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# Factors influencing public perception of drinking water quality

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**Abstract**

A better understanding of the processes that influence public perception can contribute to improvements in water management, consumer services, acceptability of water reuse and risk communication, among other areas. This paper discusses some of the main variables involved in public perception of drinking water quality. Research on this topic suggests that perceptions of water quality result from a complex interaction of diverse factors. In many circumstances, the estimation of water quality is mostly influenced by organoleptic properties, in particular flavour. In addition, a variety of other factors also have an influence on perceptions of quality. These include risk perception, attitudes towards water chemicals, contextual cues provided by the supply system, familiarity with specific water properties, trust in suppliers, past problems attributed to water quality and information provided by the mass media and interpersonal sources. The role and relevance of these factors are discussed in detail.

*Keywords:* Consumer satisfaction; Drinking water; Organoleptics; Quality perception; Risk perception

## 1. Introduction[1]

A combination of different factors, including changes in the social role of science, complexity and uncertainty, contributed to the emergence of the general public as an important actor in water management. In this context, some authors even suggested that "perception may very well become more important than reality [...] especially when it comes to the quality of drinking water" (Sheat, 1992: 3). While until the early 1990s quality standards were widely accepted as a kind of scientific yardstick (Fawell & Miller, 1992), it is now increasingly noticed that "the judgement of safety—or what is an acceptable level of risk in particular circumstances—is a matter in which society as a whole has a role to play" (WHO, 2004) and that "standards should be based on the protection of human health and consumer acceptability" (IWA, 2004: §7.7). This view has been echoed by some policy makers (see for example DEFRA, 2005).

[1] This paper was prepared when the author was based at University of East Anglia, Norwich, UK. The views presented in this paper are not necessarily those of UNESCO and do not commit the organization in any way.

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The integration of perspectives from the general public can be challenging and pose difficulties for water professionals concerned with the implementation of optimal technical solutions, but ignoring such perspectives can lead to public discontentment and implementation problems. For instance, Barraqué (2003) argued that the continuous deterioration of public confidence in the water supply of developed countries may ultimately lead to the disruption of supply services. On the other hand, a better understanding of the processes involved in public perception of water quality, may provide a contribution to multi-stakeholders processes, help to improve consumer services and satisfaction, foster communication, promote cooperation and prevent conflict. This paper discusses some of the main factors that influence public perception of drinking water quality.

Since the late 1960s, a considerable amount of research has focused on attempting to understand how water quality is perceived. However, the existing literature on this topic is highly heterogeneous and difficult to synthesise as a single holistic theory. Work on water perception has focused on different kinds of water, has been based on different scientific paradigms and—within the same paradigm—has used diverse methodological and conceptual approaches. Moreover, a significant part of the research on drinking water has a strong emphasis on water-related behaviour, particularly on bottled water consumption (Doria, 2006). Additionally, it should be noted that most research in this area has been conducted in developed countries with stringent water quality standards and reliable supplies. Consequently, current knowledge may be geographically biased and extrapolations to developing countries may be inadequate. This paper starts with a discussion of the main factors that modulate perceptions and concludes by looking at the way such factors are combined to shape the perception of drinking water quality.

## 2. Sensorial information (organoleptics)

The importance given by the public to drinking water organoleptics (i.e. sensorial information from taste, odour, colour and turbidity) is currently paramount for quality perception, service satisfaction, willingness to pay and the selection of water sources (e.g. Warren, 1996; Jardine *et al.*, 1999). Within this context, some projections have estimated that taste will be the key issue for public waterworks managers by 2045 (see Gordon, 2000). In many surveys, satisfaction with organoleptics is usually high in absolute terms ($>70\%$ of satisfied consumers), but it is often low when compared with other aspects of the water supply service (see AWWA, 1993; Grondin *et al.*, 1995; Levallois *et al.*, 1999; MORI, 2002). It is not entirely understood why so much importance is given to something purely aesthetical, but it was suggested that the public may relate organoleptics to health risks (Jardine *et al.*, 1999; Doria *et al.*, 2005). Another hypothesis is that drinking water is increasingly regarded as a product that should be enjoyed, rather than a basic necessity.

Sensory information is often interrelated. Taste and odour rely on close physiological processes and the originating stimuli can derive from the same substance. In many circumstances, the interaction between taste, odour and colour can also be due to psychological factors, as people expect sensorial information to be consistent (Noble, 1996). Although interrelated, the relative importance attributed to each of the senses varies according to time and culture. In western countries, water taste is usually identified as more important than odour or appearance (e.g. Warren, 1996; MORI, 2002), perhaps because taste can detect water chemicals at lower concentrations than other senses (Young *et al.*, 1996).

## 3. Risk perception

Survey research generally indicates that most people in countries with reliable supplies perceive tap water risks as small (e.g. Grondin *et al.*, 1995; Grondin & Levallois, 1999). Even in places with persistent water-treatment deficiencies and microbiological contamination, when consumer notifications are released, the magnitude of perceived risks of tap water is close to the average point of the questionnaire measurement scale (Anadu & Harding, 2000). Perceptions of drinking water safety and risk seem to be consistent and tap water is generally regarded as safe (e.g. AWWA, 1993; DWI, 1998; C.I. Eau, 2000; MORI, 2002). In contrast, a high risk is generally attributed to the pollution of drinking water, even when it is placed in perspective against a number of serious hazards, such as toxic wastes and natural disasters (Fischer *et al.*, 1991; Jianguang, 1994; EORG, 2002). The combination of the words "water" and "pollution" seems to make a crucial difference. While the risks associated with drinking water are now remarkably low in the countries where these surveys were performed, this situation may be perceived as unstable and deteriorating (e.g. Slovic, 2000: 253). Such belief in the decline of water quality may be due to a general inter-temporal pessimism (see Hagerty, 2003).

