

CONTAMINANTS OF CONCERN IN RECYCLED WATER

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Abstract

This paper reviews significant research pertaining to exposure sources for five contaminants known to be in raw wastewater. For all five contaminants investigated the estimated daily intake calculated to result from consumption of recycled water was several orders of magnitude below the estimated daily intake associated with other exposures such as food.

Introduction

In the early 2000s many Australian state governments began considering reclamation of wastewater as a means of combating water scarcity issues associated with drought, climate change and population growth. This has generated significant debate in parliament, the media and in the community over the potential of human health effects associated with exposure to recycled water. In 2007 the Co-operative Research Centre for Water Quality and Treatment (CRCWQT, 2008) conducted a survey across five Australian capital cities examining community views on recycled water. Half of the 3000 respondents expressed an unwillingness to drink recycled water. Encouragingly, 74 per cent of all respondents said they would be willing to drink recycled water if they could be assured of its safety.

To provide a clearer understanding of the potential exposures consumers face from recycled water, this paper reviews the most significant research pertaining to exposure sources for five contaminants known to be in raw wastewater and therefore potentially present in treated water. The paper does not purport to provide a comprehensive meta-analysis of the existing literature for each contaminant, but provides a snapshot of the most significant exposure sources for each contaminant compared with the predicted exposure resulting from consumption of recycled water. Five compounds were selected representing four groups of contaminants identified as being of interest by the scientific community, water industry providers and/or the general public:

- Pharmaceuticals and personal care products

- 17 α -ethinylestradiol (EE2) the active ingredient in the contraceptive pill and a known endocrine disruptor,
- galaxolide (HHCB), a musk fragrance that has been detected in human breast milk;

- Phthalates

- di-2-ethylhexyl phthalate (DEHP), a plasticiser used extensively in household, medical and food packaging products;

- Herbicides

- Atrazine, which is used extensively in Australia for weed control; and

- Disinfection by-products

- N-Nitrosodimethylamine (NDMA), which can be produced during drinking water disinfection and also occurs naturally.

Effects of the Compounds Chosen

Pharmaceutical and personal care products

Concern regarding the health effects of pharmaceuticals in wastewater first emerged in the mid to late 1960s (Snyder *et al.*, 2003), however the role of pharmaceuticals and personal care products as pollutants received limited attention until the 1990s. Prior to this time the majority of water quality and risk assessment research focussed on persistent chemicals such as pesticides and industrial chemicals. In contrast to pesticides and industrial chemicals, which have temporal and spatial variability associated with their release into the water cycle, PPCPs directly and continuously enter the water cycle globally via human excretion (Daughton and Ternes, 1999) and have been termed "pseudo-persistent". PPCPs also enter the water cycle from medical treatment facilities (Daughton and Ternes, 1999), the disposal of expired or unused medication via toilets or burial in landfill, and accidental spills at pharmaceutical manufacturing plants and the disposal of illicit drugs (Reddersen *et al.*, 2002). An

Alternative sources of exposure.

extensive range of studies has been published since 2000 regarding the detection, removal, environmental impact and potential health consequences associated with PPCPs in water. While antibiotics have received the most scientific attention (Daughton and Ternes, 1999) hormones, in particular estrogens, have generated the most public concern.

17 α -Ethinylestradiol (EE2; CASRN 57-63-6)

The synthetic estrogen EE2 is an active ingredient found in oral contraceptive pills. Some studies have linked low concentrations of EE2 in wastewater effluent to reproductive changes in male fish (Jobling *et al.*, 1998, Filby *et al.*, 2007), while other studies have proposed EE2 may only be partially related to observed increases in vitellogenin in male fish (Desbrow *et al.*, 1998). This uncertainty has generated debate at the scientific level and concern at the community level.

Concentrations of EE2 from monitoring studies for wastewater effluent in England ranged from undetectable (<0.2ng/L) to 7ng/L (Desbrow *et al.*, 1998). In Australia concentrations ranging between 0.01ng/L-1.30ng/L have been detected in wastewater treatment plant (WWTP) effluents in subtropical and temperate regions (Williams *et al.*, 2007).

