

*Review*

## **An Educational Resource Based on Water and Health as a Teaching Aid in French Primary Schools Part I: Identification of Needs and Content**

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**Abstract:** It is a commonplace that water is essential for life, but to what extent is the general public, and children in particular, aware of how water affects health? The aim of this review was to consider the relationship between water and health under three main headings: the importance of hydration for children, dietary intake of water, and water as an essential factor in hygiene contributing to good health. The literature was reviewed to provide a rationale for the implementation of teaching about water and health in French primary schools under three main areas: (i) the importance of hydration for school children and water promotion in primary schools; (ii) the problem of overweight/obesity and the need to adopt healthy drinking habits as defined in French nutritional policy; (iii) the survey of the quality of drinking water in France and its relationship with good hygiene practices. There are currently few educational resources in France on water and health that teachers can use in the classroom. This review gives reasons why a “Water and Health” learning resource is a useful tool and shows how it can be developed within the constraints imposed by the school syllabus and in accordance with French nutritional and environmental policy.

**Keywords:** children; primary school; water; health promotion; environmental education; educational resource

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## 1. Introduction

Why promote water and health education at school? Everybody knows that water is essential for life, that humans can survive only a few days without it, but how aware are members of the general public, and children in particular, of the effects of water on health? We first performed a review of the relationship between water and health in children, followed by a rationale for the implementation of teaching about water and health in French primary schools. In addition, an investigation into educational resources currently available on this theme in France was carried out.

## 2. The Relationship between Water and Health in Children

To bring the relationship between water and health within a child's scope of knowledge, it may be considered under three main headings: the importance of hydration for children, dietary intake of water and water as an element in hygiene and health.

### 2.1. The Importance of Hydration for Children

*Total body water:* Total body water (TBW) varies with body composition: lean body mass is composed of about 73% water and fat body mass of 10% water [1]. The percentage of TBW in relation to body mass decreases according to the proportional increase in body fat, as seen in post-pubertal girls and in overweight children [2]. The Fels longitudinal study, a study of the growth, development and body composition of a sample of persons living predominantly in Southwest Ohio, used deuterium nuclear magnetic resonance spectroscopy to provide measurements of TBW in Caucasian boys and girls from 8 to 20 years of age [3]. The results showed the progression of TBW, which changes in volume with age: boys tend to have significantly higher proportions of TBW than do girls and the mean percentage of body water in weight decreases to about 46% in men and 43% in women by the age of 60 years [4].

*Hydration/dehydration in children:* Optimal hydration status is essential for adequate physical and mental functioning [5]. Fluid requirements relative to body weight are greatest during the neonatal period and throughout childhood: infants and children retain water for growth and have higher non-renal water losses because of a higher body surface area related to body mass [6]. As a consequence, children may be more susceptible to fluid losses and are, therefore, at greater risk of dehydration than adults [2]. Inadequate hydration has been linked to many factors that may impact on children's education and health [7]. However, children may not recognize the need to replace fluids [8]. Mild dehydration, caused by fluid loss (defined as a 1–2% loss of body weight), can be responsible for numerous illnesses [9,10]. Mild dehydration seems to produce alterations in a number of important aspects of cognitive function in children such as mental concentration, alertness, and short-term memory [11]. However, studies in children are scarce and have involved a small number of subjects [2]. Studies on the connection between fluid intake and the risk of urinary tract infections have

yielded conflicting results, but adequate hydration is recognized as important and may enhance the effects of antimicrobial therapy on these infections in adults [12]. Likewise in adults, prolonged mild dehydration can be associated with chronic constipation [13]. Severe dehydration (defined as a 10% loss of body water) is equally life-threatening in infants and adults [6]. However, it takes infants much less time to reach this stage, because the TBW pool in relation to water turnover is low [6].

