WHO/FWC/WSH/16.44

Dichlorvos in Drinking-water

Background document for development of
WHO *Guidelines for Drinking-water Quality*

Preface

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection. A major World Health Organization (WHO) function to support access to safe drinking-water is the responsibility "to propose ... regulations, and to make recommendations with respect to international health matters ...", including those related to drinking-water safety and management.

The first WHO document dealing specifically with public drinking-water quality was published in 1958 as *International Standards for Drinking-water*. It was subsequently revised in 1963 and in 1971 under the same title. In 1984–1985, the first edition of the WHO *Guidelines for Drinking-water Quality* (GDWQ) was published in three volumes: Volume 1, Recommendations; Volume 2, Health criteria and other supporting information; and Volume 3, Surveillance and control of community supplies. Second editions of these volumes were published in 1993, 1996 and 1997, respectively. Addenda to Volumes 1 and 2 of the second edition were published in 1998, addressing selected chemicals. An addendum on microbiological aspects reviewing selected microorganisms was published in 2002. The third edition of the GDWQ was published in 2004, the first addendum to the third edition was published in 2006 and the second addendum to the third edition was published in 2008. The fourth edition was published in 2011, and the first addendum to the fourth edition was published in 2017.

The GDWQ are subject to a rolling revision process. Through this process, microbial, chemical and radiological aspects of drinking-water are subject to periodic review, and documentation related to aspects of protection and control of drinking-water quality is accordingly prepared and updated.

Since the first edition of the GDWQ, WHO has published information on health criteria and other supporting information to the GDWQ, describing the approaches used in deriving guideline values and presenting critical reviews and evaluations of the effects on human health of the substances or contaminants of potential health concern in drinking-water. In the first and second editions, these constituted Volume 2 of the GDWQ. Since publication of the third edition, they comprise a series of free-standing monographs, including this one.

For each chemical contaminant or substance considered, a background document evaluating the risks for human health from exposure to the particular chemical in drinking-water was prepared. The draft health criteria document was submitted to a number of scientific institutions and selected experts for peer review. The draft document was also released to the public domain for comment. Comments were carefully considered and addressed as appropriate, taking into consideration the processes outlined in the *Policies and Procedures Used in Updating the WHO Guidelines for Drinking-water Quality* (http://apps.who.int/iris/bitstream/10665/70050/1/WHO_HSE_WSH_09.05_eng.pdf) and the *WHO Handbook for Guideline Development* (http://www.who.int/publications/guidelines/handbook_2nd_ed.pdf), and the revised draft was submitted for final evaluation at expert consultations.

During the preparation of background documents and at expert consultations, careful consideration was given to information available in previous risk assessments carried out by the International Programme on Chemical Safety, in its Environmental Health Criteria monographs and Concise International Chemical Assessment Documents, the International Agency for Research on Cancer, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Meeting on Pesticide Residues and the Joint FAO/WHO Expert Committee on Food Additives (which evaluates contaminants such as lead, cadmium, nitrate and nitrite, in addition to food additives).

Further up-to-date information on the GDWQ and the process of their development is available on the WHO website and in the current edition of the GDWQ.

Acknowledgements

The first draft of *Dichlorvos in drinking-water, Background document for development of WHO Guidelines for Drinking-water Quality* was prepared by Professor Shane Snyder, University of Arizona, Tucson, United States of America (USA), to whom special thanks are due.

The work of the following experts was crucial in the development of this document and others in the first addendum to the fourth edition:

Dr M. Asami, National Institute of Public Health, Japan
Dr R.J. Bevan, Cranfield University, United Kingdom
Dr J. Cotruvo, Joseph Cotruvo & Associates and NSF International WHO Collaborating Centre, USA
Dr A. Eckhardt, Umweltbundesamt (Federal Environment Agency), Germany
Professor J.K. Fawell, United Kingdom
Ms M. Giddings, Health Canada, Canada
Dr A. Hirose, National Institute of Health Sciences, Japan
Dr P. Marsden, Drinking Water Inspectorate, United Kingdom
Professor Y. Matsui, Hokkaido University, Japan
Dr M.E. Meek, University of Ottawa, Canada
Dr E. Ohanian, Environmental Protection Agency, USA
Professor C.N. Ong, National University of Singapore, Singapore
Dr S. Ramasamy, Environmental Protection Agency, USA
Professor S. Snyder, University of Arizona, USA

The draft text was discussed at the expert consultations for the first addendum to the fourth edition of the GDWQ, held on 2–5 December 2013 and 23–26 February 2015. The final version of the document takes into consideration comments from both peer reviewers and the public.

