How to measure chlorine residual

 WHO Regional Office for South-East Asia The importance of chlorine in water Many of the most common diseases found in traumatised communities after a disaster or emergency are related to drinking contaminated water. The contamination can be from microorganisms (Table 1) or natural and man made chemicals (Table 2). This fact sheet concentrates on the problems caused by drinking water contaminated by micro-organisms as these are by far the most common and can be reduced by chlorination. Chemical contamination is difficult to remove and requires specialist knowledge and equipment. Diarrhoea\* Typhoid\* Hepatitis\*” Cholera\* .

Diseases related to drinking water contaminated with micro-organisms

`\*NOTE: Contaminated water is not the only cause of these diseases; water quantity, poor sanitation and poor hygiene practices also play a role People who live in the same place all their lives and regularly drink contaminated water may develop some resistance to the contaminants and suffer little or no health problems. However communities affected by an emergency are very different. Emergencies have three relevant effects on people, they:  Force people to move to new places where the water quality is different from what they usually drink and for which they have no immunity;  Force people to live in poor conditions such as tents or temporary building which make it difficult to retain good hygiene practices; and  Affect their diet, often lowering their nutritional level and making them more vulnerable to disease. It is therefore important that all people affected by an emergency are provided with water of a high quality. There are a number of ways of improving the quality of drinking water. The most common are sedimentation and filtration followed by disinfection (these are discussed in other fact sheets). Disinfection (the killing of harmful organisms) can be achieved in a number of ways but the most common is through the addition of chlorine. However chlorine will only work correctly if the water is clear (box 1). Table 2. Some chemical contaminants of drinking water that may be a danger to health Arsenic Cadmium Chromium Cyanide Fluoride Lead Mercury Box 1 How does chlorine kill When chlorine is added to water it purifies by destroying the cell structure of organisms, thereby killing them. However the process only works if the chlorine comes into direct contact with the organisms. If the water contains silt the bacteria can hide inside it and not be reached by the chlorine. Chlorine takes time to kill all the organisms. In water above about 18o C the chlorine should be in contact with the water for at least 30 minutes. If the water is colder then the contact time must be increased. It is normal therefore to add chlorine to water as it enters a storage tank or a long delivery pipeline to give the chemical time to react with the water before it reaches the consumer. The effectiveness of chlorine is also affected by the Ph (acidity) of the water. Chlorination is not effective if the Ph is above 7.2 or below 6.8. 2 Technical Note No. 11 WHO/SEARO Technical Notes for Emergencies How to measure chlorine residual Chlorine residual Chlorine is a relatively cheap and readily available chemical that, when dissolved in clear water in sufficient quantities, will destroy most disease causing organisms without being a danger to people. However the chlorine is used up as organisms are destroyed. If enough chlorine is added, there will be some left in the water after all the organisms have been destroyed, this is called Free Chlorine. (Figure 1) Free chlorine will remain in the water until it is either lost to the outside world or used up destroying new contamination. Therefore if we test water and find that there is still some free chlorine left, it proves that most dangerous organisms in the water have been removed and it is safe to drink. We call this measuring the Chlorine Residual. Measuring the chlorine residual in a water supply is a simple but important method of checking that the water that is being delivered is safe to drink When and where to test water The most common place to use chlorine as a disinfectant is in a piped water supply. Regular chlorination of other water supplies is difficult and usually reserved for disinfection after repair and maintenance. The chlorine residual is usually tested at the following points:  Just after the chlorine has been added to the water to check that the chlorination process is working;  At the outlet of the consumer nearest to the chlorination point to check that residual chlorine levels are within acceptable levels (between 0.5 and 0.2 mg/l); and  At the furthest points in the network where residual chlorine levels are likely to be at there lowest. If chlorine levels are found to be below 0.2 mg/l it might be necessary to add more chlorine at an intermediate point in the network.

The amount of chlorine residual changes during the day and night. Assuming the pipe network is under pressure all the time (Box 2) there will tend to be more residual chlorine in the system during the day than at night. This is because the water stays in the system for longer at night (lower demand) and so there is more opportunity for the water to be contaminated which will use up the residual chlorine. Chlorine residual should be checked regularly. If the system is new or has been rehabilitated then check daily until you are sure that the chlorination process is working properly. After that check at least once a week.