In addition to risk magnitude, very few studies have tried to discriminate which health risks are perceived to be associated with drinking water. In a Canadian survey, respondents identified gastrointestinal disorders, infectious diseases, cancer, contamination and intoxication as potential risks (Levallois *et al.*, 1999).

The perception of drinking water risks is largely influenced by the same cognitive-emotive processes that affect risk perception in general. Some of these factors are discussed in detail further in this paper and include trust in institutions, external information, familiarity, demographics and perceived control. Additionally, several other factors are known to influence perception of risks, including heuristics and biases, risk characteristics (e.g. uncertainty, voluntary exposure, fairness) and personal/societal level of exposure (for a review see Pidgeon *et al.*, 1992). However, most research in risk perception has focused on large risks or on new and controversial hazards of which respondents have little personal experience. As a result, their findings may not be transferable to the case of drinking water (Canter *et al.*, 1993/94; Johnson & Scicchitano, 2000). In this case, risk perception seems to be largely derived from direct experience via organoleptics.

Few studies have specifically focused on risk perception of drinking water and looked for the factors that influence it. Syme & Williams (1993) analysed "water quality risk judgement" (a composite variable that measures "lack of risk") and found it to be weakly ($R^2_{adj} = 0.25$) predicted by neighbourhood satisfaction, trust in governmental agencies with water-related competencies, perceived control over the water supply, belief in human control of environmental problems, borewater use, perceived variability of water quality and gender. A study by Johnson (2003) found personal concern about drinking water risks to be explained ($R^2_{adj} = 0.30$) by the belief that there are serious environmental health problems in the places where respondents live and by low personal control over their own health risks. In that study, personal concern was not found to be significantly influenced by demographics, perceived drinking water safety, trust water utilities, the belief that experts should decide about health risks, or technical information reporting violations of drinking water standards. Doria *et al.* (2005) found the perception of tap water risks to be explained ($R^2_{adj} = 0.52$) by satisfaction with water colour, flavour, interpersonal information, remembrance of water-related health problems and impersonal information. Regarding the level of exposure, Park *et al.* (2001) reported that the mean concern with drinking water chemical contamination was significantly higher at the societal level than at

the personal level, a difference that may be due to optimistic bias. In addition, personal vulnerability can also affect perceived risk of tap water, which is generally higher among susceptible groups and patients with debilitating diseases (Parkin *et al.*, 2001).

## 4. Water chemicals and microbiological parameters

Water acts as a good solvent for many substances that influence organoleptics and may pose health risks. Some generalisations have attempted to describe the relationship between water chemical composition and water flavours. Bruvold (1968) demonstrated a linear relationship between the intensity of water taste and the level of mineral content. Using a consumer panel methodology, Falahee & MacRae (1995) compared the preference for different waters (e.g. distilled water, tap water, filtered tap water) and found that waters with high mineral content were generally preferred over those with low mineral content. Notwithstanding, the sensory differences were very subtle and chlorine concentration and filtration of tap water made almost no difference to preference. In addition, Zoeteman *et al.* (1978) found that cations (e.g. sulphates) are more likely to produce objectionable flavours than anions (e.g. chlorine). Apart from taste, chemicals can also influence odour and colour. The effect of specific chemicals on colour is well-known, but very few studies have tried to relate chemical content to the visual satisfaction of drinking water. Attempts to relate a general chemical parameter (total dissolved solids) to the overall acceptability of tap water quality in different Australian locations failed to produce clear-cut results; the location with the highest level of dissolved solids was also the one with the highest acceptability of water quality and the lowest perceived risks (Syme & Williams, 1993). A similar conclusion was reached in Taiwan, where respondents' satisfaction with drinking water samples did not seem to be related to dissolved solids, hardness or alkalinity (Lou *et al.*, 2007).

The widespread chemophobia that emerged during the 1970s and 1980s is sometimes transposed to drinking water. In a survey conducted in Toronto (Canada), 72% of the respondents said that they were concerned with the presence of chemical pollutants in their drinking water (Auslander & Langlois, 1993). Respondents who were concerned with chemicals attributed lower ratings to water quality. A survey in the USA found that 55% of respondents considered chemicals in water to be a problem (Centre for Communication Dynamics, 1985) and 57% of the respondents of an Italian survey mentioned that not knowing the composition of tap water was one of the main causes for concern or dissatisfaction when using it (Contu *et al.*, 2004).

The main risk management strategy followed during the 20th century has been to supply water with a concentration of chemicals well below levels regarded as unsafe. However, surveys in the USA have shown that while most respondents believe their water meets safe drinking water standards, approximately 40% think they are not strict enough (AWWA, 1993). Moreover, only 20% would willingly accept small amounts of chemicals in their drinking water, even if they level met regulated standards (Centre for Communication Dynamics, 1985). Although the situation may have changed with the introduction of more stringent standards, these results are likely to be related to a more fundamental cause. Kraus *et al.* (1992) reported that the lay public tends to emphasise the importance of exposure to chemicals irrespective of the dose. Even if the motivations to understand and control chemical risks are similar to those of experts, members of the public are more likely than toxicologists to agree that the simple reduction (but not elimination) of a chemical in drinking water does not necessarily imply that the risks are also reduced (a belief that seems to be related to education). Possibly as a consequence, when

compared with toxicologists, the public tends to be much more pessimistic about the potential risks of chemicals and more sceptical about their benefits. For the public, the belief that dose and exposure mediates risk is strongly related to positive attitudes towards chemicals.

Of the many chemical substances that can be present in drinking water, very few are the target of public attention. Some of the chemicals most frequently alluded to are chlorine, limescale/hardness and lead. Other chemicals—such as fluoride, nitrates, pesticides, heavy metals and industrial chemicals—are sometimes specified, but their relevance within the general context of drinking water perceptions seems to be minute or restricted to specific locations (e.g. Mahler *et al.*, 1999).