The coordinator was Ms J. De France, WHO Headquarters, with support from Mr P. Callan, Australia. Strategic direction was provided by Mr B. Gordon, WHO Headquarters. Dr A. Tritscher and Dr P. Verger, WHO Headquarters, provided liaisons with the Joint FAO/WHO Expert Committee on Food Additives and the Joint FAO/WHO Meeting on Pesticide Residues, whereas Dr R. Brown and Ms C. Vickers, WHO Headquarters, provided liaisons with the International Programme on Chemical Safety. Dr M. Perez contributed on behalf of the Radiation Programme, WHO Headquarters. Dr R. Yadav, WHO Headquarters, provided input on pesticides added to drinking-water for public health purposes.

Ms P. Ward and Ms L. Robinson provided invaluable administrative support at the expert consultations and throughout the review and publication process. Ms M. Sheffer of Canada and Dr H. Cadman of Australia were responsible for the scientific editing of the document.

Many individuals from various countries contributed to the development of the GDWQ. The efforts of all who contributed to the preparation of this document and in particular those who provided peer or public domain review comments are greatly appreciated.

Abbreviations

ADI	acceptable daily intake
ARfD	acute reference dose
bw	body weight
FAO	Food and Agriculture Organization of the United Nations
HBV	health-based value
ISO	International Organization for Standardization
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
K_{oc}	soil adsorption coefficient
K_{ow}	octanol–water partition coefficient
NF	nanofiltration
NOAEL	no-observed-adverse-effect level
RO	reverse osmosis
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme

Contents

Dichlorvos is the International Organization for Standardization (ISO)–approved common name for 2,2-dichlorovinyl dimethyl phosphate (Chemical Abstracts Service No. 62-73-7).

1. MAJOR USES

Dichlorvos is a broad-spectrum organophosphorus insecticide. Like other organophosphorus compounds, its mode of action is via the inhibition of cholinesterase activity. Dichlorvos is used primarily as an insecticide for controlling household pests and for protecting stored products from insects. It is also used as a veterinary insecticide (EXTOXNET, 1996). It is no longer approved for use in some jurisdictions, such as the European Union, because of concerns over its acute toxicity (EU, 2012).

2. POTENTIAL FOR OCCURRENCE IN WATER

Dichlorvos is highly soluble in water (18 000 mg/L), has a low octanol–water partition coefficient (log K_{ow} 1.9) and is quite volatile before dissolving in water (vapour pressure 2100 mPa) (Anyusheva et al., 2012). Once dissolved, dichlorvos has a low tendency to enter the gas phase (Gautier, Le Calvé & Mirabel, 2003). The Henry's Law constant for dichlorvos has been experimentally determined to be 1.90×10^{-1} Pa·m^3·mol^{-1} (Steen et al., 2001), reinforcing its predominance in the aqueous phase once dissolved. With a soil adsorption coefficient (log K_{oc}) of 1.4 (Teunissen-Ordelman & Schrap, 1997), dichlorvos is expected to be very mobile in soils (McCall et al., 1980). Dichlorvos is also rapidly degraded by microbial activity and hydrolysis in soil and does not adsorb to sediments. Degradation in water occurs primarily through hydrolysis, with a half-life in rivers and lakes of approximately 4 days (EXTOXNET, 1996). The major degradate of the insecticide metrifonate, also known as trichlorfon, an irreversible organophosphate acetylcholinesterase inhibitor, in both soil and water has been identified as dichlorvos, and it has been suggested that both have little potential to contaminate groundwater because of their rapid degradation in soil (USEPA, 1997).

There are relatively few studies on the occurrence of dichlorvos in source waters. A study investigating 16 reservoirs in the Haihe River basin in China detected dichlorvos in all samples analysed (method detection limit of 1.4 ng/L); concentrations ranged from 10 to 50 ng/L, with a mean value of 26.3 ng/L (Gao et al., 2012). In a separate study of seven major river basins in China, dichlorvos was the most frequently detected organophosphorus pesticide, with 89.1% of over 600 samples testing positive; the Yellow River had the highest average dichlorvos concentration, at 40.7 ng/L, whereas the Yangtze River had the highest single dichlorvos concentration, at 1552 ng/L (Gao et al., 2009). Among 12 samples of surface water from an agricultural region of Turkey, the pesticide with the highest concentration was dichlorvos, at 322.2 ng/L (Tuncel, Oztas & Erduran, 2008). A study in Lake Biwa, Japan, found no detectable amounts of dichlorvos in the lake and influent river water (limit of quantification of 10 ng/L; Sudo et al., 2004).

