural crops (Hammer & Hammer 1986). However, Cadmium is a particular concern when industrial wastewater alone or mixed with sewage is used for irrigation (Jiméneza 2006). It even in much lower doses that visibly affects plants and may be harmful to animals and is stored in the kidney and liver (Jiméneza 2006). Similarly copper which may be harmful to ruminants (cows and sheep but not to mono-gastric animals) at concentrations too low to visibly affect plants (Jiméneza 2006). Moreover, Molybdenum causes undesirable effects in animals consuming forage with 10–20 parts per million and the consumption of crops with more than five milligrams of molybdenum per kilogram of feed is toxic to cattle, particularly ruminants (Jiméneza 2006). Another most prevalent toxicity is boron. It comes from household detergents and industrial sources and the problem of specific ion toxicity can be accelerated when reclaimed water is used in arid areas with high evapotranspiration rates (Lee, Lesikar & Waller 2003). Specific ions may accumulate in soil water, posing human and animal heath hazards and the capability of photosynthesis can be impeded as well (Lee, Lesikar & Waller 2003). Besides, domestic wastewater used for irrigation consequences the accumulation of metals on the upper layer of soil but causes no adverse effect on crops even after long term application (Jiméneza 2006). But wastewater containing industrial effluents with high metal contents does not only accrue on the soil surface but also affect crops and eventually consumers (Jiméneza 2006).

WHO recommends a microbiological quality guideline for wastewater used in agriculture which is given table-2. Irrigation from wastewater causes havoc when it enters surface water and drinking water sources. Because wastewater contains a wide variety of organic compounds (Jiméneza 2006). Exposure to these chemicals causes breast, prostate and testicular cancer, diminished semen quantity and quality and impaired behavioural/mental, immune, and thyroid function in children (Toze 2006b). Moreover, emerging chemical pollutants like EDC can be found in the wastewater used for agriculture. But concentration of EDCs in untreated sewage effluent is up to several thousand times lesser than natural hormones and the risk from different EDCs depends on the estrogenic potency of each organism (Toze 2006a). For instance, the principal human estrogen 17β estradiol has an estrogen equivalent (EEQ) of 1 while DDT has an EEQ of 1×10^{-6} which implies a person would have to consume 1,000,000 parts of DDT to get the equivalent estrogenic response as 1 part of 17β estradiol (Toze 2006a). The concentration of 17β estradiol in raw sewage has been found to be as little as 19 ng/L where as the modern oral contraceptive pill contains between 20 and 35 μg of estrogen (Toze 2006a). Hence it can be estimated that the estimated daily dose for females from the contraceptive pill is 16,675 EEQ, whilst the equivalent daily EEQ dose from environmental organochlorides is 0.0000025 (Toze 2006a). It can be deduced that the low concentration of EDCs in treated recycled water reveals virtually no risk of health concern. While health risk of humans is considered as negligible (Toze 2006b), reproductive abnormalities, altered immune function, and population disruption potentially linked to exposure to these substances have been observed in amphibians, birds, fish, invertebrates, mammals, and reptiles (WHO 1999 cited in Jiméneza 2006). It was reported that gulls living in areas contaminated with DDT exhibited deformed sex organs and skewed sex ratios (Fry & Toone 1981, Fry et al. 1987 cited in Snyder et al. 2003). Moreover, due to the presence of estrogenic-like compounds in the Florida everglades, the Floridian alligators were found to suffer from problems related to size and development of male gonads in Juvenile male alligators (Guillette et al. 1994 cited in Toze 2006b). Another instance is that there was an increase in intersexuality of riverine fish which was linked to the presence of EDCs in UK waterways (Jobling et al. cited in Toze 2006b).

Besides, the concentration of PhACs in treated effluents is much lower than the concentration used in drugs and personal care products (Table-3) and hence there is little health risk if taken up by the crops (Toze 2006b). Major concerns might be associated with the development of antibiotic resistance in soil and water micro-organisms due to the discharge of antibiotics into the environment (Guardabassi et al. 1998 cited in Toze 2006b).