Chlorine is sometimes mentioned as a cause of objectionable tastes, but there are also suggestions that subtle tastes may be interpreted as a sign of water safety (Kelly & Pomfret, 1997). Nonetheless, as much as 33% of respondents to a Canadian survey pointed out an excessive taste of chlorine to justify their dissatisfaction with tap water (CP-LM, 2001). On the infrequent occasions when chlorination is covered by the mass media, it is often described using negative metaphors, being related to the risks of its by-products (Driedger & Eyles, 2003). Analysis of factor loadings of risk perceptions related to different substances and activities in the USA shows that water chlorination scores relatively high on an "unknown factor" (associated with risks that are not observable, unknown to those exposed and/or to science, new, or that have a delayed effect) and low on a "dread factor" (associated with risks that are perceived as controllable, individual in nature, with non-fatal consequences, equitable, have low risk to future generations, are easily reduced and voluntary; see Slovic, 2000). As large scale chlorination of drinking water began approximately one century ago, the loadings on the "unknown"/"new" score are somewhat unexpected. In these studies, other substances with similar scores to chlorination are fluoridation, saccharin, coal tar hair dyes and marijuana. In addition, an analogous analysis with several water-related activities and substances shows that water chlorination scores moderately on an "ecological impact factor" (indicating that it has high relevance, presents health risks, can affect many people and can lead to loss of species in aquatic environments) and scores very high on a "human benefits factor" (indicating that it is equitable and beneficial; see McDaniels *et al.*, 1997). In the same study, lay respondents attributed a moderate risk to water chlorination (4.4 in a 7-point scale), a value that did not significantly differ from the estimation of experts (3.8 over 7). Both lay and expert respondents considered chlorine in drinking water to be one of the lower risk substances that were evaluated in this research.

Limestone and water hardness have several practical implications, with the potential to cause scaling and influence organoleptics. Excessive limestone or hardness is indicated by 13% and 23% of respondents of, respectively, Canadian and French surveys to justify dissatisfaction with tap water (C.I. Eau, 2000; CP-LM, 2001). Although no quantitative studies seem to have explored satisfaction with limestone/hardness or its strength for perceptions of quality and risk, interviews and mental models research in the UK provide a good analysis of the cognitive processes involved. In this context, Strang (2001: 10) reported the ambivalence regarding water hardness in terms of its potential health risks and benefits, with one of her informants stating that: "You know that hard water is bad for you in some ways, you know that soft water is bad for you in some ways, so where do you go?" In addition, Owen *et al.* (1999) used a mental model approach to explore laypeople's beliefs about water hardness and compared these with a mental model of experts. The authors found that laypeople's conceptualisations would sometimes fit the experts' model, being connected with the raw water source, the treatment process and mainly with the estimation of problems. However, the analysis revealed that more than half of laypeople's beliefs about drinking water hardness are misconceptions, correct but imprecise beliefs,

or irrelevant peripheral concepts. This situation may lead to problems in the interpretation of hardness information and to difficulties in risk communication.

Another drinking water chemical that has received some public attention is lead, mostly owing to its neurotoxicological effects. In many cases the addition of lime supplemented with orthophosphate has minimised exposure, but as a significant proportion of lead in drinking water may come from old household pipes, the control and reduction of residual lead concentrations is to a large extent dependent on public perception and support. However, public concern about lead contamination seems to be relatively low, even among vulnerable populations. Fisher *et al.* (1993), focusing on the risks commonly associated with schools, found that members of school-related groups (students, parents, teachers and staff) were more concerned about drugs, alcohol, tobacco and asbestos than with lead in drinking water. In France, very few survey respondents think that their drinking water has lead in it (9% in 1998), but this proportion seems to be increasing (12% in 2000; C.I. Eau, 2000). Griffin & Dunwoody (2000) showed that risk perception of lead in drinking water can be modestly explained ($R^2_{adj} = 25$) by prior experience of other water risks (i.e. cryptosporidiosis), information from health professionals, information from family and friends, belonging to an ethnic minority, social status, gender and age; no significant influence was found for several other variables, including hazard presence, testing tap water lead and information from the mass media and government agencies. Griffin & Dunwoody (2000) felt that the low magnitude of the relationships they found was a result of a low level of personal involvement, interest and motivation regarding lead in drinking water.

Along with chemicals, microbiological agents form another important component of drinking water, having the potential to influence organoleptics and can pose risks to human health. Microbiological risks have been dramatically reduced with the introduction of chlorination and other treatments and this is reflected in the low public concern about microbiological contamination. Only 7% of French survey respondents believe that their tap water has microbes and viruses (C.I. Eau, 2000) and less than 5% of survey respondents in Idaho (USA) considered bacteria in drinking water an important problem (Mahler *et al.*, 1999).

## 5. Contextual indicators

Context can provide indirect information about water quality. Such cues are interpreted from prior experience and can lead to expectations that will strongly influence perception. In the case of drinking water, contextual cues can be derived from taps, water pipes, bottles and the characteristics of the place where water is consumed, among other possibilities. Research about the effect of contextual indicators on drinking water perception is scarce and often restricted to the distribution system. Focus groups in Hamilton (Canada) and Washington (USA) found that some people attribute tap water contamination to the distribution system (Jones *et al.*, 2007), including rusting pipes (Parkin *et al.*, 2001). In Sardinia (Italy), a relatively large number of survey participants (55.7%) mentioned the distribution system condition as one of the main causes for concern and dissatisfaction with tap water (Contu *et al.*, 2004). Further evidence on the link between perceived quality and context is provided by studies with other beverages, which found indicators such as bottle design and labels very strongly to influence taste satisfaction and product preference (e.g. Woolfolk *et al.*, 1983). In addition, the main factors influencing the public estimation of water quality of rivers and lakes are contextual (e.g. the presence of fish or rubbish in the margins—Moser, 1984; House & Sangster, 1991).