Galaxolide (HHCB; CASRN 1222-05-5)

Polycyclic musks are the most commonly used musk fragrances in personal care products and detergents accounting for 60 per cent of global synthetic musk sales (Rimkus, 1999). Of the seven polycyclic musks, galaxolide (HHCB) has the highest production worldwide. Its only known use is as a fragrance in personal care products and household detergents (Ford *et al.*, 1999). Products containing HHCB include cosmetics, perfumes, shampoos, soaps, moisturising creams, laundry detergents, fabric softeners, household cleaners and air fresheners (Rimkus, 1999, HERA, 2004, Slanina, 2004).

Human skin patch trials and oral gavage studies in rats suggest that HHCB is not toxic to humans (Epstein, 1974 and Moreno 1975, cited in Opdyke,

1976). However concerns regarding the human health risks associated with HHCB have emerged following its detection in human breast milk (Müller *et al.*, 1996, Zehringer and Herrman, 2001), plasma (Hutter *et al.*, 2005) and adipose tissue samples (Müller *et al.*, 1996, Rimkus and Wolf, 1996). HHCB has also been seen to bioaccumulate in the muscle and adipose tissue of fish (Draisci *et al.*, 1998, Eschke *et al.* 1994, cited in Mersch-Sundermann *et al.*, 1998). HHCB has been detected in wastewater and in rivers downstream from WWTPs at concentrations up to 150ng/L (Müller *et al.*, 1996, EPHC/NHMRC/NRMMC, 2008).

Plasticisers

Di-2-Ethylhexyl phthalate (DEHP; CASRN 117-81-7)

Di-2-Ethylhexyl phthalate (DEHP), the most highly used plasticiser worldwide (Latini, 2005) is a synthetic chemical that makes polyvinyl chloride (PVC) products flexible (ATSDR, 2002). Wide use of DEHP began in Japan and the United States of America during the 1930s (Huber *et al.*, 1996) and it is ubiquitous in the environment due to its use in an extensive range of products and its ability to be released into the air and food. Products containing DEHP include food packaging films, intravenous tubing, blood storage bags, household, plumbing and construction products, some children's toys, baby pants, wet weather clothing, shower curtains, swimming pool liners, garden hoses, furniture and automobile upholstery, tablecloths, wall coverings, floor tiles, pavements, and wire and cable insulation (ATSDR, 2002, Huber *et al.*, 1996, Wams, 1987). DEHP is highly lipophilic and does not bind to polymer, which increases its likelihood to leach from plastic food packaging into food in the presence of fats, oils and lipoproteins (ATSDR, 2002, CPSC, 1985).

Reviews of the limited data available on potential human toxicity have found no evidence to suggest toxicity associated with oral or intravenous exposure to DEHP for humans (IARC, 2000, ATSDR, 2002, EC, 2002). However, DEHP has been shown to be carcinogenic in mice and rats. The carcinogenic potential of DEHP for humans is contradicted by a number of international bodies (IARC, 2000, USEPA, 2000). The USEPA (2000) classifies DEHP as a 'probable human carcinogen' citing the evidence of carcinogenicity in rats and mice while the International Agency for Research on Cancer (2000) proposes there is 'inadequate evidence (...) to evaluate carcinogenicity for humans'. The ATSDR

(2002) argues that data from animal studies conducted prior to 2002 do not provide sufficient evidence to suggest environmental exposures to DEHP will cause adverse health effects in humans to justify the need for further epidemiological investigations. DEHP has been detected in secondary treated effluent at concentrations up to 182µg/L (Martinen *et al.*, 2003, Fromme *et al.*, 2002).

Herbicides

1.3 Atrazine (CASRN 1912-24-9)

Atrazine is a synthetic herbicide used selectively to control broadleaf weeds in agricultural cropping and non-selectively to control weeds in public, industrial and residential areas (ATSDR, 2003). Atrazine is one of the two most extensively used herbicides in Australia and the most frequently used in the United States (Radcliffe, 2002). Use in Australia is primarily industrial for maintaining roadsides, railroads etc. with agricultural uses including triazine-tolerant canola, sorghum, maize, sugar cane, forestry and the maintenance of irrigation channels (APVMA, 2008, Radcliffe, 2002). In 1998 the Australian government cancelled licensing for atrazine to be used for home gardens and non-agricultural purposes (APVMA, 2008). Prior to this it was used broadly for maintenance of residential lawns, golf courses and sporting fields.