3. Indirect Potable Reuse

Indirect potable reuse is the introduction of recycled water into a system where it may eventually be used as a potable water source (Sedlak, Gray & Pinkston 2000). In most cases, primary source of recycled water is municipal wastewater effluent (Sedlak, Gray & Pinkston 2000). But to overcome the distaste problem of reclaimed water by the consumers, in some cases for extra filtration by the soil treated wastewater is recharged directly or indirectly to reservoir or aquifers for future withdrawal (Gillies 1981). Moreover, artificial replenishment of groundwater has become imperative as this resource is being exhausted because of extensive potable and non-potable use. But there are several environmental issues and health hazards associated with micro-pollutants regarding use of potable water from reservoirs and groundwater.

Table 2
WHO Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture
(WHO 1989 cited in Bitton 2005, p.605).

Category	Reuse condition	Exposed group	Intestinal Nematodes (Arithmetic Mean no. of Eggs per Litre)	Faecal Coliforms (Geometric Mean no. per 100 mL)	Wastewater Ttreatment Expected to Achieve the Required Microbiological Quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consume, public	≤1	≤1000	A series of stabilization ponds designed to achieve the microbiological quality indicated or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture, and trees	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation crops in category B if exposed of workers and public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology but not less than primary sedimentation

Table 3
Concentration of pharmaceutical drugs per dose and concentration in sewage effluents
(Toze 2006a, p.44)

Name	Drug type	Conc. (mg per tablet)	Conc. In sewage effluent ($\mu g\ l^{-1}$)
Ibuprofen	Analgesia	400, 600, 800	0.37
Gemfibrozil	Lipid regulator	600	0.40
Amoxicillin	Antibiotic	250, 500	>100
Ciprofloxacin	Antibiotic	100, 250, 500	0.68
Carbamazepine	Antiepileptic	100, 200, 400	2.1

Microbial contaminants like bacterial, viral, or protozoan or larger organisms along with toxic chemicals are the most common risk factors when producing drinking water (Asano, Takashi & Cotruvob 2004). Moreover, control of virus and protozoa in reclaimed water is of great concern inspite of having meet the microbiological standards of drinking water, e.g., less than or equal to one total coliform bacteria/100 ml, or no detectable *E. coli* per 100 ml (Asano, Takashi & Cotruvob 2004). The reason is that the typical microbial indicators alone are inadequate for that application as reclaimed wastewater derived from municipal wastewater has higher pathogen concentrations than even heavily polluted natural water (Asano, Takashi & Cotruvob 2004). Additionally, study of Foster et al. (Cited in Jiméneza 2006) has informed that some micro-organisms, particularly viruses can reach aquifers if they are present in high concentrations in reused water. Furthermore, persistence of viruses is generally higher in groundwater than in surface waters (Bitton 2005).

Most humic compounds found in reclaimed water are assumed to be by-product of the wastewater treatment process and don't pose any health hazard if consumed in small amount (Karimi, Redman & Ruiz 1998). Whenever they enter potable water supplies they cause health risk because they react with free chlorine to generate disinfection by-products (i.e., THMs) (Karimi, Redman & Ruiz 1998). Moreover, when absorbing to soil particles, immobilized organic matter may act as a food source for the local microbial population (Johnson and Chen 1995 cited in Karimi, Redman & Ruiz 1998).