Regarding the place where water is consumed, neighbourhood satisfaction can moderately influence the acceptability of tap water quality (Syme & Williams, 1993) and the belief that there are serious environmental health problems in the area of residence has a significant effect on personal concern regarding drinking water risks (Johnson, 2003). Notwithstanding, Griffin & Dunwoody (2000) found no relationship between inhabiting a home likely to have problems with leaded pipes and water-related risk perceptions.

Knowledge about the place where drinking water is abstracted seems to be weakly associated with perceptions of quality and risk (Grondin *et al.*, 1995; Grondin & Levallois, 1999). This suggests that drinking water and water resources are not entirely distinct in people's minds, but such results may be due to confounding factors, including chemical differences. Moreover, public knowledge about water sources is often limited, with some surveys pointing out that only half of the respondents can correctly identify their tap water source (Grondin *et al.*, 1995; Oliver, 1999).

## 6. Prior experience

Prior personal experience provides the basis for the interpretation of new information and can have a strong effect on perceptions of water quality and risk, among many other variables. Tastes, odours and colours are only attributed to specific compounds, such as salt or sugar, to the extent of what was previously learned. Experience sets a standard and qualitative research on water organoleptics suggests that people prefer what they are used to (Strang, 2001). Therefore, the acceptability of water with identical physicochemical compositions can vary geographically. For instance, people from a region where drinking water is typically yellowish may consider a bluish water to be strange and perhaps unsatisfactory. The importance of familiarity for satisfaction with organoleptics can be exemplified by food preferences, in particular when neo-phobia leads to the rejection of unfamiliar products (Pliner & Pelchat, 1991) and with the preference for domestic—versus foreign—products (Prescott, 1998). The profound role of previous experience has lead to the hypothesis that foods are assessed to match expectations (Cardello, 1994) and the same may happen with drinking water. Moreover, the familiarity–liking relationship is one of the most robust generalizations in marketing research, with the products of familiar brands being preferred over those of unfamiliar brands (Rindfleisch & Inman, 1998).

Apart from preferences for quality and organoleptics, familiarity also influences perceptions of risk. Several studies in risk perception have demonstrated that people who are familiarised with hazardous substances or activities perceive them to be less risky (see Slovic, 2000). In relation to drinking water, Owen *et al.* (1999) studied how a change in the raw water source of a public supply resulted in an increase of water hardness and drastically raised consumers' complaints. Although complainers were already familiar with the hard water of the area, even having positive attitudes towards it, the sudden change in water quality and lack of specific information lead to consumer anxiety.

Notwithstanding, an exception to the familiarity–liking relationship seems to occur with tourists, who are often more positive about the characteristics of drinking water than local residents (Contu *et al.*, 2004). These findings may perhaps be attributable to the mood of tourists or to their attempts to please a local researcher. Similar differences were reported in perceptions of rivers and lakes (e.g. Happs, 1986), one possible hypothesis being that sporadic problems of pollution are unfamiliar to infrequent visitors (House, 1996). Moreover, familiarity may not be attainable in regions where the water quality changes frequently and the lack of strong expectations may lead to uncertainty and dissatisfaction.

Frequent changes in quality are inversely associated with quality acceptability and water risk judgments (Syme & Williams, 1993).

Personal experiences are not always positive or neutral. Adverse experiences can also influence perception, leading to an increase in risk judgments. For example, the experience of water-related cryptosporidiosis slightly increases the worry and the perceived risks of *Cryptosporidium* (Griffin *et al.*, 1998) and the increased concern is transposed to perceptions of lead contamination of tap water (Griffin & Dunwoody, 2000). Syme & Williams (1993) found a weak but significant correlation between prior negative experiences and the acceptability of drinking water quality and risk (in this study, negative experience was only measured by poor taste and limited water quantity). Nonetheless, the overall influence on risk perception may be modest in countries where few people have experienced health problems attributable to drinking water (e.g. only 4% of respondents in Canadian surveys believed they or a family member were physically affected by the quality of the drinking water—Grondin *et al.*, 1996, for public supplies; Jones *et al.*, 2006, for private supplies).

## 7. Impersonal and interpersonal information

According to social learning theory, we learn both by direct experience and by information from the experience of others (Bandura, 1977). Information about water can be obtained from a variety of impersonal and interpersonal sources. The importance of particular information sources varies geographically and is influenced by demographics and other factors. In Toronto (Canada), the main sources used by the public to get information about water are the mass media (37%), friends and relatives (21%) and environmental groups (16%; Auslander & Langlois, 1993); in France the main sources are city councils (35%), regional newspapers (33%) and television (11%; IFEN, 2000); in Idaho (USA) the preference goes to newspapers (63%), television (52%) and cooperative extension brochures (32%; Mahler *et al.*, 1999). In spite of the variety of sources used for water-related information, most European and USA survey respondents consider themselves to be insufficiently informed about tap water (AWWA, 1993; EORG, 2002), a belief that was also elicited in focus-group research in Canada (Jones *et al.*, 2007). However, at least in France and in some parts of the USA, this proportion seems to be slowly decreasing (C.I. Eau, 2000; Johnson & Scicchitano, 2000). A study in Sardinia (Italy) identified the topics that consumers would like to receive information about and stressed the interest on drinking water safety and water treatments (Contu *et al.*, 2004). In this survey, less than one-fifth of the respondents expressed no interest in water-related information. In a survey among users of private water supplies in Canada, most respondents have expressed interest in more information about water quality testing (81%) and water treatment options (71%) (Jones *et al.*, 2006).