As dichlorvos is volatile, atmospheric transport can occur, and the pesticide can subsequently be deposited in precipitation. Dichlorvos has been measured in rainfall at concentrations as high as 107 ng/L and 330 ng/L in Canada and Japan, respectively (Feigenbrugel et al., 2006). Another study has reported dichlorvos in rainwater in Japan, with a maximum concentration of 740 ng/L (Sakai, 2006). Lower concentrations were reported in rainwater in Belgium, with a maximum concentration of 29.2 ng/L in 1998 (Quaghebeur et al., 2004).

3. TOXICITY

As with other organophosphorus insecticides, the inhibition of cholinesterase activity, causing neurotoxicity, is the most sensitive toxicological end-point following acute or repeated exposures to dichlorvos. The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Meeting on Pesticide Residues (JMPR) in 2011 (FAO/WHO, 2012; WHO, 2012) concluded that dichlorvos is unlikely to be genotoxic in vivo. In the absence of an in vivo genotoxic response and any carcinogenic response relevant to humans, JMPR concluded that dichlorvos is unlikely to pose a carcinogenic risk to humans. JMPR noted some reproductive toxicity in rats but concluded that dichlorvos did not cause developmental toxicity and that it was not teratogenic.

JMPR confirmed the current acceptable daily intake (ADI) of 0–0.004 mg/kg body weight (bw) based on the no-observed-adverse-effect level (NOAEL) of 0.04 mg/kg bw per day for the inhibition of erythrocyte acetylcholinesterase activity in a 21-day study in male volunteers (WHO, 1994). The ADI was previously based on the NOAEL of 0.033 mg/kg bw per day in a 28-day study in male volunteers for the same end-point (FAO/WHO, 1968) and before that on the NOAEL of 0.37 mg/kg bw per day in a 90-day study in dogs for the inhibition of brain cholinesterase activity (FAO/WHO, 1967).

JMPR considered two new studies conducted in male volunteers (Gledhill, 1997a–f) at doses higher than those tested in the two pivotal human studies underpinning the current ADI. Neither study was considered a suitable basis for an ADI, because clear NOAELs had not been demonstrated. JMPR considered the ADI to be protective for other, non-neurotoxic effects of dichlorvos observed in short- and long-term studies with repeated doses and in studies of reproductive and developmental toxicity, where the use of an interspecies safety factor of 10 would be appropriate. The absence of any age- or sex-specific differences in cholinesterase inhibition in rats confirmed that the current ADI was protective of the entire population.

JMPR established an acute reference dose (ARfD)[1] of 0.1 mg/kg bw, based on the NOAEL of 1 mg/kg bw for erythrocyte acetylcholinesterase inhibition in the acute oral study in male volunteers and using a tenfold intraspecies safety factor (Gledhill, 1997c,d). The NOAEL is supported by observations in two other volunteer studies in which no erythrocyte acetylcholinesterase inhibition occurred 1 day after dosing at 0.5 and 0.1 mg/kg bw, respectively (Gledhill, 1997a,b,e,f).

4. DERIVATION OF A HEALTH-BASED VALUE[2]

Pesticides provide a special case for establishing health-based values (HBVs) for drinking-water in terms of the potential exposure from other sources, because they are deliberately

[1] The estimate of the amount of a substance in food or drinking-water, expressed on a body weight basis, that can be ingested in a period of 24 hours or less without appreciable health risk to the consumer.

[2] Formal guideline values are established when one of the following criteria has been met: 1) there is credible evidence of occurrence of the chemical in drinking-water combined with evidence of actual or potential toxicity, 2) the chemical is of significant international concern or 3) the chemical is being considered for inclusion or is included in the World Health Organization Pesticide Evaluation Scheme (WHOPES). For some chemicals, no formal guideline values are established when occurrence is likely to be well below a level that would be of concern for health. Establishing a formal guideline value for such substances may encourage Member States to incorporate a value into their national standards when this may be unnecessary. When a formal guideline value is not established, a "health-based value" may be determined in order to provide guidance to Member States when there is reason for local concern. This reference value provides both a means of judging the margin of safety in the absence of a specific guideline value and a level of interest for establishing analytical methods.

applied to food crops. JMPR concluded that the daily intake of dichlorvos in food was 5–30% of the upper bound of the ADI (FAO/WHO, 2012), which suggests that exposure from food varies widely and will depend on local circumstances and usage. A further uncertainty regarding exposure comes from potential for inhalation from use of dichlorvos as a domestic insecticide.