There are emerging contaminants relevant to groundwater recharge. They are i) trace organics such as: potential endocrine disrupting compounds (EDCs), pharmaceutically active compounds (PhACs), and N-nitrosdimethylamine (NDMA), ii) some trace inorganics and iii) microbes, e.g., nanobacteria $(\approx 0.1 \mu m)$ (Asano, Takashi & Cotruvob 2004). A large portion of the organic chemicals of most types is removed by treatment technologies or remained insignificant amounts which might have unknown concern (Asano, Takashi & Cotruvob 2004). Some PhACs are not completely metabolised after consumption by humans and animals and are excreted in original form and others are converted into other compounds which may be released as parent compound during treatment of sewage (Masters, Verstraten & Heberer 2004). Hence residues and metabolis of PhACS and EDCs have been detected in untreated and treated wastewater at sewage treatment plants and in surface waters receiving treated or untreated agricultural or municipal sewage effluents (Masters, Verstraten & Heberer 2004). Even residues of PhACs are found at low concentration in ground and drinking water (Masters, Verstraten & Heberer 2004). Actually researches are underway to find out the suitable treatment technologies for removing PhACs and EDCs (Masters, Verstraten & Heberer 2004). It is still to be seen if the existing or future ground water recharge techniques will reduce these compounds (Masters, Verstraten & Heberer 2004). In this regard, it will take time to set drinking water regulation as the sources, occurrence, and fate and transport of these compounds and their effects of exposure on human health are not yet up to the mark (Masters, Verstraten & Heberer 2004). Moreover, European Council Directive's 1998 specification (cited in Masters, Verstraten & Heberer 2004) is that drinking water is not allowed to contain chemical substances as it might be injurious to health whereas the German Environment Agency set a threshold standard between 0.1 and 0.3μg/L for each compound (Masters, Verstraten & Heberer 2004).

Pharmaceuticals and personal care products (PPCPs) present in surface water or wastewater may also affect groundwater quality where water is used to recharge groundwater (Drewes et al. 2003). It doesn't have any acute effect on human health but rather manifests imperceptible effects on human and aquatic life with the accumulation over long time (Daughton and Ternes 1999 cited in Drewes et al. 2003). Because of hydrophilic, resistance to biotransformation pharmaceuticals are a potential source of contamination of drinking water sources (Drewes et al. 2003).

There are various sources of pharmaceuticals in groundwater aquifers, mainly from untreated and treated wastewater (Drewes et al. 2003). These substances are not completely eliminated during wastewater treatment or biodegraded in the subsurface environment (Bruser et al. 1999, Heberer et al. 2002 cited in Drewes et al. 2003). Moreover, several studies in Europe indicate that antiepileptic drugs such as carbamazepine and primidone are barely removed during wastewater treatment, bank filtration, and groundwater recharge (Terners 1998, Kuehn & Mueller 2000, Brauch et al. 2000, Heberer et al. 2001, Heberer et al. 2002 cited in Drewes et al. 2003). However, the full extent and ramifications of the presence of PPCPs in groundwater are largely unknown (Drewes et al. 2003).

A conceptual framework for various assays for trace organic compounds and their relative significance to human health risk is shown in the figure-3.

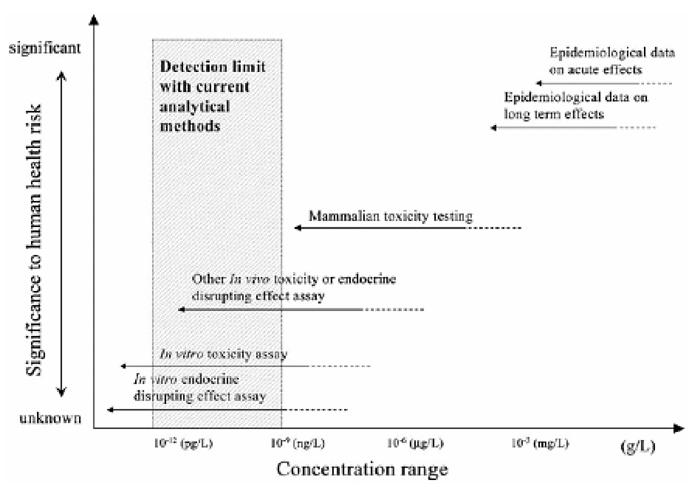

Fig. 3. Conceptual framework for various assays for trace organic compounds and their relative significance to human health risk (Tsuchihashi et al. 2002 cited in Asano et al. 2004, p. 1946)

4. Toilet Flushing

Approximately 30% and 60% of water usage respectively in-home and in commercial buildings are being used for toilet flushing (Lazarova, Hills & Birks 2003). Its practice is observed in different counAstries such as Australia, Canada, France, Germany, Japan, UK, USA (Lazarova, Hills & Birks 2003). Usually treated graywater or recycled water is used for this purpose.