Testing for chlorine residual: The most common test is the dpd (diethyl paraphenylene diamine) indicator test, using a comparator. This test is the quickest and simplest method for testing chlorine residual. With this test, a tablet reagent is added to a sample of water, colouring it red. The strength of colour is measured against standard colours on a chart to determine the chlorine concentration. The stronger the colour, the higher the concentration of chlorine in the water Several kits for analysing the chlorine residual in water, such as the one illustrated in Figure 2, are available commercially. The kits are small and portable. Caution All forms of chlorine are harmful to health. Avoid skin contact and do not inhale the fumes. Chlorine should always be stored in cool, dark , dry and sealed containers and out of reach of children. Figure 1.

Effect of chlorine residual 2.0 mg/l 2.5 mg/l Chlorine added 1.5 mg/l Water requires 2.0mg/l of chlorine to destroy all organisms Water not disinfected All organisms destroyed and 0.5 mg/l residual chlorine remaining All organisms destroyed but no chlorine left for future.

How to measure chlorine residual Step 1. Place one tablet in the test chamber (a) and add a few drops of the chlorinated water supply under test. Step 2. Crush the tablet, then fill chamber (a) with the chlorinated water supply under test. Step 3. Place more of the same water supply under test (without a tablet) in the second chamber (b). This is the blank control for colour comparison. Step 4. The level of residual chlorine (R) in mg of chlorine per litre of water (mg/l) is determined by comparing the colour of the water supply under test in chamber (a) with the tablet added with the standard colours on the vessel (chamber (b)). Note: Chamber (c) would be used if a higher chlorine residual is to be measured.

Essential hygiene messages in post disaster emergencies Box 2. Chlorination and intermittent supplies There is no point in chlorinating pipe networks if the water supply is intermittent. All pipe systems leak and when the water supply in switched off, the pressure will drop and contaminated water will enter the pipes through the breaks in the pipe wall. No level of residual chlorine acceptable to consumers will be able to deal with such high levels of contamination. All intermittent water supplies should be assumed to be contaminated and measures taken to disinfect it at the point of use.

GENERAL DESCRIPTION

Identity Element or compound CAS no. Molecular formula Chlorine 7782-50-5 Cl2 Hypochlorous acid 7790-92-3 HOCl Sodium hypochlorite 7681-52-9 NaOCl

Physicochemical properties of chlorine (1,2) [Conversion factor in air: 1 ppm = 2.9 mg/m3 ] Property Value Boiling point -34.6 °C Melting point -101 °C Density 3.214 g/litre at 0 °C and 101.3 kPa Vapour pressure 480 Pa at 0 °C Water solubility 14.6 g/litre at 0 °C Organoleptic properties The taste and odour thresholds for chlorine in distilled water are 5 and 2 mg/litre, respectively. In air, chlorine has a pungent and disagreeable odour (2). Major uses Large amounts of chlorine are produced for use as disinfectants and bleach for both domestic and industrial purposes, and it is also widely used to disinfect drinking-water and swimmingpool water and to control bacteria and odours in the food industry (3,4). Environmental fate In water, chlorine reacts to form hypochlorous acid and hypochlorites. All three species exist in equilibrium with each other, the relative amounts varying with the pH. In dilute solutions and at pH levels above 4.0, very little molecular chlorine exists in solution. The concentrations of hypochlorous acid and the hypochlorite ion are approximately equal at pH 7.5 and 25 °C. Chlorine can react with ammonia or amines in water to form chloramines (4,5).

ANALYTICAL METHODS A colorimetric method can be used to determine free chlorine in water at concentrations of 0.1–10 mg/litre. Other methods allow for the determination of free chlorine, chloramines, other chlorine species, and total available chlorine, and are suitable for total chlorine concentrations up to 5 mg/litre. The minimum detectable concentration of chlorine is about 0.02 mg/litre (6).

ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE Air A mean ambient air level of 1 mg/m3 was reported for chlorine (7).

