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# Bentazone in Drinking-water

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

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## 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.

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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, United States of America (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.

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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

| | |
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| 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 |
| NOAEL | no-observed-adverse-effect level |
| USA | United States of America |
| WHO | World Health Organization |
| WHOPES | World Health Organization Pesticide Evaluation Scheme |

**Contents**

Bentazone is the International Organization for Standardization (ISO)–approved common name for 3-isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one-2,2-dioxide, with the Chemical Abstracts Service number 25057-89-0 (WHO, 2013).

## *1. MAJOR USES*

Bentazone is a post-emergence herbicide used for selective control of broadleaf weeds and sedges occurring among beans, rice, corn, peanuts, mint and others (WHO, 2013). It damages only those plants that are unable to metabolize it, as the chemical is absorbed by leaves and interferes with the ability of susceptible plants to use sunlight for photosynthesis (MacBean, 2012).

## *2. POTENTIAL FOR OCCURRENCE IN WATER*

Bentazone has a low octanol–water partition coefficient (log $K_{ow}$ −0.46; IPCS, 2008), is highly soluble in water (500 mg/L at 20 °C; Kidd & James, 1991) and is very resistant to hydrolysis. Bentazone also has low adsorption coefficient values (e.g. $K_{oc}$ 34, USDA, 2009; $K_{oc}$ 13–176, European Commission, 2000), indicating that it is very mobile in soil. However, photodegradation occurs in soil and water. Half-lives in soil have been estimated to range from <14 to 98 days (USEPA, 1994; Verschueren, 2008; MacBean, 2012). Dissipation half-life values were up to 33 days in field dissipation studies in the United States of America (USA) (USEPA, 1994).

Because of its high mobility, bentazone is liable to leach under conditions of extreme rainfall (e.g. storms shortly after application) and is expected to pass through the soil profile and via cracks to the underlying aquifer. Once outside the zone of biological action, there is no abiotic mechanism for its degradation. Some contamination of the groundwater would be expected to occur under these circumstances. This potential has been confirmed by some reports of bentazone in groundwater (Joint Meeting on Pesticides, 1997). Concentrations in groundwater range from 0.01 to 120 µg/L (KIWA, 1990; USEPA, 1994; HSDB, 2003).

Surface waters can be polluted by effluents from production plants, drainage waters and actual use in the water (rice fields). Bentazone frequently occurs in surface water in Japan in areas where it was used in significant quantities in rice farming; concentrations up to 14 µg/L have been detected. The highest concentration in drinking-water was 1 µg/L (Japan Water Works Association, 2009–2012). The maximum bentazone concentration measured in drinking-water in Germany was 0.185 µg/L (Federal Ministry of Health and Federal Environment Agency, Germany, 2013).

## *3. TOXICITY*

In 2012, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Meeting on Pesticide Residues (JMPR) evaluated bentazone (WHO, 2013). Bentazone has moderate acute toxicity when administered orally to rats, guinea pigs and rabbits. Repeated-dose toxicity studies (subchronic and chronic) in mice, rats and dogs indicate that effects on haematology and blood coagulation (e.g. prolongation of prothrombin time and partial thromboplastin time) are consistently observed. Bentazone is not carcinogenic in rats or mice and showed no evidence of genotoxicity in a range of in vitro and in vivo assays. No reproductive effects were observed at the highest dose tested in a two-generation reproductive toxicity study in rats, and bentazone was not teratogenic in rats or rabbits.