With an allocation of 20% of the upper bound of the JMPR ADI of 0.004 mg/kg bw to drinking-water and the assumption that a 60 kg person consumes 2 L of drinking-water per day, an HBV of 0.02 mg/L (20 µg/L) can be derived for dichlorvos. The default allocation factor of 20% has been used to account for the fact that available food exposure data, which suggest that exposure via this route is low, do not generally include information from developing countries, where exposure via this route may be higher, and as potential exposure via inhalation from indoor air resulting from the use of dichlorvos as a domestic insecticide is unknown (for further information, see Section 8.2.2, "Relative source allocation", of the *Guidelines for Drinking-water Quality*; WHO, 2017).

5. CONSIDERATIONS IN APPLYING THE HEALTH-BASED VALUE

The HBV for dichlorvos is protective against health effects resulting from lifetime exposure from drinking-water. Small exceedances above the HBV for short periods are unlikely to have an impact on health. If these exceedances are due to massive contamination, however, such as that found in emergency or spill situations, the acute HBV of 3 mg/L (derived from the JMPR ARfD) would provide a useful point of reference for the provision of advice to consumers. This acute HBV indicates the concentration of dichlorvos in drinking-water that a person could consume for 24 hours without appreciable health risk (for further information, see Section 8.7.5 of the *Guidelines for Drinking-water Quality*; WHO, 2017).

Routine monitoring of dichlorvos is not considered necessary. However, Member States should consider local usage and potential situations such as spills in deciding whether and where to monitor. In the event that monitoring results show levels above the HBV on a regular basis, it is advisable that a plan be developed and implemented to address the situation.

As a general principle, efforts should be made to keep the concentration of pesticides in water as low as possible and to not allow concentrations to increase up to the HBV.

6. ANALYSIS IN WATER

Dichlorvos can be measured in water at levels well below the HBV. EN 12918 uses solvent extraction and gas chromatographic analysis and has a limit of quantification of 0.01 µg/L (European Committee for Standardization, 1999). The United States Environmental Protection Agency method 622 (USEPA, undated) also uses gas chromatographic separation with mass spectrometric detection and can achieve a reporting limit of 0.1 µg/L or lower.

7. TREATMENT TECHNOLOGIES

Conventional treatment, including coagulation, filtration and chlorination, is not effective for reducing the concentration of dichlorvos in water. Catalytic ozonation has been shown to effectively oxidize dichlorvos through non-selective hydroxyl radical pathways (Kim et al., 2002); however, conventional ozonation is likely inefficient based on the structure of dichlorvos. Activated carbon is not likely to be highly effective for the removal of dichlorvos due to the pesticide's high water solubility and low octanol–water partition coefficient. Dichlorvos does not have a significant absorbance for ultraviolet light and thus is not

expected to undergo efficient direct photolysis; however, the addition of hydrogen peroxide or use of catalysts can oxidize dichlorvos through generation of non-selective radical species (Rahman & Muneer, 2005). Only sparse data exist demonstrating removal of dichlorvos by reverse osmosis (RO) and nanofiltration (NF) membranes (Kiso et al., 2005 and Kosutic et al, 2005). Both publications indicated that RO membranes would achieve good removal of dichlorvos (>85%), whereas NF membranes would provide significantly lower removal (4–60%). The variability of NF performance for dichlorvos removal appeared to be roughly proportional to sodium chloride rejection. Thus, membrane type and operational conditions play a large role in the effectiveness of the process for dichlorvos removal though RO would be expected to be an effective barrier, based on removal studies and predictions (Hofman et al., 1997).

8. CONCLUSION

It is not considered necessary to establish a guideline value for dichlorvos, as it occurs in drinking-water sources or drinking-water at concentrations well below those of health concern. Where monitoring results show the presence of dichlorvos in drinking-water on a regular basis, an HBV of 0.02 mg/L can be applied. In an emergency or spill situation, an acute HBV of 3 mg/L may provide useful guidance.

9. REFERENCES

Anyusheva M, Lamers M, Schwadorf K, Streck T (2012). Analysis of pesticides in surface water in remote areas in Vietnam: coping with matrix effects and test of long-term storage stability. Int J Environ Anal Chem. 92(7):797–809.