*Functions of body water:* Body water also has fundamental functions in the control of body temperature, which is regulated by body water loss through sweat production, which in turn is dependent upon environmental temperature and humidity and physical activity levels. However, if sweat loss is not compensated for by fluid intake, hypo-hydration can occur, with concurrent increases in body temperature [11]. Children have a different response to increases in temperature and different thermoregulatory mechanisms than healthy adults: they may respond to hypo-hydration with a higher relative increase in core temperature than adults and with a lower propensity to sweat, thus losing some of the benefits of evaporative cooling [11]. The kidneys are fundamental in the regulation of water balance, *via* a hormonally mediated process that is a complex notion for children to understand. In addition to regulating fluid balance, the kidneys require water for removing waste from the bloodstream and for its excretion in urine [11].

These effects on children's health underline the importance of promoting the dietary intake of water since it is the sole fluid required for proper body functioning.

## 2.2. Dietary Intake of Water

Water is essential for life [1]. Despite its well-established importance, it is often ignored as a dietary constituent or very cursorily treated in most studies of nutrient intakes. Water is not only consumed directly as a liquid, it is also obtained from food. Hence, total water intake includes tap water and bottled water, water from beverages, such as soft drinks and juices, and water in food [14]. In children (aged 9–13 years old), about 75% of water intake comes from fluid intake and 25% from food [15]. Water is also obtained to a very small extent from metabolic pathways (oxidation of macronutrients that provide metabolic water) [15]. A diet rich in vegetables and fruits provides more significant amounts of total water intake than fast food products [14].

The American Institute of Medicine recommends 2,400 mL/day and 2,100 mL/day of total water, respectively, for American boys and girls from 9–13 years old [15]. According to the recommendations of the European Food Safety Authority (EFSA), total water intake should be 2,100 and 1,900 mL/day, respectively, in boys and girls in the same age group [14].

Recent data on water intake by children are scarce. Only a few studies have been made of water intake, especially in healthy children of industrialized countries (Table 1) [16–18].

In the “Comportement et Consommations Alimentaires en France” survey (CCAF survey), Bellisle *et al.* reported that water (tap water and bottled water) was the main source (52%) of liquid in the total daily fluid intake of children from 6–11 years old (Table 1) [17]. However, in the Dortmund Nutritional and Anthropometric Longitudinally Designed Study (DONALD study), Sichert-Heller *et al.* observed that the daily intake of water (tap water and mineral water) accounted for 36% of the total daily fluid intake in German boys and girls from 9–13 years old and was lower than that of water from beverages (Table 1) [16]. Similar results were reported in the NHANES survey, with plain water

(i.e., tap water, water from a cooler, drinking fountain, spring water and non-carbonated bottled water, as defined by the National Center for Health Statistics of the Center for Disease Control) representing 38% of total daily fluid intake (Table 1) [18]. Moreover, in this latter survey, the 24 h-intake of plain water was inversely associated with the intake of beverage moisture and total sugars but positively with food moisture in children and in adolescents [18].

**Table 1.** Daily intake of water in children.

Study (year, country)	Age (years)	Gender (n)	Tap water and bottled water (g/day)	Water from beverages (g/day)	Total water (g/day)
DONALD study (1985–1999, Germany) [16]	9–13	Boys ( <i>n</i> = 541)	344	626	1,891 *
		Girls ( <i>n</i> = 542)	298	524	1,676 *
CCAF survey (2004, France) [17]	6–11	Boys and girls ( <i>n</i> = 566)	549	495	–
NHANES (2005–2006, USA) [18]	6–11	Boys and girls ( <i>n</i> = 1,004)	469	745	1,644 **

\* Total water = tap water + mineral water + beverages + water in food+ oxidation; \*\* Total water = plain water (i.e., tap water, water from a cooler, drinking fountain, spring water and non-carbonated bottled water, as defined by the National Center for Health Statistics of the Center for Disease Control) + beverages + water in food.

Despite certain differences in the definition of the kind of water included in these studies, the findings suggest that the daily intake of plain water is relatively low compared to that of water from beverages [16–18]. Children must be encouraged to have a regular daily intake of plain water, which should be presented as the sole essential drink and an important vector of mineral salts.

### 2.3. Water as an Element in Personal, Domestic and Swimming Pool Hygiene

About three quarters of the European population live in an urban environment, where the collection and the treatment of wastewater are part of regular practice [19]. Water treatment processes are essential because water can be polluted by a variety of naturally occurring and human-created contaminants, making it unsuitable for drinking and other purposes [19]. However, access to clean drinking water is not sufficient to eliminate the risk of water-related diseases, which cannot be decreased without compliance with good hygiene practices. In France, as in other industrialized countries, this has been made easier since the widespread development of sanitation facilities and water supplies in the 1990s [19,20].