JMPR established an acceptable daily intake (ADI) of 0–0.09 mg/kg body weight (bw) derived from a no-observed-adverse-effect level (NOAEL) of 9 mg/kg bw per day from the

same study (Takehara, 1984) used as the critical study by JMPR in 1991 (WHO, 1992), a 2-year toxicity and carcinogenicity study in rats, on the basis of prolonged blood coagulation and clinical chemistry changes indicative of effects on liver and kidney at 35 mg/kg bw per day. A safety factor of 100 was applied. This ADI was supported by the NOAEL of 13.1 mg/kg bw per day observed in a 1-year study in dogs for anaemia, altered blood coagulation parameters, clinical signs and weight loss seen at the highest dose of 52.3 mg/kg bw per day (Allen et al., 1989); the NOAEL of 14 mg/kg bw per day in a two-generation study in rats, on the basis of reduced parental feed consumption and body weight gain and reduced pup body weight resulting from parental toxicity at 59 mg/kg bw per day (Suter et al., 1989); and the NOAEL of 12 mg/kg bw per day in a 2-year toxicity and carcinogenicity study in mice, based on prolongation of prothrombin time and an increased incidence of testicular calcification at 47 mg/kg bw per day (Takehara, 1985, 1989).

JMPR did not establish an acute reference dose (ARfD)[1] for bentazone in 2012, but reaffirmed its previous conclusion in 2004 (WHO, 2005) that no ARfD was necessary. JMPR considered that the post-implantation loss seen in a rat developmental toxicity study was not caused by a single dose and that no other effects were observed in repeated-dose studies that could be due to a single dose (WHO, 2013).[2]

## *4. DERIVATION OF A HEALTH-BASED VALUE[3]*

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 applied to food crops. JMPR concluded that the daily intake of bentazone in food was up to 1% of the upper bound of the ADI (FAO/WHO, 1999), which suggests that exposure from food is low.

With an allocation of 20% of the upper bound of the JMPR ADI of 0.09 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 0.5 mg/L (500 µg/L) can be derived for bentazone. 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 (for further information, see Section 8.2.2, "Relative source allocation", of the *Guidelines for Drinking-water Quality*; WHO, 2017).

[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] JMPR will be placing bentazone on its agenda for a future meeting specifically to determine whether there is a need to establish an ARfD, as new toxicology studies have become available that may lead to the development of an ARfD. This background document will be updated, if necessary, following the JMPR meeting.

[3] 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.

## *5. CONSIDERATIONS IN APPLYING THE HEALTH-BASED VALUE*

The HBV for bentazone is protective against health effects resulting from lifetime exposure to the pesticide from drinking-water. Small exceedances of the HBV for short periods would not normally constitute a health emergency, and the *Guidelines for Drinking-water Quality* (WHO, 2017) provide guidance on how to make such judgements (see Section 8.7.5). For example, in the event of a spill or other short-term problem, a higher allocation of the ADI to drinking-water could be justified.

Routine monitoring of bentazone 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*

Analytical methods are available that can detect bentazone at levels below the HBV. For example, bentazone can be determined by gas chromatography with electron capture detection after liquid–liquid extraction, with a detection limit of about 0.1 µg/L (Eaton et al., 2005). Liquid chromatography with tandem mass spectrometry has also been applied, providing a limit of quantification of 0.01 µg/L (Sklivagou, Papadopoulou & Bakoulis, 2010).

## *7. TREATMENT TECHNOLOGIES*

Conventional treatment, including coagulation and filtration, is not effective for reducing the concentration of bentazone in water. Activated carbon adsorption is fairly effective for hydrophilic pesticides such as bentazone, but it requires a high dose; powdered activated carbon with a dosage of a few tens of milligrams per litre or more is required for 80% removal with a contact time of 0.5–2 hours (Matsui, 2010). Ultraviolet light with hydrogen peroxide used as an advanced oxidation process has been shown to reduce bentazone concentrations by 60% in surface water (Kruithof & Martijn, 2013).

## *8. CONCLUSION*

It is not considered necessary to establish a guideline value for bentazone, as it usually occurs in drinking-water sources or drinking-water at concentrations well below those of health concern. Where monitoring results show the presence of bentazone in drinking-water on a regular basis, an HBV of 0.5 mg/L can be applied. In assessing the significance of an exceedance of the HBV, Section 8.7.5 of the *Guidelines for Drinking-water Quality* (WHO, 2017) should be consulted.

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