EU (2012). Regulation (EU) No 649/2012 of the European Parliament and of the Council of 4 July 2012 concerning the export and import of hazardous chemicals. Off J Eur Union. L201:60–106 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:201:0060:0106:EN:PDF, accessed 12 September 2014).

European Committee for Standardization (1999). EN 12918:1999. Water quality – Determination of parathion, parathion-methyl and some other organophosphorus compounds in water by dichloromethane extraction and gas chromatographic analysis. Brussels: European Committee for Standardization.

EXTOXNET (1996). Extension Toxicology Network, Pesticide Information Profiles: Dichlorvos (http://extoxnet.orst.edu/pips/dichlorv.htm, accessed 10 September 2014).

FAO/WHO (1967). Evaluation of some pesticide residues in food. Rome: Food and Agriculture Organization of the United Nations; and Geneva: World Health Organization (FAO/PL:CP/15; WHO/Food Add./67.32; http://www.inchem.org/documents/jmpr/jmpmono/v66apr06.htm, accessed 22 March 2016).

FAO/WHO (1968). 1967 evaluations of some pesticide residues in food. Rome: Food and Agriculture Organization of the United Nations; and Geneva: World Health Organization (FAO/PL:1967/MM/11/1; WHO/Food Add./68.30; http://www.inchem.org/documents/jmpr/jmpmono/v067pr10.htm, accessed 22 March 2016).

FAO/WHO (2012). Pesticide residues in food – 2011. Report of the Joint Meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and the WHO Core Assessment Group on Pesticide Residues. Rome: Food and Agriculture Organization of the United Nations and World Health Organization (FAO Plant Production and Protection Paper 211).

Feigenbrugel V, Le Person A, Le Calvé S, Mellouki A , Muñoz A, Wirtz K (2006). Atmospheric fate of dichlorvos: photolysis and OH-initiated oxidation studies. Environ Sci Technol. 40(3):850–7.

Gao JJ, Liu L, Liu X, Zhou H, Lu J, Huang S et al. (2009). The occurrence and spatial distribution of organophosphorous pesticides in Chinese surface water. Bull Environ Contam Toxicol. 82(2):223–9.

Gao JJ, Liu L, Liu X, Lu J, Hao H, Yuan H et al. (2012). The organic contamination survey and health risk assessment of 16 source water reservoirs in Haihe River basin. Water Sci Technol. 65(6):998–1006.

Gautier C, Le Calvé S, Mirabel P (2003). Henry's law constants measurements of alachlor and dichlorvos between 283 and 298 K. Atmos Environ. 37(17):2347–53.

Gledhill AJ (1997a). Dichlorvos: a study to investigate erythrocyte cholinesterase inhibition following oral administration to healthy volunteers. Central Toxicology Laboratory, Macclesfield, England, United Kingdom. Unpublished report no. CTL/P/5251 (3 February 1997); AMVAC report reference 500-TOX-006 [cited in WHO, 2012].

Gledhill AJ (1997b). First supplement to: Dichlorvos: a study to investigate erythrocyte cholinesterase inhibition following oral administration to healthy volunteers. Central Toxicology Laboratory, Macclesfield, England, United Kingdom. Unpublished report no. CTL/P/5251 (8 October 1997); AMVAC report reference 500-TOX-009 [cited in WHO, 2012].

Gledhill AJ (1997c). Dichlorvos: a study to investigate the effect of a single dose on erythrocyte cholinesterase inhibition in healthy male volunteers. Central Toxicology Laboratory, Macclesfield, England, United Kingdom. Unpublished report no. CTL/P/5393 (25 March 1997); AMVAC report reference 500-TOX-007 [cited in WHO, 2012].

Gledhill AJ (1997d). First supplement to: Dichlorvos: a study to investigate the effect of a single dose on erythrocyte cholinesterase inhibition in healthy male volunteers. Central Toxicology Laboratory, Macclesfield, England, United Kingdom. Unpublished report no. CTL/P/5393 (8 October 1997); AMVAC report reference 500-TOX-010 [cited in WHO, 2012].

Gledhill AJ (1997e). Dichlorvos: a single blind, placebo controlled, randomised study to investigate the effects of multiple oral dosing on erythrocyte cholinesterase inhibition in healthy male volunteers. Central Toxicology Laboratory, Macclesfield, England, United Kingdom. Unpublished report no. CTL/P/5392 (24 March 1997); AMVAC report reference 500-TOX-008 [cited in WHO, 2012].