The actual risk atrazine presents to human health remains unclear despite many toxicological and epidemiological studies. It has been identified as a mild skin and severe eye irritant, however its carcinogenicity status is unclear. Numerous studies have been conducted on workers exposed during application, and the exposure experienced by their families coming into contact with clothing and other exposed items, however results remain inconclusive (APVMA, 2008, Hopenhayn-Rich *et al.*, 2002, Gammon *et al.*, 2005, Garcia, 2003). With the progression of epidemiological and toxicological research over the past 15 years atrazine's carcinogenicity classification has been clarified from 'possible human carcinogen' to 'not a likely human carcinogen/not classifiable' since 1988 (APVMA, 2008, US EPA, 1994). Atrazine has been detected in wastewater effluent at concentrations up to 20.9ng/L (Hua *et al.*, 2006).

DBPs and Industrial

1.4 N-Nitrosodimethylamine (NDMA; CASRN 62-75-9)

NDMA is formed as a result of both anthropogenic and natural processes.

NDMA is also a by-product of many industrial processes including drinking water treatment, leather tanning and the production of rubber products and tyres (Mitch *et al.*, 2003). During drinking water treatment NDMA forms as a result of a reaction between the disinfection chemical, usually chlorine, and organic matter, the higher the level of organic matter in the water being disinfected the higher the level of NDMA (Mitch *et al.*, 2003). NDMA also forms naturally in air, soil and water due to chemical, biological and photochemical processes (Liteplo and Meek, 2002). It is also generated in animals and humans during metabolism when stomach acids react with the nitrite and nitrate in food (Fristachi and Rice, 2007). NDMA is a component of rocket engine fuel and in Australia can be found in herbicides containing oxyfluorfen as the active constituent (APVMA, 2007).

Initial concerns regarding the health effects of nitrosamines, including NDMA, emerged in the 1960s with detection of NDMA in beer, cured meats, rubber products including baby bottle nipples and tobacco smoke (Haorah *et al.*, 2001). NDMA is a member of a family of potent carcinogens and is considered a probable human carcinogen (Mitch *et al.*, 2003). It is very toxic if inhaled or swallowed at high concentrations (ATSDR, 1989). Five deaths have been linked to NDMA exposure, three via ingestion and two via inhalation (Mitch *et al.*, 2003). Concerns about NDMA in drinking water arose in the mid 1990s when it was detected at high concentrations in surface and well waters near a rocket testing site in the US and also in chlorinated drinking water supplies in Canada (Mitch *et al.*, 2003). NDMA has been detected at 24ng/L in drinking water (Fristachi and Rice, 2007).

Methods

Concentrations

Data pertaining to the highest concentrations of each of the five selected contaminants detected in sewage and drinking water was drawn from international scientific literature, databases and published government reports. In the limited instances where multiple data sets were available for detection of a contaminant in sewage or drinking water, the highest detected concentration was used to calculate predicted exposure based on the principle of worst case scenario.

For other exposure sources estimated daily intake data from documented exposures for each contaminant was obtained from international scientific

literature, databases and publicly available government reports. Where multiple data sets were available for an exposure source the highest exposure concentration that most reflected a potential exposure scenario in Australia based on probable dietary intake or socio-economic factors was selected. Concentrations relating to occupational exposure associated with the production of any of the contaminants were not included in this study as they are not reflective of probable exposure by the general population.

Predicted concentrations of the selected contaminants were calculated by applying a 3-log (i.e. 99.9 per cent) removal to the highest reported concentration of each contaminant found in secondary-treated sewage. The 3-log removal is conservatively based on the minimal expected removal of the contaminant throughout the multiple stages of treatment that occur between the point of wastewater effluent to the tap (Snyder *et al.*, 2003, Snyder *et al.*, 2007).

Estimated daily intakes

Estimated daily intake from recycled water was calculated by multiplying the predicted concentration in recycled water by an assumed water consumption of 2L per day. To enable comparisons between all exposure sources estimated daily

Table 1. Acceptable daily intake (ADI) for a 70/kg adult (µg/day).

Contaminant	ADI from water (µg/d) ^a
17α-Ethinylestradiol (EE2)	0.003
Galaxolide (HHCB)	3600
Di-2-Ethylhexyl phthalate (DEHP)	20
Atrazine	40
N-Nitrosodimethylamine (NDMA)	0.02

^a Derived by multiplying the guideline values (µg/L) in (EPHC/NHMRC/NRMMC, 2008) by a standard water consumption of 2L/day.

intakes were calculated for a 70kg adult and data are presented as µg/day. The predicted daily intake associated with recycled water for each contaminant was also evaluated against an acceptable daily intake derived from the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2), (EPHC/NHMRC/NRMMC, 2008) as outlined in Table 1.