Information may lead to changes in knowledge and emotions, having a potential effect on the way drinking water quality and risks are perceived. The impersonal impact hypothesis suggests that information from the mass media predominantly influences perceptions at the societal level, but not at the personal level; and interpersonal information mostly affects perceptions at the personal level, but not at the societal level (Tyler, 1980).

Regarding impersonal sources of information, drinking water has a considerable interest to a vast audience and is therefore a particularly good topic for the media to explore. Media coverage is conditioned by newsworthiness rules, which define that information about uncommon events and poor conditions are the most pertinent (Bjerström, 2002). Consequently, drinking water risks are often

publicized on television, in mainstream movies (e.g. *A Civil Action* in 1999 and *Erin Brockovich* in 2000) and the printed media (Driedger & Eyles, 2003). In this context, it is not surprising that about 38% of survey respondents in the USA claimed to have seen or heard something in the media that made them worried about tap water (AWWA, 1993). As a result, water professionals sometimes criticise the media for spreading inaccurate information (Fawell & Miller, 1992). However, in spite of early suggestions that the mere reporting of a potential problem would lead to increases in risk perception, the overall impact of the media on public perception is generally very limited (for a review see Wahlberg & Sjöberg, 2000).

Satisfaction with organoleptics does not seem to be influenced by media coverage of water quality problems (AWWA, 1993; Grondin *et al.*, 1995). Even news reports about the large Milwaukee *Cryptosporidium* outbreak were only seen by about half of the public in the USA and their impact on perceived water quality and on trust in water suppliers seems to have been restricted (AWWA, 1993).

Reliance on television can have a statistically significant but very weak effect on risk perceptions of chemical contaminants in drinking water at the societal level, but reliance on newspapers does not seem to have any noticeable influence (Park *et al.*, 2001). Furthermore, as predicted by the impersonal hypothesis, there is some evidence that the media has no significant effect on the perception of drinking water contamination at the personal level (Griffin & Dunwoody, 2000; Park *et al.*, 2001). Nonetheless, exceptions are presented by Syme & Williams (1993), who found that trust in the Australian media was weakly associated with both water risk judgements and water quality acceptability and by Doria *et al.* (2005), who reported a weak relationship between having heard worrying water-related news and perceived risk from tap water. Griffin *et al.* (1998) assumed a different causal path that suggests that people would look for specific information to explain their health condition or to confirm their expectations. In this study, reliance on the mass-media for water-related *Cryptosporidium* information is poorly explained ($R^2 = 0.09$) by personal risk worry of future cryptosporidiosis.

Interpersonal sources—usually comprising family members and friends—are less frequently mentioned than the mass media as a trusted channel of environmental information (e.g. EORG, 2002). However, their influence on perceptions and behaviour seems to be often stronger than that of mass-mediated sources (Park *et al.*, 2001; Doria *et al.*, 2005), although their influence has been overlooked in the drinking water context.

With regard to scientific and technical information, several communication strategies have been developed since the 1980s to increase public knowledge and to heighten awareness of water issues (e.g. Glicker, 1992). It was initially assumed that scientific and technical information might strongly attenuate differences between the public and experts. However, the impact of such efforts was often more limited than anticipated, highlighting the difficulties that may emerge when communicating about water issues with the public (see Owen *et al.*, 1999; Parkin *et al.*, 2003; Doria *et al.*, 2006b).

The effect of scientific and technical information on public perception has been addressed by several studies. Johnson (2003) compared the impact of US Consumer Confidence Reports presenting drinking water standards violations. The majority (76%) of respondents considered the reports comprehensible, but only 58% said they would read them carefully. Although those who read the reports expressed concerns about the health effects of drinking water, they did not differ from a control group. Moreover, the difference in concern between those who read violation and no-violation texts is very small, suggesting that their influence on consumer judgments is minimal. In addition, the evaluation of a "boil water notice" leaflet, issued by a water company during a contamination episode, showed that the leaflet was partially ignored by 64% of the households surveyed and was not more effective than information

provided by the mass media and by interpersonal sources (O'Donnell *et al.*, 2000). Likewise, information from health and medical magazines seems to have a significant but very weak effect on risk perceptions of chemical contaminants in drinking water, both at the societal and personal levels (Park *et al.*, 2001). Research on interpersonal information from experts—usually health professionals—suggests that their influence on drinking water perceptions is also small or even non-significant (Griffin & Dunwoody, 2000; Park *et al.*, 2001; Doria *et al.*, 2006a).

Overall, research indicates that external information is sometimes linked to perception, either because information affects risk perception, or because risk perception leads to information search. Nonetheless, the general strength of this link seems to be modest, on one hand because such information is ignored by a relatively large proportion of the target audience and on the other hand because many other factors are involved in modelling risk perception of water issues. The combined influence of interpersonal and mass-mediated information only explains a very small proportion of the variance of risk perception of water chemicals ($R^2 < 0.15$; Park *et al.*, 2001). However, in areas with a very large number of consumers, the impact of information may noticeably increase consumer complaints and enquiries to water companies and regulators.

## 8. Trust in water companies and other groups

The public sees large differences in the capacity and willingness of various groups to provide information or to handle environmental issues (e.g. Johnson & Scicchitano, 2000; Viklund, 2003). In many countries, scientists and members of environmental NGOs are typically the most trusted groups (e.g. EORG, 2002). However, there is a crisis of social trust in many western countries and even the groups regarded as the most credible are only trusted by a proportion of the population (EORG, 2002; Welch *et al.*, 2005). This is reflected in the perceived potential of experts and government spending to address water-related problems. In a USA survey, 57% of the respondents think experts are likely to reduce threats to society from water pollution and 46% believe that government spending can do something to solve such problems (O'Connor *et al.*, 1998). Trust in the mass media and governmental groups is usually lower than that placed in scientists and NGOs (e.g. EORG, 2002). Commercial companies are generally the least trusted group. Water companies do not seem to be an exception, with a considerable proportion of survey respondents thinking that their suppliers are more concerned about making money than about their customers (AWWA, 1993; MORI, 2002). Nonetheless, in the case of communications with the public, credibility can be influenced by the content of the message and water companies are regarded as highly trustworthy when communicating about contamination emergencies (Doria *et al.*, 2006b).