2 Water Chlorine is present in most disinfected drinking-water at concentrations of 0.2–1 mg/litre

(3). Food Cake flour bleached with chlorine contains chloride at levels in the range 1.3–1.9 g/kg. Unbleached flour may contain small amounts of chlorite (400–500 mg/kg)

 Estimated total exposure and relative contribution of drinking-water The major routes of exposure to chlorine are through drinking-water, food, and contact with items either bleached or disinfected with it. KINETICS AND METABOLISM IN LABORATORY ANIMALS AND HUMANS Most studies on the pharmacokinetics of chlorine, hypochlorous acid, or hypochlorites employ reactive 36Cl-labelled compounds and probably reflect the fate of the chloride ion or other reaction products generated from the parent molecules. In rats, hypochlorous acid was readily absorbed through the gastrointestinal tract, distribution being highest in the plasma; smaller amounts were found in bone marrow, kidney, testes, lung, skin, duodenum, spleen, liver, and bone (9,10). In vivo, sodium hypochlorite was metabolized to trichloroethanoic acid, dichloroethanoic acid, chloroform, and dichloroacetonitrile (11). Hypochlorous acid administered to rats was excreted primarily in the urine and faeces, mostly in the form of chloride ion (10). None was excreted in expired air (9). EFFECTS ON LABORATORY ANIMALS AND IN VITRO TEST SYSTEMS Acute exposure Calcium hypochlorite has an oral LD50 in the rat of 850 mg/kg of body weight (2). Short-term exposure No consistent effects on organ weights or histopathology of tissues were noted in SpragueDawley rats (10 per sex per dose) given chlorine in drinking-water at 0, 25, 50, 100, 175, or 200 mg/litre (males: 0, 2, 7.5, 12.8, or 16.7 mg/kg of body weight per day; females: 0, 3.5, 12.6, 19.5, or 24.9 mg/kg of body weight per day) for 90 days (12) or in rats fed flour containing 1257 or 2506 mg of chlorine per kg (62.5 or 125 mg/kg of body weight per day) for 28 days (13). Enhanced weight gain was observed in all male rats (10 per dose) given drinking-water containing chlorine at 0, 20, 40, or 80 mg/litre (0, 4.1, 8.1, or 15.7 mg/kg of body weight per day) for 6 weeks (14). The results of a 4-week study in which female C57BL/6N mice were given hyperchlorinated tapwater (4.8–5.8 mg/kg of body weight per day) suggested an adverse effect on the macrophage defence mechanisms of mice. The LOAEL in this study was 4.8 mg/kg of body weight per day (15). In a study in which male CR-1:CD-1 mice (30 per dose) received chlorinated drinking-water (0.02, 0.2, 2.9, or 5.8 mg/kg of body weight per day) for 120 days, none of the mice showed evidence of a statistically significant change in humoral or cell-mediated immune response. A NOAEL of 5.8 mg/kg of body weight per day was identified (16). 3 Long-term exposure F344 rats (50 per sex per dose) were administered sodium hypochlorite in drinking-water (males: 0.05% or 0.1%, 75 or 150 mg/kg of body weight per day; females: 0.1% or 0.2%, 150 or 300 mg/kg of body weight per day) for 2 years. Effects included a dose-related depression in body weight gain in all groups, depressed liver, brain, and heart weights in males given a 0.05% dose, decreased salivary gland weights in both female groups, and decreased kidney weights in females given 0.2% (17). In a 2-year bioassay, F344 rats and B6C3F1 mice were given chlorine in drinking-water at levels of up to 275 mg/litre (up to 24 mg/kg of body weight per day for male rats and male mice, 15 mg/kg of body weight per day for female rats, and 22 mg/kg of body weight per day for female mice). There was a dose-related decrease in water consumption for both mice and rats. No effects on body weight or survival were observed in any of the treated animals (18). Wistar rats were fed cake prepared from flour treated with 1250 or 2500 mg of chlorine per kg (males: 12.8 or 25.3 mg/kg of body weight per day; females: 17.0 or 35.0 mg/kg of body weight per day) for 104 weeks. A dose-related reduction in spleen weight was seen in females, and dose-related haematological effects were observed in both sexes. A LOAEL of 12.8 mg/kg of body weight per day was identified in this study (19). Reproductive effects, embryotoxicity, and teratogenicity C3H/HeJ and C57BL/6J mice administered drinking-water containing 10 mg of residual chlorine per litre (1.9 mg/kg of body weight per day) for 6 months showed no adverse reproductive effects (20). In a seven-generation study in which rats were given drinking-water chlorinated at 100 mg/litre (10 mg/kg of body weight per day), no treatment-related effects on fertility were found (21). Oral administration of hypochlorite ion or hypochlorous acid at 100, 200, or 400 mg of chlorine per litre (1.6, 4.0, or 8.0 mg/kg of body weight per day) resulted, in the case of hypochlorite, in dose-related increases in the amount of sperm-head abnormalities in male B6C3F1 mice. A NOAEL of 8.0 mg/kg of body weight per day was identified for hypochlorous acid and a LOAEL of 1.6 mg/kg of body weight per day for hypochlorite ion (22). Mutagenicity and related end-points Sodium hypochlorite has been found to be mutagenic in Salmonella typhimurium TA1530 and TA100 but not