*Personal hygiene:* In terms of personal hygiene, it is well known that hand washing and other good hygiene practices can prevent infectious diseases such as gastrointestinal illness *via* hand-to-mouth transmission of pathogenic microorganisms present in faeces [19]. Prüss *et al.* have shown the significant and avoidable burden of diseases from water (mainly diarrhoeal diseases) in a study of sanitation and hygiene at a worldwide level [21]. Oral hygiene is also very important. The consumption of sugar-sweetened beverages may be a key contributor to the occurrence of dental carries, which, however, have significantly decreased in industrialized countries, in part due to regular brushing of teeth and to the widespread use of fluoride toothpastes [22]. Unlike other industrialized

countries, France has not introduced water fluoridation, but fluoride salt or fluoride toothpaste are commercially available and fluoride medication is prescribed when necessary [23]. In French children, caries levels are low compared with those of earlier generations but they are still higher in groups of a low socio-economic status [24].

*Domestic hygiene:* There is now greater public awareness of the need for hygiene rules in the home such as safe food handling and preparation [25]. Household surfaces play a major role in disease transmission [25,26]. For example, an American study in a school setting suggested that regular cleaning of desks and other classroom surfaces reduces the risk of gastrointestinal illness [26].

*Swimming pool hygiene:* In France, learning to swim is a national priority and is an integral part of the primary school curriculum [27]. Strict hygiene rules must be observed by children at swimming pools, where the water is treated with chlorinated disinfectants. Microbiological contaminants, introduced by swimmers into the pool, can lead to illnesses such as diarrhoeal diseases [28]. In addition, organic matter such as hair and skin flakes from swimmers can react with the chlorinated disinfectants used to treat the swimming-pool water with the result that the amount of disinfectant available to kill germs is reduced, which, in turn, can generate toxic compounds like trihalomethanes, chloramines and haloacetic acids that have adverse health effects [28]. Swimmers need, therefore, to be informed and educated to make pools safer and healthier.

### **3. A Rationale for the Implementation of Teaching about Water and Health in French Primary Schools**

It is important that primary school children be informed about the relation between water and health. An effective educational programme could: (1) encourage the drinking of water to enable children to maintain proper hydration; (2) help develop healthy drinking habits; and (3) promote good hygiene practices and environmental awareness by instilling in children a sense of personal responsibility and respect for their environment.

#### *3.1. The Importance of Hydration Status of Schoolchildren and Water Promotion in Primary Schools*

Hydration/dehydration status of schoolchildren: Evidence suggests that the hydration status of children is compromised [7,29–31]. Although the effects of dehydration on cognitive function are now well documented in adults, there are few studies examining the relationship between hydration status and cognitive function in school children. Bar-David *et al.* performed cognitive testing in voluntarily dehydrated 10–12 year old school children in Israel, whose urine osmolality was more than 800 mOsm/kg H<sub>2</sub>O [29]. The results showed no effect of initial dehydration levels on cognitive performance at the first test in the morning. At lunchtime, however, short term memory was impaired in the dehydrated group [29]. In another study, of voluntary dehydration among 429 elementary schoolchildren from 8–10 years old residing in a hot environment, the same authors observed high osmolality (above 800 mOsm/kg H<sub>2</sub>O) in 67.5% of the urine samples [7]. Although these data reflect specific climatic conditions, the authors advised that good drinking habits and maintaining an appropriate fluid balance should be an essential part of a healthy lifestyle. In France, Bonnet *et al.* assessed morning hydration status in a sample of 529 French schoolchildren from 9–11 years old by measuring food and fluid intake at breakfast and morning osmolality 30 minutes after breakfast [30]. They showed that 62% of

children had a urine osmolality greater than 800 mOsm/kg H<sub>2</sub>O and that, of this number, 22.7% had a urine osmolality over 1,000 mOsm/kg H<sub>2</sub>O, more predominantly in boys than in girls (72% versus 52%) [30]. In addition, almost two-thirds of school children had hydration deficit on arriving at school in the morning, despite water intake at breakfast. In a cross-sectional study, elevated urine osmolality was observed in two-thirds of healthy American children in the morning [31]. Over 90% of the children had breakfast but 75% did not drink water [31]. These findings suggest that children's fluid intake at breakfast does not suffice to maintain an adequate hydration status for the whole morning. Higher fluid intake at breakfast and/or additional fluid intake during the morning should be recommended, suggesting that water promotion in primary school could be of interest.