For toilet flushing the most important attribute is considered to be no odour. But in a study 40.4% of respondents had objection against a swampy smell with recycled water used for toilet flushing (Hurlimann & McKay 2006). Moreover, this can contribute to indoor air exposure to volatile substances such as trihalomethanes or radon or even Legionella spp. organisms from growth in plumbing systems (Asano, Takashi & Cotruvob 2004). Inhalation dose of these matters can be equivalent to the amount from ingestion of water (Asano, Takashi & Cotruvob 2004).

Besides, very high numbers of *E. coli* (up to 510,000 per 100 mL) and Enterococcus (up to 570,000 per 100 mL) were observed in some toilet bowls supplied with graywater (Albrechtsen 2002). This lower microbial quality of the water in the toilets flushed with graywater, gave rise to concern. First of all, the treatment systems become much more complicated and rely on proper maintenance, which can be a problem (Albrechtsen 2002). Secondly, such systems typically are installed in apartment buildings where graywater is collected from many apartments even with disease-carrying persons, who may excrete pathogenic agents (e.g. Hepatitis) which then will be mixed and distributed to all the other apartments connected to the system (Albrechtsen 2002). In this way a graywater system theoretically constitutes a significant risk.

Though socio-cultural factors play an important role on the way to implement this system, but when considering water saving, wastewater management, energy consumption, land management this is really sustainable. However, different countries have different legislations for water quality criteria required for toilet flushing (Table-4).

Table 4
Water quality criteria for toilet flushing and other urban uses in various countries Lazarova, Hills & Birks 2003, p. 70

	FC (CFU/100ml)	TC (CFU/100ml)	E.coli (CFU/100ml)	BOD_5 (mg/L)	Turbidity (NTU)	TSS (mg/L)	DO (% saturation)	pH	Cl_2 residual (mg/L)
US.EPA (g)	14 for any sample 0 for 90% sample		1	10	2			6-9	1 CT=30
Florida (m)	25 for any sample 0 for 75% sample			20		5			1
Texas (m)	75(m)			5	3				
Canada, BC[c] (m)	2.2 median 14 any sample			10	5	10			
Germany (g)	100 (g)	500(g)		20(g)	1-2(m)	30	80-120	6-9	
Japan (m)	10 for any sample	10		10	5			6-9	
S.Australia			<10	<20	<2				
WHO lawn irrigation	200(g) 1000(m)								
EC bathing water	100(g) 2000(m)	500(g) 10,000(m)			2(g) 1(m)		80-120 (g)	6-9	
UK BSRIA proposed (g)	14 for any sample 0 for 90% sample								

g=guideline, m=mandatory

5. Concluding Remarks

Microbial pathogens are discrete particles, randomly distributed, present in low numbers in large volume of water, thus there is a corresponding difficulty in predicting and managing risk (Toze 2006b). Even tertiary treatment doesn't ensure complete removal of pathogens because some pathogens are resistant to disinfection processes (e.g., Cryptosporidium is resistant to chlorination and adenovirus is resistant to UV radiation) (Toze 2006a). Thus, the potential presence of microbial pathogens even at very low numbers in recycled water must be considered as a real risk. Besides, chemical compounds are evenly distributed, their detection is more likely and prediction is straightforward (Toze 2006b) in this regard. But the environmental fate and behaviour of EDCs and PhACs are still less known (Karimi, Redman & Ruiz 1998). Furthermore, the current large number of known EDCs and PhACs in wastewater, as well as the possible existence of other potential and as yet unknown chemicals-of-concern, makes it complicated to predict the removal of all of these chemicals under all treatment methods or environmental conditions (Toze 2006a). Reverse osmosis is found most effective in removing EDCs, PhACs, PCPs (Snyder et al. 2003) but it is not cost effective and hence not suitable for every purpose of wastewater reuse. Moreover, these chemicals would have rather impact on natural environments such as rivers and lakes, ecological balance than on humans. Therefore, wastewater is to be treated to a level according to its purpose keeping in mind that it doesn't cause any harm to ecological balance.

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