TA1538 (23,24). Calcium and sodium hypochlorite both produced chromosomal aberrations in Chinese hamster fibroblast cells without metabolic activation (24). Hypochlorite ion and hypochlorous acid were negative in the in vivo erythrocyte micronucleus assay and in bone marrow aberration studies (22). Carcinogenicity F344 rats (50 per sex per dose) were given sodium hypochlorite in drinking-water (males: 0.05% or 0.1%, 75 or 150 mg/kg of body weight per day; females: 0.1% or 0.2%, 150 or 300 mg/kg of body weight per day) for 2 years. Experimental groups did not differ from controls with respect to the total tumour incidences or mean survival times, and most of the tumours found were of types that commonly occur spontaneously in F344 rats. The authors concluded that sodium hypochlorite was not carcinogenic in rats (17). In a seven-generation toxicity study, the incidence of malignant tumours in rats consuming drinking-water with a free chlorine level of 100 mg/litre (10 mg/kg of body weight per day) 4 did not differ from that in controls (21). The incidence of tumours in treated animals was not significantly elevated in F344 rats and B6C3F1 mice (50 per sex per dose) given solutions of sodium hypochlorite (70 or 140 mg/kg of body weight per day for male rats, 95 or 190 mg/kg of body weight per day for female rats, 84 or 140 mg/kg of body weight per day for male and female mice) in their drinking-water for 103–104 weeks (25). In a 2-year bioassay, F344 rats and B6C3F1 mice were given chlorine in drinking-water at levels of 0, 70, 140, or 275 mg/litre (8, 13, or 24 mg/kg of body weight per day for male rats; 5, 7, or 15 mg/kg of body weight per day for female rats; 8, 15, or 24 mg/kg of body weight per day for male mice; and 1, 13, or 22 mg/kg of body weight per day for female mice). Although there was a marginal increase in mononuclear-cell leukaemia in the groups of female rats given 140 and 275 mg/litre, it was considered to be equivocal evidence of carcinogenic activity because the incidence was significantly elevated compared with controls only for the middle dose and the incidence of leukaemia in the concurrent controls was lower than the mean in historical controls (18). EFFECTS ON HUMANS Exposure to chlorine, hypochlorous acid, and hypochlorite ion through ingestion of household bleach occurs most commonly in children. Intake of a small quantity of bleach generally results in irritation of the oesophagus, a burning sensation in the mouth and throat, and spontaneous vomiting. In these cases, it is not clear whether it is the sodium hypochlorite or the extremely caustic nature of the bleach that causes the tissue injury. The effects of heavily chlorinated water on human populations exposed for varying periods were summarized in a report that was essentially anecdotal in character and did not describe in detail the health effects observed (26). In a study on the effects of progressively increasing chlorine doses (0, 0.001, 0.014, 0.071, 0.14, 0.26, or 0.34 mg/kg of body weight) on healthy male volunteers (10 per dose), there was an absence of adverse, physiologically significant toxicological effects in all of the study groups (27). It has been reported that asthma can be triggered by exposure to chlorinated water (28). Episodes of dermatitis have also been associated with exposure to chlorine and hypochlorite (29,30). In a study of 46 communities in central Wisconsin where chlorine levels in water ranged from 0.2 to 1 mg/litre, serum cholesterol and low-density lipoprotein levels were higher in communities using chlorinated water. Levels of high-density lipoprotein (HDL) and the cholesterol/HDL ratio were significantly elevated in relation to the level of calcium in the drinking-water, but only in communities using chlorinated water. The authors speculated that chlorine and calcium in drinking-water may interact in some way that affects lipid levels (31) An increased risk of bladder cancer appeared to be associated with the consumption of chlorinated tapwater in a population-based, case–control study of adults consuming chlorinated or non-chlorinated water for half of their lifetimes (32). GUIDELINE VALUE In humans and animals exposed to chlorine in drinking-water, specific adverse treatmentrelated effects have not been observed. IARC has concluded that hypochlorites are not classifiable as to their carcinogenicity to humans (Group 3) (17). The guideline value for free chlorine in drinking-water is derived from a NOAEL of 15 mg/kg of body weight per day, based on the absence of toxicity in rodents that received chlorine as hypochlorite in drinking-water for up to 2 years (18). Application of an uncertainty factor of 100 (for inter- and intraspecies variation) to this NOAEL gives a TDI of 150 µg/kg of body weight. With an allocation of 100% of the TDI to drinking-water, the guideline value is 5 5 mg/litre (rounded figure). It should be noted, however, that this value is conservative, as no adverse effect level was identified in this study. Most individuals are able to taste chlorine or its by-products (e.g. chloramines) at concentrations below 5 mg/litre, and some at levels as low as 0.3 mg/litre.