Gledhill AJ (1997f). First supplement to: Dichlorvos: a single blind, placebo controlled, randomised study to investigate the effects of multiple oral dosing on erythrocyte cholinesterase inhibition in healthy male volunteers. Central Toxicology Laboratory, Macclesfield, England, United Kingdom. Unpublished report no. CTL/P/5393 (9 October 1997); AMVAC report reference 500-TOX-011 [cited in WHO, 2012].

Hofman J, Berendonk EF, Folmer HC, Kruithof JC (1997). Removal of pesticides and other micropollutants with cellulose-acetate, polyamide and ultra-low pressure reverse osmosis membranes. Desalination, 113(2–3):209–14.

Kim BS, Fujita H, Sakai Y, Sakoda A, Suzuki M (2002). Catalytic ozonation of an organophosphorus pesticide using microporous silicate and its effect on total toxicity reduction. Water Sci Technol. 46(4–5):35–41.

Kiso Y, Nishimura Y, Kitao T, Nishimura K (2005). Rejection properties of non-phenylic pesticides with nanofiltration membranes. J Membr Sci. 171:229–37.

Kosutic K, Furac L, Sipos L, Kunst B (2005). Removal of arsenic and pesticides from drinking water by nanofiltration membranes. Sep Purif Technol. 42(2):137–44.

McCall PJ, Swann RL, Laskowski DA, Unger SM, Vrona SA, Dishburger HJ (1980). Estimation of chemical mobility in soil from liquid-chromatographic retention times. Bull Environ Contam Toxicol. 24(2):190–5.

Quaghebeur D, De Smet B, De Wulf E, Steurbaut W (2004). Pesticides in rainwater in Flanders, Belgium: results from the monitoring program 1997–2001. J Environ Monit. 6(3):182–90.

Rahman MA, Muneer M (2005). Photocatalysed degradation of two selected pesticide derivatives, dichlorvos and phosphamidon, in aqueous suspensions of titanium dioxide. Desalination. 181(1–3):161–72.

Sakai M (2006). Acute toxic tests of rainwater samples using *Daphnia magna.* Ecotoxicol Environ Saf. 64(2):215–20.

Steen RJCA, van der Vaart J, Hiep M, Van Hattum B, Cofino WP, Brinkman UAT (2001). Gross fluxes and estuarine behaviour of pesticides in the Scheldt Estuary (1995–1997). Environ Pollut. 115(1):65–79.

Sudo M, Kawachi T, Hida Y, Kunimatsu T (2004). Spatial distribution and seasonal changes of pesticides in Lake Biwa, Japan. Limnology. 5(2):77–86.

Teunissen-Ordelman HGK, Schrap SM (1997). 1996 Aquatic Outlook. An analysis of issues pertaining to aquatic environments: pesticides. Amsterdam: Institute for Inland Water Management and Waste Water Treatment (RIZA Policy Document No. 97.038; http://publicaties.minienm.nl/download-bijlage/11867/pesticides-an-analysis-of-issues-pertaining-to-aquatic-environments.pdf, accessed 22 March 2016).

Tuncel SG, Oztas NB, Erduran MS (2008). Air and groundwater pollution in an agricultural region of the Turkish Mediterranean coast. J Air Waste Manage Assoc. 58(9):1240–9.

USEPA (undated). Method 622: The determination of organophosphorus pesticides in municipal and industrial wastewater. United States Environmental Protection Agency (https://www.epa.gov/sites/production/files/ 2015-10/documents/method_622_1992.pdf, accessed 22 March 2016).

USEPA (1997). Reregistration Eligibility Decision (RED): Trichlorfon. Washington (DC): United States Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances (https://archive.epa.gov/pesticides/reregistration/web/pdf/0104.pdf, accessed 22 March 2016).

WHO (1994). Pesticide residues in food – 1993 evaluations. Part II. Toxicology. Geneva: World Health Organization (WHO/PCS/94.4; http://www.inchem.org/documents/jmpr/jmpmono/v93pr05.htm, accessed 22 March 2016).

WHO (2012). Pesticide residues in food – 2011 evaluations. Part II. Toxicological. Geneva: World Health Organization (http://apps.who.int/iris/bitstream/10665/75147/1/9789241665278_eng.pdf?ua=1, accessed 22 March 2016).

WHO (2017). Guidelines for drinking-water quality, fourth edition incorporating first addendum. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/dwq-guidelines-4/en).