Results & Discussion

Estimated daily intakes for each contaminant via numerous exposure pathways are presented in Table 2.

17α-Ethinylestradiol (EE2)

The most significant EE2 exposure is the daily ingestion of contraceptive pills,

which only occurs in pre-menopausal women. Results from a 2001 survey reported approximately 27 per cent of Australian women aged 18-49 were taking the contraceptive pill (Yusuf and Siedlecky, 2007). While this figure provides some quantification of contraceptive pill use in Australia and may be beneficial in modelling concentrations of EE2 entering Australian wastewater treatment plants, as has been done by Braga *et al.* (2005), it must be considered an underestimate. Only women 18 years and over were surveyed and 86 per cent of 18 to 24 year olds reported beginning use of the contraceptive pill in their teenage years (Yusuf and Siedlecky, 2007).

The most probable source of exposure for males or females not taking the pill is intake from drinking water drawn from surface waters receiving wastewater effluent. Although EE2 is detected in sewage treatment effluent at concentrations 10 times lower than 17β-estradiol (E2 - a natural hormone), EE2 is significantly more potent than E2 (Desbrow *et al.*, 1998). The intake of EE2 from water is, however, much lower than the prescribed dose for contraception (Fig. 1). The daily intake levels of EE2 for pre-menopausal women using oral contraceptives range from 20-50 µg/day dependent upon the prescribed pill

Table 2. Estimated daily intake (EDI) of contaminants of concern for a 70/kg adult^a (µg/day).

Contaminant	Exposure Pathway	EDI (µg/d)	Reference
EE2	Oral contraceptive	20-50	(Shufelt and Bairey Merz, 2009)
	Drinking water (Germany)	0.001	(Kuch and Ballschmiter, 2001)
	Recycled water	0.00054	
HHCB	Fish consumption	2.066-8.262	(Slanina, 2004)
	Combined daily exposure - household cleaning products	4.9 ^b	(HERA, 2004)
	Body lotion	1800 ^c (absorbed dose)	(Slanina, 2004)
	Fragrance cream	1740 ^c (absorbed dose)	(Slanina, 2004)
	Eau de toilette	680 ^c (absorbed dose)	(Slanina, 2004)
	Drinking water	0.042	(HERA, 2004)
	Recycled water	0.0003	
DEHP	Workplace (general population)	70-28700	(Huber <i>et al.</i> , 1996)
	Combined exposure (general population)	210-2100 ^d	(Latini, 2005, Huber <i>et al.</i> , 1996)
	Car temp >60°C	210	(Huber <i>et al.</i> , 1996)
	Drinking water	<70	(Huber <i>et al.</i> , 1996)
	Recycled water	0.4	
ATRAZINE	Diet incl. drinking water (USA)	16.38-59.99 (Acute)	
		3.22-20.2 (Chronic)	(Rodriguez <i>et al.</i> , 2005)
	Drinking water (USA)	0.052	(Snyder, 2008)
NDMA	Recycled water	0.00176	
	Endogenous processes	22.9	(Fristachi and Rice, 2007)
	Beer	0.02	(Fristachi and Rice, 2007)
	Drinking water	0.0033	(Fristachi and Rice, 2007)
	Recycled water	0.0011	

^a Assumed water consumption 2L/day; ^b Adult 60kg body weight; ^c based on single application per day; ^d excludes workplace and medical exposure.

(Shufelt and Bairey Merz, 2009), whereas the estimated daily intake of EE2 associated with consumption of recycled water is 0.00054µg/day (Fig. 1).

Galaxolide (HHCB)

Humans are exposed to HHCB via ingestion, inhalation and dermal exposure. The majority of HHCB is excreted (Ford *et al.*, 1999), and ingestion via drinking water, including potable water, has been proposed as a potential exposure route by some authors (HERA, 2004, Rimkus, 1999). The highest exposures to HHCB are associated with consumption of breast milk and fish (Fig. 2). Infants consuming 0.7L of breast milk with approx 3.7 per cent w/w fat to milk concentration have an estimated daily HHCB intake of 6.81 µg/kg of body weight (bw)/day (Slanina, 2004). It is important to note that whilst the concentration of HHCB in fish can be measured precisely, individual daily intakes can vary up to four-fold depending on individual fish consumption patterns.