Chlorine Residual Testing Fact Sheet The presence of free chlorine residual in drinking water indicates that: 1) a sufficient amount of chlorine was added to the water to inactivate most of the bacteria and viruses that cause diarrheal disease; and, 2) the water is protected from recontamination during transport to the home, and during storage of water in the household. Because the presence of free residual chlorine in drinking water indicates the likely absence of disease-causing organisms, it is used as one measure of the potability of drinking water. This Fact Sheet describes: 1. The processes that occur when chlorine is added to water, and the definitions involved with these processes; 2. Why and how the Safe Water System program recommends testing of free chlorine; and, 3. Methods to test free chlorine in the field in developing countries. Definitions When chlorine is added to water as a disinfectant, a series of reactions occurs. These reactions are graphically depicted on the following page. The first of these reactions occurs when organic materials and metals present in the water react with the chlorine and transform it into compounds that are unavailable for disinfection. The amount of chlorine used in these reactions is termed the chlorine demand of the water. Any remaining chlorine concentration after the chlorine demand is met is termed total chlorine. Total chlorine is further subdivided into: 1) the amount of chlorine that then reacts with nitrates present in the water and is transformed into compounds that are much less effective disinfectants than free chlorine (termed combined chlorine); and, 2) the free chlorine, which is the chlorine available to inactivate disease-causing organisms, and is thus a measure used to determine the potability of water. For example, when chlorine is added to completely pure water the chlorine demand will be zero, and there will be no nitrates present, so no combined chlorine will be formed. Thus, the free chlorine concentration will be equal to the concentration of chlorine added. When chlorine is added to natural waters, especially water from surface sources such as rivers, organic material will exert a chlorine demand, and combined chlorine will be formed by reaction with nitrates. Thus, the free chlorine concentration will be less than the concentration of chlorine initially added. Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov 2 Chlorine Addition Flow Chart Chlorine Added Initial chlorine concentration added to water Free Chlorine Concentration of chlorine available for disinfection Combined Chlorine Concentration of chlorine combined with nitrogen in the water and not as effective for disinfection Total Chlorine Remaining chlorine concentration after chlorine demand of water Chlorine Demand Reactions with organic material, metals, other compounds present in water prior to disinfection Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov 3 Why Do We Test Free Chlorine in Drinking Water? The CDC Safe Water System (SWS) program is an intervention proven to reduce diarrheal disease incidence in developing countries that consists of three elements: water treatment with dilute sodium hypochlorite at the point-of-us; storage of water in a safe container; and, education to improve hygiene and water and food handling practices. The sodium hypochlorite solution is generally packaged in a bottle with directions instructing users to add one full bottle cap of the solution to clear water (or 2 caps to turbid water) in a standard-sized storage container, agitate, and wait 30 minutes before drinking. The CDC SWS project recommends testing free chlorine in the following circumstances: • To conduct dosage testing in project areas before starting an SWS program • To monitor and evaluate projects by testing stored drinking water in households The goal of dosage testing is to determine how much sodium hypochlorite solution to add to water that will be used for drinking to maintain free chlorine residual in the water for the average time of storage of water in the household (typically 24 hours). This goal differs from the goal of infrastructure-based (piped) water treatment systems, whose aim is effective disinfection at the endpoints (i.e., water taps) of the system. The WHO recommends “a residual concentration of free chlorine of greater than or equal to 0.5 mg/litre after at least 30 minutes contact time at pH less than 8.0.” This definition is only appropriate for users who obtain water directly from a flowing tap. A free chlorine level of 0.5 mg/L can maintain the quality of water through a distribution network, but is not optimal to maintain the quality of the water when it is stored in the home in a bucket or jerry can for 24 hours. Thus, CDC recommends in SWS programs that: 1. At 1 hour after the addition of sodium hypochlorite solution to water there should be no more than 2.0 mg/L of free chlorine residual present (this ensures the water does not have an unpleasant taste or odor). 2. At 24 hours after the addition of sodium hypochlorite to water in containers that are used by families for water storage there should be a minimum of 0.2 mg/L of free chlorine residual present (this ensures microbiologically clean water). Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov 4 This methodology is approved by the WHO, and is graphically depicted below. The maximum allowable WHO value for free chlorine residual in drinking water is 5 mg/L. The minimum recommended WHO value for free chlorine residual in treated drinking water is 0.2 mg/L. CDC recommends not exceeding 2.0 mg/L due to taste concerns, and chlorine residual decays over time in stored water. WHO Maximum Taste Threshold Sample Decay Curve WHO Minimum The SWS project recommends testing free chlorine in homes of SWS users to evaluate whether or not users are using the SWS (as measured by presence or absence of free chlorine residual) and whether they are using it correctly (as measured by free chlorine residuals in the 0.2-2.0 mg/L range). This approach is useful for program monitoring because the presence of free chlorine residuals in stored water obtained from an unchlorinated source is an objective, quantitative measure that people are using the SWS hypochlorite solution. Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov 5 Methods to Test Free Chlorine in the Field in Developing Countries There are four main methods to test free and total chlorine residual in drinking water in the field in developing countries: 1) Pool test kits; 2) Color-change test tubes; 3) Color-wheel test kits; and, 4) Digital colorimeters. All four methods depend on a color change to identify the presence of chlorine, and a measurement of the intensity of that color to determine how much chlorine is present. This fact sheet does not consider commercial test strips for chlorine residual testing, because of their relatively higher cost (0.15-1.00 USD) per test. When only a small number of tests are needed it is possible that commercial test strips could be a viable, cost-effective option. 1. Pool test kits The first option for chlorine residual testing uses the liquid chemical OTO (othotolidine) that, when added to water with total chlorine in it, causes a color change to yellow. To complete the test, users simply fill a tube with water, add 1-5 drops of the solution, and look for the color change to yellow. These kits are sold in many stores as a way to test the concentration of total chlorine in swimming pool water. This method does not measure free chlorine. Benefits of the pool test kits are: • Low cost • Very easy to use • Easily purchasable Drawbacks of the pool test kits are: • Degradation of the OTO solution can cause inaccurate readings over time • Generally not reliable quantitative results • Lack of calibration and standardization • Measurement of total chlorine, not free chlorine Cost and Ordering Information Pool test kits can be obtained from many home supply and pool stores at a cost of approximately $5- 20 each. Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov 6 2. Test-tube DPD color comparator The Lamotte Company developed a rapid presence/absence test kit for free chlorine residual in response to the 2004 tsunami in Indonesia. The test tube color comparator uses DPD (N,N diethyl-p-phenylene diamine) tablets that causes a color change to pink in the presence of chlorine. To use the kit, users add 5 mL of water to the test tube, add one rapidly dissolving DPD-1R tablet, and compare the results to a color chart. This kit combines the simplicity of the pool test kits, with the benefit of testing for free chlorine residual instead of total chlorine residual. To use this kit to measure total chlorine, a DPD-4R tablet can be added instead of the DPD-1R tablet to the water sample, or a DPD-3R tablet can be added to the sample water after the DPD-1R tablet has been added and the free chlorine residual has been read. Although the test kit is not available as a package from Lamotte, the individual components (test tube, DPD tablets, and color chart) can be ordered individually. Test kit instructions and part numbers can be found at: http://www.lamotte.com/pages/common/pdf/instruct/3529.pdf. Benefits of the test tube kit are: • Low cost • Very easy to use • Measurement of free chlorine Drawbacks of the test tube kit are: • Generally not reliable quantitative results • Lack of calibration and standardization Cost and Ordering Information The kit parts are available from the Lamotte Company (www.lamotte.com) for a cost of approximately $5 for both the test tube and color comparator chart, and approximately $70 for 1,000 DPD tablets. Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov 7 3. Color wheel test kits Color wheel test kits also use DPD tablets or powder that, when added to water with free or total chlorine present in it, cause a color change to pink. The color wheel test kits are more accurate than the pool test kits / test tube DPD color comparators and simpler and less expensive than digital meters. This is because users measure the intensity of the color change, as compared with a sample of water to which no DPD has been added, using a color wheel to visually match the color change to a numerical reading. The test kit can be used to measure either free chlorine or total chlorine, or both, generally within a range of 0-3.5 mg/L, equivalent to 0-3.5 ppm (parts per million). Please note that DPD tablets and powders are company specific, and that using one company’s test kit with another company’s DPD tablets is not recommended. Also note that although all DPD-1 tablets measure free chlorine, there is variation between companies as to whether the total chlorine tablet is added to the same sample water the free chlorine is tested in or whether it is added to fresh sample water. Benefits of the color-wheel test kits are: • Accurate quantitative readings if used correctly • Low cost Drawbacks of the color-wheel test kits are: • Potential for user error • Lack of calibration and standardization Cost and Ordering Information Color wheel test kits can be ordered from: Hach Company www.hach.com Part Number: CN-66 Approximately $44 Lamotte Company www.lamotte.com Part Number: 3308 Approximately $55 Additional DPD tablets or powders can be ordered as well, at a cost of approximately $70 per 1,000 tablets or sachets. Chlorine Residual Testing Fact Sheet, CDC SWS Project, safewater@cdc.gov.