Trust in companies and institutions is often linked to the perception of quality and risk, but the causal order of this relationship is not entirely clear and may vary according to the case. Trust is often considered to be an antecedent of risk perception, influencing the selection and impact of information about risk, the acceptability of potential hazards and the acceptability of regulators' decisions (see Pidgeon *et al.*, 2003). Trust in companies also influences perceived product quality and consumer satisfaction (Selnes, 1998). However, several authors have argued for an opposite causal influence, considering that perceptions of quality and risk lead to trust in institutions and companies (Selnes, 1998; Poortinga & Pidgeon, 2005). Additionally, a series of other factors compose or potentially influence trust, including perceptions of care, value similarity, competence, integrity, cooperation and openness

(Poortinga & Pidgeon, 2003; Welch *et al.*, 2005). Possibly because of variations in these factors, the association between trust and risk perception oscillates according to the country (Viklund, 2003).

In the case of drinking water, trust in governmental agencies with water-related competencies is associated with both risk judgements and the acceptability of water quality (Syme & Williams, 1993). Trust in water suppliers is moderately associated with the perception of contextual indicators (e.g. the supply system quality) and is weakly associated with perceived water quality (Doria *et al.*, 2005). However, the influence of trust in water suppliers on risk perception is very weak or even non-significant (Johnson, 2003; Doria *et al.*, 2005). Moreover, focus group research reported the co-occurrence of negative and cynical views about water companies with high levels of satisfaction with the water supply and sewerage services (MORI, 2002). Although service satisfaction is often directly associated with trust, a potential explanation is provided by the concept of "critical trust" (Walls *et al.*, 2004), which refers to the capacity of people to criticise individuals and/or organizations that they nonetheless value and support.

## 9. Perceived control

Perceived control is often central to perception and acceptability. In the context of drinking water, personal control is generally restricted. In Australia, the general belief in human control of environmental variables was found to be moderately associated with judgments of water risks and the acceptability of water quality; the perception of personal control over the water supply was also associated with risk judgments and quality acceptability (Syme & Williams, 1993). In a survey in Italy, lack of control was frequently (53%) mentioned by respondents as cause for concern and dissatisfaction when using tap water (Contu *et al.*, 2004). Differences in perceived control are also likely to underlie the difference in perceptions of drinking water safety between the users of public supplies (27% regard it unsafe) and the users of private wells (13% regard it unsafe—Jordan & Elnagheeb, 1993). There are some suggestions that good communication with water companies is interpreted by consumers as a form of control.

## 10. Demographics, cultural background and world views

Demographics are often weakly but significantly associated with many variables, including perceptions of risk, organoleptics, knowledge and the selection of information channels (e.g. Kraus *et al.*, 1992; AWWA, 1993; Stevens, 1996; Parkin *et al.*, 2001). Demographic variables are often closely interrelated, it being difficult to establish causal effects. Moreover, their effect on water perceptions is likely to be mediated by other factors, such as perceived control and context (see the regression analysis in Johnson, 2003).

The influence of gender on risk perception has been the focus of much attention, with women generally perceiving higher risks and expressing more concern and worry than men. Several studies found gender differences in the perception of risks associated with tap water chemicals and pollution (AWWA, 1993; Anadu & Harding, 2000; Griffin & Dunwoody, 2000), but this is not always the case (e.g. Griffin *et al.*, 1998; Johnson, 2003). Multiple hypotheses have been suggested to explain gender differences, including a higher sense of vulnerability felt by women, gender structures, socio-political factors and differences in world views and trust.

Age is often weakly associated with several variables, such as risk perception and satisfaction with the water supply service. Age may interfere with perception of flavours and odours, influencing how they are described (Stevens, 1996). Younger respondents are more likely to be dissatisfied with the tap water supply service (MORI, 2002) and to perceive tap water as slightly riskier (Grondin *et al.*, 1995; Park *et al.*, 2001) or less safe (AWWA, 1993; Parkin *et al.*, 2001). Notwithstanding, some studies reported different relationships, with older respondents attributing higher risks to drinking water (Syme & Williams, 1993). In the broader risk perception literature, the role of age remains ambiguous and is likely to be hazard-dependent.

Several other demographic variables may influence water-related perceptions. Education and income were found to be inversely associated with the risk perception of drinking water (Grondin *et al.*, 1995; Grondin & Levallois, 1999), but some authors failed to verify these relationships (Park *et al.*, 2001) or reported mixed results (Syme & Williams, 1993). Education influences the interpretation of dose–response relationships of chemicals in drinking water, suggesting that more educated people are likely to attribute smaller risks to drinking water contamination (Kraus *et al.*, 1992). However, this effect may be attenuated by a direct relationship between education and the perception of chemical pollution of drinking water (Auslander & Langlois, 1993). In addition, Johnson (2003) found no significant effect of education on personal concern with tap water risks. Education also influences the selection of environmental communication channels, with the more educated giving more attention to magazines and less to television (EORG, 2002).