Estimated daily intakes via dermal contact during the application of personal care products are even less predictable than those such as ingestion, due to the variability in individual usage patterns of personal care products. While some estimates of daily intakes via the application of cologne and body lotions are provided by Slanina (2004), it has been suggested only a small amount of applied dose is absorbed (Ford *et al.*, 1999). Notable also is the level of combined exposure associated with use of household cleaning products (HERA, 2004) (Table 2). Estimated daily exposure via recycled water is negligible in comparison to other exposure sources (Fig. 2).

Di-2-Ethylhexyl phthalate (DEHP)

Humans are exposed to DEHP during the production, use and disposal of plastic products either by ingestion, inhalation or dermal contact (ATSDR, 2002) across their entire lifetime, including the intra-uterine period (Latini, 2005). Attempts to quantify exposure are hindered by the difficulties associated with separating exposures (CPSC, 1985) and estimating the amount of DEHP leached from various sources (Wams, 1987). The ubiquitous dispersal of DEHP in our environment and multiplicity of exposure routes have made calculating exposure levels via individual sources complicated. Numerous attempts have been made to determine concentrations of DEHP in air, water and food products and the rate of leaching from PVC as predictors of exposure; refer to Huber *et al.* (1996) for a comprehensive review. However it is important to remember that rarely do these exposures occur in isolation. Additionally, dietary exposure varies considerably between countries and according to culture with regard to food types – i.e. high fat or low fat – and food storage techniques. Recent research has calculated combined exposure using urinary metabolites of DEHP (Koo and Lee, 2005, Koch *et al.*, 2003). Exposure via consumption of recycled water is highly probable as DEHP is introduced into wastewater by both human waste and waste from production plants for PVC products (Wams, 1987).

Medical treatments are the cause of the highest exposures to DEHP. The most significant chronic exposure, 4-3100 µg/kg bw, occurs in haemodialysis patients and the highest acute exposure, 42-140000µg/kg bw, is seen in infants receiving temporary life support in the instance of cardiac and respiratory failure (Tickner *et al.*, 2001, Huber *et al.*, 1996). For the general population combined exposure to DEHP for a 70kg adult is estimated to range between 210-2100mg/day (Huber *et al.*, 1996). Workplace air is the most significant everyday exposure (Fig. 3). Notably this is not occupational exposure

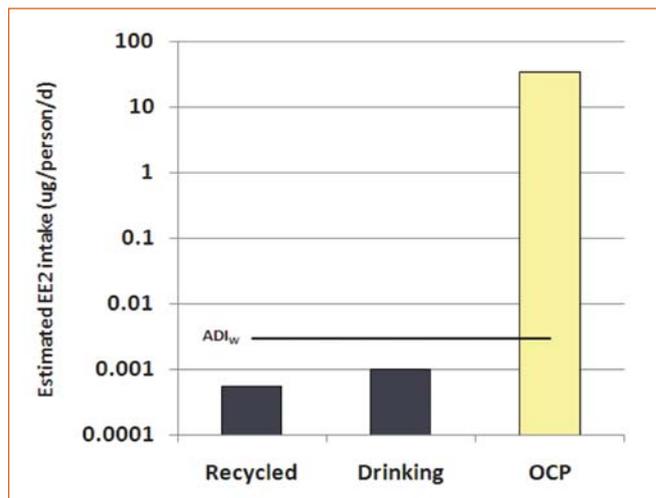


Figure 1. Estimated daily intake of 17-ethinylestradiol (EE2) via exposure route. Notes: OCP: Oral Contraceptive Pill; ADI_w: Acceptable daily intake from water (EPHC/NHMRC/NRMMC, 2008).

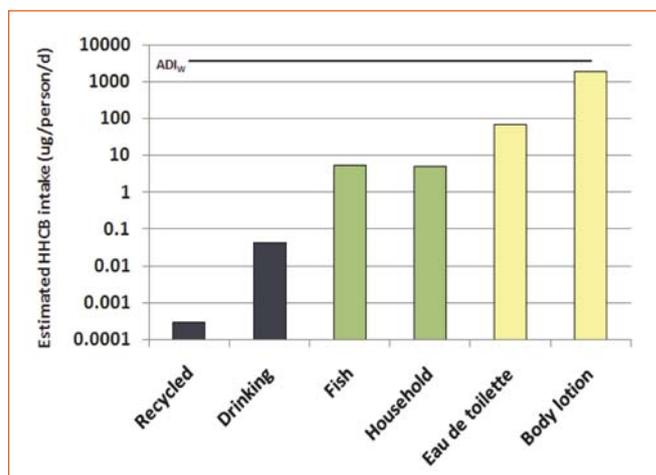


Figure 2. Estimated daily intake of Galaxolide (HHCB) via exposure route. Notes: ADI_w: Acceptable daily intake from water (EPHC/NHMRC/NRMMC, 2008).