4. Digital Colorimeters Digital colorimeters are the most accurate way to measure free chlorine and/or total chlorine residual in the field in developing countries. To use the colorimeters: 1) a DPD-1 (free chlorine) or DPD-3 (total chlorine) tablet or powder is added to a vial of sample water that causes a color change to pink; and, 2) the vial is inserted into a meter that reads the intensity of the color change by emitting a wavelength of light and automatically determining and displaying the color intensity (the free or total chlorine residual) digitally. The range of the meters is generally 0-4 mg/L, equivalent to 0-4 ppm (parts per million). Please note that DPD tablets and powders are company specific, and that using one company’s test kit with another company’s DPD tablets is not recommended. Benefits of the digital colorimeters are: • Highly accurate readings • Fast results • EPA approved Drawbacks of the digital colorimeters are: • Expense • Necessity of calibration with standards • Necessity for skilled operator.

What is chlorine? Chlorine is the most widely used disinfectant in the home. It is also disinfectant used by the water industry to maintain hygienic conditions within the public water supply network of pipes. At the very low levels used in drinking water it is perfectly safe. Much higher concentrations are routinely used safely for other purposes such as sterilisers for baby feeding bottles and by the leisure and health care industry in spas, hydrotherapy pools and swimming pools. The reason why chlorine can be a concern in drinking water relates to the fact that some people can be very sensitive to its taste and smell. The following information explains why you may notice a chlorine taste or smell in your drinking water and what you can do if you are particularly sensitive. What do I do if I notice the chlorine in my water? The level of chlorine in tap water is very low in England and Wales which contrasts very favourably with practices in other countries where much higher levels are common. Typically water companies keep the level of residual disinfectant in the form of free or combined chlorine to 0.5 mg/l or less. However sometimes during maintenance of the pipe network higher levels are needed. If you occasionally notice a slight taste or smell of chlorine it is probably due to maintenance work in your area, it will not be a long lasting problem and there is no cause to worry. BUT, if you notice a particularly bad or strong smell or TCP like taste which makes your tap water unpalatable, or you notice a smell or taste for the first time which does not go away in a short time, then you should contact your water company immediately. Enquiry and emergency numbers are listed under WATER in your telephone directory or on the back of your water bill. Why use chlorine? Water is safe when it leaves the treatment works and the trace of chlorine is there only to preserve the high quality of the water as it passes through the miles of pipes used to convey water to homes and workplaces. Chlorine has a long history of about 100 years of safe use for hygiene purposes worldwide. Why can I taste or smell chlorine in my water? There can be minor variations in the amount and the form of the chlorine present in each water supply. Water companies set the levels as part of the safe management of the whole network. Drinking Water Inspectorate, Area 7e, 9 Millbank, c/o Nobel House, 17 Smith Square, London, SW1P 3JR E-mail: dwi.enquiries@defra.gsi.gov.uk Website: http://www.dwi.gov.uk Tel: 030 0068 6400 For this reason if your property is located near to the water treatment works the level of chlorine may be a little higher in your tap water than it is at properties several miles further away. Water companies are required to have in place a residual disinfectant management policy designed to ensure a minimum level at the remotest part of the network whilst also ensuring the maximum level is still acceptable to all consumers. The operation of a water distribution network is a complex task and occasionally levels of chlorine are not optimal. If you do not like the smell or taste then a simple way to remedy the problem is to cool the tap water before using it for drinks. Place a jug with a lid in your fridge for a short period but always remember to throw away any unused water after 24 hours and clean the jug regularly. Are these low amounts of chlorine harmful? No. The World Health Organisation has set a health based guideline maximum value of 5 mg/l for chlorine as a residual disinfectant in drinking water. The levels in tap water in England and Wales are well below this guideline and most water companies aim to keep the level below 1 mg/l. Your water company will provide you with a free water quality report showing the maximum and minimum level of residual chlorine in your local water supply on request. You can also look up minimum and maximum levels of residual chlorine in water supplied by each water company on our website here. What else can I do if I am sensitive to tastes or smells? Cooling tap water in the fridge is all that is needed. However, if you wish you could always try using a simple jug filter with an activated carbon cartridge. If you do decide to use a filter, or you have a modern fridge which has an integral water judge fitted, then you must follow all the manufacturer's instructions carefully. Not doing so can give rise to contamination and hygiene problems. You can find more advice on water filters here. Remember........ • Always use freshly drawn water for drinking or cooking, taking it from a cold water tap supplied directly off the water mains. This is nearly always the cold tap in your kitchen. • When no water has been used in the house for several hours, draw off a washing up bowlful before using water for drinking. This will ensure that you do not drink water which may have been standing for a long time in your pipes. • Do not use hot water or water from your bathroom taps for drinking or cooking because it usually comes from a storage tank in the loft and is not as fresh or as safe as water directly from the mains. • If you notice a particularly bad or strong smell or TCP like taste which means you cannot drink the water then this may indicate a problem with your home plumbing arrangements and you should contact your water company so they can investigate and give you advice on how Drinking Water Inspectorate, Area 7e, 9 Millbank, c/o Nobel House, 17 Smith Square, London, SW1P 3JR E-mail: dwi.enquiries@defra.gsi.gov.uk Website: http://www.dwi.gov.uk Tel: 030 0068 6400 to improve your plumbing arrangements. A common cause of TCP like tastes is the hoses that are used to connect domestic appliances to the water supply. Some plastic kettles and anti-splash devices fitted to or inside modern taps may also be the cause.