*Water promotion in primary schools:* Muckelbauer *et al.* led a combined environmental and educational intervention focused on the promotion of drinking water in German elementary schools [32]. In this latter study, 2,950 children (aged 8 years old), took part in a randomized control cluster trial [32]. The intervention included the installation of water fountains and the presentation of four classroom lessons by teachers [32]. After the intervention, water consumption was increased (1.1 glasses per day greater) in the intervention group [32]. The process evaluation, conducted during the intervention period (one school year) and a subsequent 19-month follow-up, showed that the intervention had potential for sustained modifications in the beverage consumption habits of children [33]. Eleven out of the 17 intervention schools taking part kept the water fountains throughout the follow-up period [33]. The mean water flow of the fountains decreased initially, but thereafter remained stable [33]. Most teachers allowed pupils to drink during classes, but about a third considered this as intrusive [33]. The national "Water is cool in school" campaign, launched in the UK in 2000 by the Education and Resources for Improving Childhood Continence, was aimed at promoting improved drinking water access in UK schools. In a subsequent study, Kaushik *et al.* determined whether fluid intake and frequency of toilet visits were associated with children's access to drinking water in the classroom in 145 schoolchildren in year 2 (aged 6–7 years old) and 153 in year 5 (aged 9–10 years old) [34]. The authors showed not only that most children had an inadequate fluid intake in school but also that children drank significantly more water if they were allowed to have water bottles on their desk [34]. Contrary to teachers' expectations, there was no trend observed between water access and frequency of toilet visits [34]. For some teachers, free water access had the disadvantages of potential distraction, misbehaviour with water bottles and spillage [34]. Although some environmental confounders (room temperature, children's participation in sports activities) were not recorded, the authors concluded that primary schools should promote water drinking in class [34].

Schoolchildren should be encouraged to acquire good water drinking habits to enable them to maintain proper hydration (*i.e.*, drinking water regularly all over the day without waiting for thirst). To achieve this, they need to be taught about the role of water as a body constituent, the sensation of thirst, the hydration status of the body and certain specific situations in which fluid requirements are greater.

### 3.2. The Problem of Overweight/Obesity and the Need to Adopt Healthy Drinking Habits as Defined in French Nutritional Policy

Overweight/obesity: Obesity in childhood and adolescence is increasingly a worldwide problem. In France, 18% of children and adolescents between the ages of 3 and 17 years old are overweight (including the obese), and 3% of boys and 4% of girls are classified as obese [35]. For this reason, the prevention of overweight and obesity in childhood is a major public health concern. In a recent systematic review and meta-analysis of randomized controlled trials and prospective cohorts studies on dietary sugars and body weight, robust evidence was provided of a relation between sugar consumption and body weight in the prospective cohort studies, but to a lesser extent in the randomized controlled trials [36]. The authors reported an increased odds-ratio for being overweight or obese (1.55 (1.32–1.82)) in relation to intakes of sugar-sweetened beverages after a one year follow-up in prospective studies in children [36]. Other reviews suggest that water has a potentially important role to play in reducing energy intake and consequently in obesity prevention [37,38]. Moreover, Muckelbauer *et al.* have provided evidence that water might prevent overweight in children [32,33]. Promoting the consumption of water in preference to other sweet beverages is a part of healthy behaviour.