There is some evidence that members of ethnic minorities are more concerned about the presence of lead in drinking water, are willing to pay more for water safety improvements and seek more information about water contamination (Jordan & Elnagheeb, 1993; Griffin & Dunwoody, 2000). Notwithstanding, minorities do not seem to be more concerned with drinking water risks (Williams & Florez, 2002; Johnson, 2003). The effect of ethnicity may be due to socioeconomic factors (Williams & Florez, 2002) or to the susceptibility of residential settings (Griffin & Dunwoody, 2000).

Regarding cultural factors, several authors have argued that culture provides socially constructed myths about nature, which are integrated in personal world views and shape the interpretation of the environment (e.g. Douglas, 1966). Canter *et al.* (1993/94) suggested that culture might influence water perceptions by interfering with several factors, particularly trust in institutions, the way risks are individualised or extrapolated in the community, beliefs in personal immunity, preferences for personal optimism and reactive behaviour. Moreover, water has an important symbolic role in folklore and in many religions. The religious role of water is primarily expressed in terms of purity and purifying power (e.g. baptisms, ablutions, deluge) and is connected with concepts of life, health, fertility and fecundity (for synthesis see Rudhartdt, 1986; Doria, 1998; Gritti, 2001). Some authors have suggested that "the religious vision of water as 'pure' may interfere with the perception of it as polluted" (Perry & Vanderklein, 1996), but this vision may also inspire good practices and water conservation.

## 11. Perception of water quality

The factors that are presented in the literature as influencing perceptions of drinking water quality vary from study to study, to a large extent because different studies have considered different variables in the original hypotheses. Using a qualitative approach, Strang (2001: 98) suggested that water quality is evaluated using a combination of three criteria: (1) readily discernible qualities of water, (2) vague

impressions and information from various sources about technical problems and (3) perceptions of social, political and economic relationships between water companies and regulatory bodies. These criteria largely correspond to organoleptics, risk perception, external information and trust in water companies and regulators.

Within quantitative approaches, Syme & Williams (1993) carried out an extensive study to explain the acceptability of drinking water quality. Acceptability was weakly ($R^2_{adj} = 0.20$) predicted by neighbourhood satisfaction, trust in relevant government agencies, perceived control over own water supply, belief in human control of environmental problems, bore water use, bad prior experiences with water quality, gender, perception of water quality variability and the daily amount of water consumed.

Doria *et al.* (2005) used a structural equation model approach and multivariate regressions to explain perceived water quality. In this study, water quality was largely influenced by water taste, with perceptions of risk, context, colour, odour, familiarity and trust also playing a role. In addition to these studies, several other works focused on the individual factors associated with perceptions of water quality. The factors identified include organoleptics (Auslander & Langlois, 1993; AWWA, 1993), dissatisfaction with chemicals (i.e. hardness, chlorine, undefined chemical pollutants, nitrates and sediments; see Auslander & Langlois, 1993; C.I. Eau, 2000), personal vulnerability (Parkin *et al.*, 2001), satisfaction with water utilities (AWWA, 1993), information from the mass media (AWWA, 1993), water quantity/availability (Auslander & Langlois, 1993), the raw water source (Grondin *et al.*, 1995) and demographics (Grondin *et al.*, 1995; Parkin *et al.*, 2001). Even if the ratings of tap water quality are stable over time, the importance of the factors mentioned by survey respondents to justify their (dis)satisfaction can vary. For example, longitudinal surveys in France found that the relevance of specific factors can oscillate as much as 15% within a 4-year period (C.I. Eau, 2000). However, under most circumstances, the influence of direct experience is the strongest. This is concordant with research in perceptions of river water quality, where the criteria applied for the overall evaluation seem to have been used hierarchically and in a multistage judgmental process, with some indicators receiving more attention than others (Moser, 1984).

Ratings of tap water quality are mostly positive in public surveys, with approximately 60–80% of respondents classifying it on the top of the rating scales (AWWA, 1993; Grondin *et al.*, 1995; C.I. Eau, 2000; CP-LM, 2001). Nonetheless, it should be noted that the relatively large number of people that attribute positive ratings to tap water quality is counterbalanced by a significant proportion that consider it fair or poor. In consonance with technical perspectives, perceptions of quality also vary accordingly to intended uses, with public satisfaction being lower for drinking purposes than for other uses, such as hygiene and cleaning (C.I. Eau, 2000).

## 12. Implications

The research discussed in this paper has implications for policy, management and research. Some implications are presented here as generalisations or suggestions that may not be applicable to all contexts. In addition, some implications are already reflected in recommendations by other authors and this paper provides or reinforces the scientific basis for their implementation. These implications and suggestions include the following:

- Direct experience via organoleptics, particularly taste, has a strong role in perceptions of water quality and its relevance should not be underestimated on the basis that these parameters are largely aesthetical.

The practice, already mainstreamed in several countries, of using both consumer and trained panels to assess drinking water flavour and odour should be maintained or reinforced if appropriate. In places with frequent or serious taste and odour problems, water managers may consider the application of robust frameworks based on multi-barrier approaches (e.g. Baker *et al.*, 2006) or other comprehensive approaches.