There has been a lot of press recently touting new water filters for faucets, showers, and entire home systems. As a marketing tactic to increase sales of these products, advertisers have been overplaying an unsubstantiated risk associated with drinking water chlorination. They overlook the benefits of chlorine as an inexpensive and highly effective disinfectant and do not recognize that the regulatory limits for chlorine and disinfection byproducts were set following a thorough review of credible health data.

The Environmental Protection Agency (EPA) says most people don’t need to treat their drinking water at home to make it safe. If taste is the primary concern, an inexpensive pitcher, refrigerator or faucet attachment with a carbon filter will likely help. A shower filter may offer extra security for people “more vulnerable to the effects of waterborne illness” such as infants, the elderly or those with compromised immune systems.

However, many consumers don’t want their tap water unfiltered at the point of use. According to a Gallup poll released last year, pollution of drinking water is the top environmental concern for Americans. Many express worries about the risk of diseases, including cancer that can be associated with contaminants such as arsenic, chlorine and pharmaceuticals sometimes found in drinking water. But there is no real evidence to back up these concerns.

The primary purpose of having chlorine in the water is to destroy the bacteria and viruses that can enter a water system in many different ways. A chlorine residual provides the primary protection from these known and well understood pathogens. It is the only effective, large scale method for residual protection of drinking water. Although chlorine can react with organic material in water to create low level contaminants, these are closely regulated by the EPA.

The EPA *requires* treated tap water to have a detectable level of chlorine to help prevent contamination. The allowable chlorine levels in drinking water (up to 4 parts per million) pose “no known or expected health risk [including] an adequate margin of safety.” Only chlorine based disinfectants can provide lasting protection from waterborne diseases throughout the distribution system from treatment plant to the consumer’s tap.

Over 98 percent of U.S. water supply systems that disinfect drinking water use chlorine. In the U.S. we have depended on chlorine as our drinking water disinfectant for over a century. Public health officials heralded water chlorination as one of the greatest public health achievements of the millennium. The real danger, when it comes to chlorine, is eliminating its use.

- See more at: http://www.waterandhealth.org/chlorine-in-tap-water-is-safe-to-drink/#sthash.E6ATbigC.dpuf