*French nutritional policy:* Over the last decade, French public health policy-makers have set multi-year health priority objectives, designing health plans and programs to improve the health of the general population. Schools are one of the areas where the authorities can implement public health policy. In France, the first National Nutrition-Health Program (Programme National Nutrition Santé [PNNS]) was introduced in 2001 [39]. The current program, PNNS 2011–2015, has as a general objective to improve the state of health of the whole population by acting on one of its major determinants, nutrition [39]. It includes a series of actions, measures and regulations and also some legislation [39]. Its strategy revolves around a number of different axes: communication, information-advertisement, education, and improvement of physical and eating behaviours and of the food supply [39]. For example, the program recommends the choice of water rather than sweetened beverages for daily intake [39]. The awareness of the need for health promotion at school, including nutrition education, has increased in proportion to the increase in the number of overweight children (global overweight prevalence, including obesity). French primary school programs now include classes on water education, mainly in terms of water as a dietary element, but also of its physical properties (states and changes of state), the water cycle in nature and the need to maintain water quality to minimize water treatments [40].

In this context, it seems important to explain to children the dietary importance of plain water. They need to be taught that plain water contains mineral salts and that these salts have a role in their overall diet. Getting them to evaluate their own fluid intake could be one way of improving their drinking habits.

### 3.3. The Survey of the Quality of Drinking Water in France and its Relationship with Good Hygiene Practices

Water sanitary control in France: In France, the quality of drinking water complies with the requirements of the European Directive 98/83/EC on the quality of tap water and with national

regulations, defined and implemented in the French Public Health Code [41–43]. Drinking water is monitored by microbiological, chemical and physical analyses in accordance with the regulations in force [41–43]. Locally, quality is assessed at two levels: (i) ongoing monitoring by the operator responsible for distribution of the water (continuous analytical monitoring, regular review of the facilities); and (ii) regular controls by the Regional Health Agencies, *i.e.*, the French local health authorities (regular analytical control, periodic inspection of facilities) [44]. Monitoring consists in detecting water resource contamination, processing failures, and contamination at the distribution level for the consumer [44]. Distribution units range from small ones serving small villages to large units that supply more than 1,000,000 people. Depending on the number of inhabitants supplied and the volume distributed, monitoring is performed daily in the largest units but only up to three times a year in the smallest [45]. In 2009, 3.2% of the French population was supplied with water that at least on one occasion did not comply with microbiological parameters [45]. For 2.9% of the population, non-compliance with regulatory values was limited insofar as it did not justify restricting the use of water for cooking [45].

*Perception of drinking water quality and risks by the French population:* A study was made in 2007 on how the quality of drinking water and the attendant risks are perceived in France by the “Barometer of Environmental Health”, an annual survey that measures indicators of attitudes, knowledge, beliefs and behaviors of the French population in the environmental field, including the perception of risks related to water [46]. This random survey was conducted through phone interviews with a representative sample of the 18–75 year old population living in France comprising more than 27,000 interviewees [46]. Among the topics of environmental health dealt with in the survey, the quality of tap water was in first place for satisfaction with the information received; 72% of respondents felt well informed about the health effects related to the consumption of poor quality water, which was considered by 40% to be a high risk to the health of the general population [46]. Only half of the respondents expressed satisfaction with the information received on the quality of water in their own town. About two-thirds of respondents (68%) reported drinking tap water, 24% consuming only tap water and 43% occasionally, while just under a third said they drank only bottled water [46]. In France, drinking tap water can be safely encouraged because its quality is strictly controlled. It also plays a role in reducing bottle waste.

*The relationship with good hygiene practices:* Access to clean drinking water is essential, but not sufficient, to eliminate water-related diseases, which must also be combated by stringent hygiene practices. Although hygiene education is integrated into the daily life of schools, Schmidt *et al.*, in a study of UK primary schools, identified barriers for school-based hygiene interventions, in particular time constraints and competing health issues [47]. Nevertheless, teachers routinely comply with good hygiene behaviour and encourage it in their pupils. One beneficial effect is to reduce absenteeism at school due to illness [26]. It has been shown, for example, that schools and school children play a major role in the spread of epidemics such as influenza. Infection spreads easily through unclean hands, and regular hand-washing can significantly prevent contamination [19]. However, some children do not wash their hands, not only because they are not aware of hand-related diseases but also because they believe that their hands are clean when there is no visible sign to the contrary. Promoting hand-washing with soap has been described as the most effective health intervention [19].