of workers involved in production but the exposure experienced by the general work force associated with DEHP leaching from wall and floor coverings, furniture and office. The interior of cars when the temperature has exceeded 60°C provide another significant daily exposure source (Huber *et al.*, 1996). Although medical exposures have been acknowledged as the highest exposure, estimated daily intakes are rarely calculated for this exposure as treatments such as blood transfusions, drips and temporary life support treatment are often short term ranging from hours to a few days. As with HHCB the level of DEHP in recycled water is insignificant when compared to combined exposure from other sources (Fig. 3).

Atrazine

In the past, occupational exposure experienced by agricultural workers was considered the most significant exposure to atrazine and has been the predominant focus of epidemiological research (Garcia, 2003). The introduction of regulations regarding protocols and procedures for use and personal protective equipment has seen exposure via this pathway significantly reduced (NRA, 1997). However, it is important to remember that these regulations have not been uniformly adopted in all countries. The families of workers can also be exposed via contact with pesticide residues on clothes,

equipment, and shoes brought into the home (Garcia, 2003). Assuming personal protective equipment is used by workers the next most probable exposure routes are ingestion of food sprayed with the herbicide and drinking water drawn from surfaces waters which receive run off.

Atrazine concentrations are not measured in the Australian Total Food Survey (Food Standards Australia and New Zealand, 2003) and the author believes dietary exposure in Australia is yet to be quantified. This may be due in part to the reduced number of cropping applications of atrazine in Australia as detailed previously. American data suggest that in acute exposure situations dietary intake of atrazine for a 70kg adult can be up to 60 mg/day (Rodriguez *et al.*, 2005). Limited published data exist on atrazine concentrations in drinking water. The studies that have been published focused on surface waters in agricultural areas in America, Canada and China (Palma *et al.*, 2008, Donald *et al.*, 2007, Na *et al.*, 2006). Only one study could be found, on atrazine concentrations in finished drinking waters, which suggested a minimal daily intake associated with drinking water (Snyder, 2008). The estimated daily intake of atrazine from recycled water is substantially lower than the ADI calculated from the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2) (EPHC/NHMRC/NRMMC, 2008) (Fig. 4).

N-Nitrosodimethylamine (NDMA)

Individuals are exposed to NDMA via ingestion, inhalation and dermal absorption. At the end of the 1980s, tobacco smoke and consumption of food products – in particular beer and cured meats products – were considered the most significant routes of exposure (ASTDR 1989). It is probable that these exposures have changed following legislation in many countries to limit smoking in enclosed areas, thereby reducing involuntary or passive exposure to tobacco smoke. Alterations in brewing techniques have also seen the concentrations of NDMA in beer reduced in several countries (Yurchenko and Molder, 2005, Baxter *et al.*, 2007).

It is now considered that the majority of the estimated 23.1mg/day dose that a 70kg adult in the general population would be exposed to results from internal processes within the human body, including metabolism (Fristachi and Rice, 2007). The level of NDMA produced internally is dependent upon the individual’s diet and is influenced by the amount of nitrate present in the foods consumed. High NDMA concentrations have been found in cured meat products such as pepperoni and salami (Jakszyn *et al.*, 2006, Yurchenko and Molder, 2007), and many vegetables including broccoli, spinach and beetroot have been shown to contribute to endogenous production (within the digestive tract) of NDMA (Fristachi and Rice, 2007).

NDMA is also a by-product of the drinking water disinfection process, with the level of NDMA being influenced by the amount of organic matter present and the presence of NDMA precursors. The advanced treatment processes that recycled water undergoes prior to entering water retention dams suggest that the level of organic matter entering the drinking water plant will be lower than in regular water. Estimates of the NDMA concentration in drinking water and recycled water both sit well below the concentration of NDMA individuals are exposed to endogenously (Fig. 5).