- The relevance of previous experience is central to consumers' assessment of quality, particularly by creating expectations about what good drinking water should taste and look like. Standards for organoleptical parameters should take into account local conditions (as recommended by WHO, 2004), which are likely to be strongly linked with consumers' familiarity. In addition, foreseeable changes in organoleptics, for instance owing to upgrades in the water distribution or treatment system, should be carefully planed and anticipate potential reactions from consumers, even when those changes are intended to improve organoleptics. A communication strategy should be used to inform consumers about the nature of foreseen changes, to take their views into consideration and to prevent negative reactions owing to an event that otherwise would be unexpected to them. If possible, such changes should be piloted with a consumer sample to assess potential implications on perceptions of quality.
- Past experience and neo-phobia can play an important role in consumers' acceptance or rejection of new supplies. For instance, communities that are not used to tap water may partially reject it when it is first introduced. In such cases, the new supply may be exclusively used for non-drinking purposes and people may continue to drink from traditional sources (e.g. fountains, wells, traditional water salesmen). To avoid situations that can largely undermine the health benefits of safe water supplies local and cultural aspects should be considered in the design of new supplies. The introduction of new modalities of water supply should be closely linked to education and training programmes within the community. Development policies should consider the role of perceptions in the elaboration of policies involving drinking-water infrastructure.
- Even when the influence of single variables on perception is statistically weak, these variables may have noticeable practical consequences. For instance, while the influence of mass-mediated information on quality perception is generally weak, a report by the media about quality problems in a large supply area with 10 million people may seriously concern 0.25% of the population and result in an additional 25,000 calls to water companies and regulators from anxious consumers. While the relative strength of the variables influencing perception may help suppliers and policy makers to prioritise actions to address consumers' expectations the practical relevance of statistically weak factors should not be underestimated.
- The research discussed in this paper strongly suggests that public perception of water quality is based on a combination of multiple factors. Changes in a single factor are likely to be balanced by the stability of other factors. Consequently, perception of the overall quality is likely to be considerably stable, even when the importance of some individual factors may vary over time. This helps to understand, for example, why media coverage of potential problems often has a relatively small impact on the perception of water quality, especially if the problems reported seem to contradict the information of direct experience via organoleptics. This stability may undermine the impact of risk communication during serious contamination emergencies and may limit the effects of water education. To enhance their impact, communication strategies should simultaneously address several factors influencing perception.
- From a results-based management perspective, it makes sense to focus on the overall impact of the water supply as a whole (i.e. on satisfaction, consumers behaviour and health), keeping the process in

perspective (e.g. water quality parameters). In this context, some suppliers have started to focus on public perceptions and/or acceptability and/or satisfaction, defining baselines and setting targets. While this approach has several benefits, it should be noted that several factors influencing perceptions of quality are beyond the control of the water suppliers. These factors include, for example, gender, neighbourhood satisfaction and population dynamics that highlight the role of familiarity and past experience (e.g. migrations and growing urbanisation). Therefore, targets for consumer perception, acceptability and satisfaction should be adjusted to take such factors into account.

- Public and consumer surveys can provide useful information about perceptions of water quality and satisfaction with the supply service. Well-designed surveys can also help to identify the main drivers of perception and satisfaction, providing useful insights for policies and service improvements. The design of surveys and the interpretation of its results should take into account perception biases (e.g. intertemporal pessimism and the belief in the decline of water quality). In addition, qualitative research methods, such as focus groups, can be used to gather additional information about perceptions or to explore emerging factors that influence perceptions.
- Consumers' perceptions of water quality are likely to be key for trust in water suppliers and other bodies, such as regulators. In addition, other factors are also involved in shaping trust. Suppliers should be aware of these factors and consider them if appropriate. For instance, the practice of organising public visits to water treatment plants may foster perceptions of openness and a strong consumer service is likely to raise perceptions of care, thus contributing to build trust.
- Freshwater education at the school, community and informal levels is important to promote a general understanding of drinking water issues. Among other benefits, adequate learning strategies have the potential to raise awareness, contributing to the development of skills and improving communication with experts. Since the basis for drinking water perception seems to be developed at an early age, it is important to start water education at the pre-school level. Educational programmes at this level that just highlight organoleptics—as is often the case with young children—may contribute to a narrow and biased understanding of water issues. Specific topics that should be addressed vary geographically and should be defined, with strong input from educators and water experts, having taken into account the community context and needs. For instance, such topics may encompass tap water sources (including groundwater sources, which are sometimes omitted in education programmes), water uses (including sanitation) and skills that may be particularly relevant in some regions (e.g. rainwater harvesting and water reuse). Interpersonal information has a significant role on perception of water quality and its promotion, for example by involving students' families in activities organised by schools, can enhance the impact of educational strategies.
- Factors influencing risk perception should be taken into account when developing emergency plans for potential water contamination events. Risk communication strategies must also address the post-emergency phase, when resources are safe and there is no need for alternative water sources or additional procedures from consumers (e.g. boiling water).
- In spite of the work developed in this area, there are knowledge gaps and research needs. For instance, it is not entirely understood how different factors interact to influence perceptions. There is a need for studies that integrate the different factors involved, simultaneously focusing on multiple factors and on drinking (tap) water perceptions under normal circumstances. In particular, little is know about the relationship between specific physicochemical water parameters and the psychological, social and cultural factors that influence perception. In addition, the role and potential relevance of several variables is largely under-studied; these variables include microbiological parameters, radiological

contamination, attitudes towards water treatments, attitudes towards the private or public status of the supplier, perceived health benefits of chlorination, perceived health benefits of tap water, interpersonal information (including the interaction of children and adults), fluoride (which has been researched mostly in other contexts, sometimes focusing on support or opposition to fluoridation) and other chemicals (e.g. pesticides and hormones). Moreover, cross-national research on this topic and studies on water-related perceptions in developing countries are scarce. Future research in this area may try to overcome present limitations.

## 13. Conclusions

Perceptions about drinking water quality result from diverse factors. Water managers and policy makers should take into account these factors, in order to anticipate potential problems and maximise the impact of projects or policies. While largely aesthetical, organoleptics often play a major role and should be carefully managed. Previous experience should be considered when planning changes to the supply system and developing quality standards. Carefully designed communication strategies should be used to communicate with consumers, particularly with regard to foreseen changes in the supply and during disrupting events. Surveys and qualitative methods can be used to inform specific policies and service improvements. Freshwater education is important from an early age and should focus on locally relevant issues, covering aspects such as tap water uses and water sources. In spite of the work developed in this area, there are knowledge gaps and research needs.

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