The need for good hygiene practices is strongly linked to the importance of water treatments. People are aware of, and concerned about, the quality of water [19,46]. Water resources are not renewable, everything must be done to protect them and all citizens must be involved, especially children, who would benefit from basic instruction in the role of water as a factor in hygiene, the key concepts of microorganisms and germ transmission, personal and domestic hygiene, the water cycle and water treatments [19]. Moreover, specific actions can be undertaken at swimming pool sessions, an activity included in the French primary school program [27]. Hygiene rules must be taught to school children when they go to the swimming pool, to make pools safer and healthier. This approach is consistent with the environmental health policy developed in France through the National Environment and Health Action Plan (Plan National Santé Environnement [PNSE]), which includes among its priorities the best strategies to ensure water quality, increase public awareness and protect susceptible populations such as children and pregnant women [48].

#### **4. Identification of Educational Resources Available in France on Water and Health as Aids for Teachers in the Classroom**

In health promotion, a resource is defined as a means of acquiring knowledge. A resource can be interactive. Its aim is to foster behaviour favourable to good health, or to stimulate momentum for changes in behaviour. It is necessary to distinguish between two types of resources: first, “documents” such as brochures, posters and books, whose main purpose is to provide information; second, “educational resources” like teachers’ tool kits, which provide not only information but also supporting material that accompanies the teaching aid [49].

Resources available in French were identified from an internet search with the Google search engine using the keywords “water and health” or “water and food” or “water and hygiene”. The search was carried out by the French online educational library (the French Sceren network) [50]. The main “documents” and “educational resources” were researched from nursery school to high school. The selected resources were analysed with reference to the table on the quality of resources published by the National French Institute for Prevention and Promotion (INPES) [51]. The Directorate for Scientific Affairs of the INPES offers an analytical framework that enables professionals to evaluate the quality of the tools they use or plan to use [51]. This grid consists of a first section on how to describe the tool for each of the five categories of criteria examined (quality of content, teaching quality, quality of support, quality of design, overall assessment), followed by the questions asked to check the suitability of the tool analyzed (critical, major or minor) and, at the end of each category of criteria, an opportunity for professionals to add their comments noting particularly noteworthy elements of the tool, both positive and negative, to better assess the conditions of its optimal use [51].

Resources were identified and classified either as documents (66%,  $n = 45$ ), educational resources (24%,  $n = 16$ ) or non-evaluated because out of print or being reprinted (10%,  $n = 7$ ). Numerous resources exist for children at nursery school level (2–5 years old). They focus mainly on water as a hygiene factor and the supporting materials are generally books of poems or stories. Educational resources exist for children between the age of 5 and 12 years, but none deals in depth with water and health as related issues in terms of the importance of hydration status, the role of water as a dietary

element, and the role of water in hygiene practices [52–57]. At high school level, the documents available are preferentially targeted at the general public.

## 5. Conclusion

This review highlights the importance of the relationship between water and health. To maintain proper hydration, especially in children, water should be drunk throughout the day. Reports from the literature all indicate that plain water intake must be encouraged in children because it is low compared to intake from beverages [16–18]. Plain water intake might also prevent weight problems in children [32,33]. The quality of tap water is strictly controlled in France and, except in specific situations, its dietary intake can be safely encouraged. In addition, compliance with good hygiene practices (personal, domestic and in public areas such as the swimming pool), is favourable to well-being and good health.

This review lends support to the teaching of water and health issues in the educational programs of French school children. To attain the objectives of these programs, a new educational resource “Water and Health”, which takes into account the constraints of the syllabus and teacher availability, was developed as a teaching aid in French primary schools [58]. It falls within the framework of the French policy on Nutritional Public Health and Environmental Health, using an approach that focuses on overall health and environmental education [58]. The teaching material is structured in modules, divided into three parts: (i) water as a body constituent, *i.e.*, a fluid essential for life and proper body functioning; (ii) water as a dietary element, *i.e.*, the sole indispensable drink and a vector of mineral salts; (iii) water as a factor in hygiene, contributing to good health [58]. Its design and validation are described elsewhere [submitted to *Education Sciences*].

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## Conflict of Interest

The authors declare no conflict of interest.

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