Conclusions

For all five contaminants investigated the estimated daily intake from consumption of recycled water was several orders of

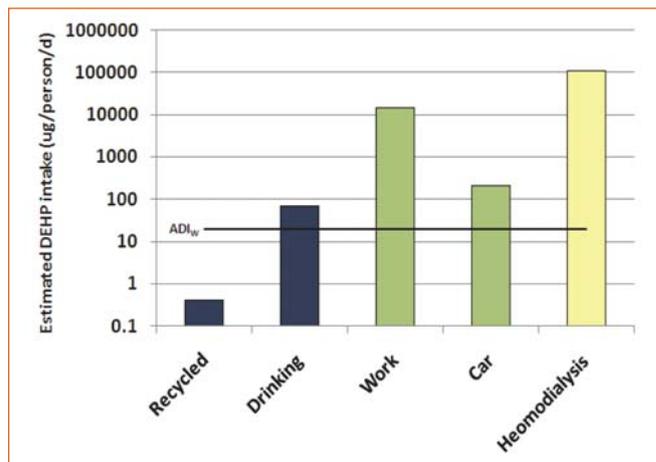


Figure 3. Estimated daily intake of Di-2-ethylhexyl phthalate (DEHP) via exposure route. Notes: ADIW: Acceptable daily intake from water (EPHC/NHMRC/NRMMC, 2008).

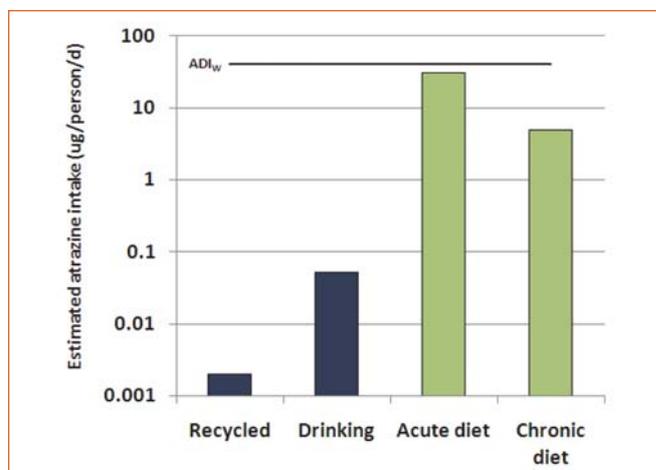


Figure 4. Estimated daily intake of Atrazine via exposure route. Notes: ADIW: Acceptable daily intake from water (EPHC/NHMRC/NRMMC, 2008).

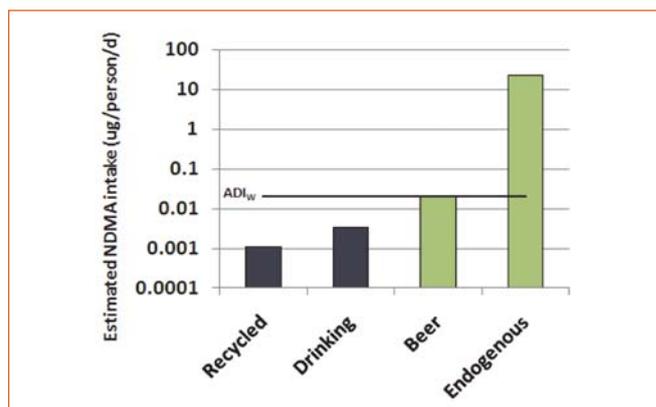


Figure 5. Estimated daily intake of N-Nitrosodimethylamine (NDMA) via exposure route. Notes: ADIW: Acceptable daily intake from water (EPHC/NHMRC/NRMMC, 2008).

magnitude below the estimated daily intake associated with other exposures such as food. Additionally, the predicted intakes for each contaminant were below the acceptable daily intake outlined in the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (phase 2) (Tables 1 and 2).

The predicted recycled water concentrations in this study were well correlated with results presented in the Interim Water

Quality Report of the Western Corridor Recycled Water Project (Queensland Water Commission Expert Advisory Panel, 2009) outlining data from the Bundamba Advanced Water Treatment Plant, Queensland, which processed effluent from four wastewater treatment plants during the period May to December 2008 (autumn to summer). EE2 was undetected at a detection limit of 1ng/L and atrazine was undetected at a detection limit of 10ng/L. NDMA was detected once only in 60 samples at a concentration of 10ng/L, and was undetected in the remainder of samples at a detection limit of 5ng/L. However the detected concentration met the Queensland standards outlined in Schedule 3B of the 2005 Public Health Regulation (Office of the Queensland Parliamentary Council, 2008).

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