098/13

TO: The Chairperson and Members
POLICY AND FINANCE COMMITTEE

FOR INFORMATION AND RECOMMENDATION

MASTERTON WATER TREATMENT PLANT FILTER UPGRADE CIVIL CONTRACT 28-12/13 TENDER

Purpose of Report

To report to Council on the tender process and recommend the Contractor for the upgrading of the Masterton Water Treatment Plant (WTP) filters.

Background

The previous Officer's Report dated 22 February 2013 recommending an invited tender process for the procurement of the WTP filter upgrade has been approved by Council.

Tender Process and Evaluation

Three local contractors were invited to tender for the civil construction contract 28-12/13. Fulton Hogan chose not to submit a tender, as they are too busy for the timeframe.

Rigg Zschokke submitted a tender price of $474,555 + GST. Oldfields submitted a tender price of $503,006 + GST.

Both tenders received are conforming and compliant with health and safety, and included all aspects of the works with no significant tags.

Given key staff from Rigg Zschokke were involved in the original construction of the WTP and they have a strong track record of work with the Masterton District Council, coupled with its competitive price, officers recommend the contract be awarded to Rigg Zschokke.

The budgeted figure for the civil aspects of the WTP filter upgrade was $475,000, thus there will be no budgetary issue in proceeding with the contract at this price.

Commissioning is currently programmed for October based on awarding this contract in May. Delays to this programme will require commissioning when summer demand is near its peak and will impose a significant supply continuity risk to the Council.

Chlorine Treatment

Attached are comments received to date from the Medical Officer of Health regarding chlorine treatment.

Steven Butcher has subsequently provided additional information regarding the risk and costs of chlorination. Documents attached are a Taiwanese chlorination study and his cost benefit analysis estimating chlorine dosing cost on the Masterton community of $2m annually.

It is noted that the 1997 study concludes *"Our findings are in no way intended to suggest that the disinfection of drinking water with chlorine should be abandoned. However, it should not be forgotten that the primary public health concern for drinking water supplies is still waterborne infectious disease transmission, against which chlorine provides very*

effective protection. Therefore, these findings should provide an impetus to identify, develop, and implement disinfection strategies that are not associated with adverse health effects".

The cost of installing a membrane filtration plant instead of upgrading the existing filters, with the potential ability to stop chlorination, has been estimated at an additional $10m. Alternative technologies identified by Mr Butcher, such as bag filters, have the potential to reduce this capital cost to $4-8m but do have increased waterborne infectious disease risks to address.

Options for the Council

Mr Butcher's estimated cost benefits of discontinuing chlorination for the community, if confirmed, would justify additional investment in the water treatment plant. His analysis has significant implications at the national and international level.

Water New Zealand, in conjunction with ESR, are currently undertaking a review of chlorination in water treatment, and will be looking at a number of issues relating to this treatment process.

The current upgrade meets the requirements of the current drinking water standards and addresses the existing supply continuity risk the Council has, which is associated with the filters distributors reaching the end of their serviceable life and earthquake risk. The upgrade will not preclude the installation of a "polishing" filter or other technology in the future if the benefits of doing so are clarified.

Recommendation

That the Council:

1. **Approve awarding the contract to Rigg Zschokke for the WTP filter upgrade civil contract 28-12/13, at a price of $474,555 + GST.**
2. **Highlight Mr Butcher's analysis with Water New Zealand and the Ministry of Health for their review.**
3. **Await the outcome of the Water New Zealand review regarding chlorination risk before determining additional water treatment options.**

James (Yongjian) Li
UTILITY SERVICES MANAGER

David Hopman
MANAGER ASSETS AND OPERATIONS

21 May 2013

Ruth Cox 523A

Subject: FW: Masterton District Council - Water Treatment discussions

Jill McKenzie <Jill.McKenzie@huttvalleydhb.org.nz> wrote:

Hi Wes,

Further to my email below having had some more time this afternoon to look at Mr Butchers presentation to Council .

An individual water supplier needs to decide on the most appropriate water source and treatment to provide a safe community drinking water supply. The Council should seek this guidance from their local infrastructure experts who submit Public Health Risk Management Plans to the local Drinking Water Assessor for approval. Chlorination is one of the recommended disinfection methods for New Zealand and we support continuation of this for the Masterton Dr inking Water Supply. Mr Butcher has provided a paper prepared for two of the Waimakariri District Council supplies around discontinuation of chlorination disinfection - the Council should note that the water sources for these supplie s are secure ground water i.e. this report is tailored to the specifics of these supplies and therefore cannot be gener alised to a different supply with a different set of parameters and risks to manage.

In terms of Mr Butchers concerns about the risk of cancer associated with chlorination and references to the Nationa l Toxicology Program Technical Report Series No. 392, the excerpt of information on cancer risk for male rats has be en taken out of context from the paper. Notably, increasing doses of chlorine exposure were not associated with inc reasing risk of cancer development (known as dose-response, this is one aspect used to assess the strength of the e vidence from research results), and the doses of chlorine that the rats were exposed to are 14-55 times higher than the maximum highest allowable level of chlorine in drinking water supplies, i.e. the doses are not comparable to dos es received by the Masterton community. The derivation of our maximum chlorine dose was based on reviewing a n umber of studies to find a level of chlorine where there was no observed adverse effect (including cancer), then app lying a 100x safety factor to allow for any uncertainty in research on long-term effects of chlorine exposure (standar d practice especially when some of the research is based on animal studies and must be translated to humans).

I also note that Mr Butcher has not referenced research he refers to as refuting the position that the WHO holds on the use of chlorination as a safe disinfection measure for community drinking water supplies (paragraph 2, page 3).

As reiterated below, I do not share the concerns of Mr Butcher regarding the discrediting of expertise used by WHO . The documents presented by Mr Butcher are publicly available and therefore I do not believe represent any hidde n agenda or undeclared conflicts of interest, lending discredit to this international body of expertise.

Once again, please let me know if there are any specific questions the councillors have following Mr Butcher's prese ntation. I can arrange a meeting with the councillors at a mutually convenient date if that is the preferred option.

Kind regards,

Jill

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My hours of work are Monday to Thursday 8.30am - 5.30pm
>>> Jill McKenzie 24/04/2013 5:38 p.m. >>>
Hi Wes,

Many thanks for forwarding this on. I've had a chance to quickly scan these documents most of which are core reso

urces for managing safe water supplies. It appears the only new information Mr Butcher is presenting is evidence h e believes discredits international and national expertise around safe drinking water supplies. I do not share his con cerns about the strength of evidence that chlorination of community drinking water supplies managed according to t he current standards is a safe and effective way of managing drinking water supplies. I have previously shared my thoughts on the problems with associating multifactorial medical conditions (such as cancer or heart disease) with a single environmental exposure such as water chlorination.

If after the councillors have heard Mr Butcher on this occasion they have specific concerns or questions I am very h appy to arrange a time to come over and meet. It would be difficult for me to come next Wednesday as I already h ave the afternoon booked out for meetings, but if you could let me know as soon as possible another suitable date t o come and talk with councillors then I can get this into my calendar and plan for other work in the Wairarapa on t hat day. At this stage my only other planned day in the Wairarapa is not until 4th June, but I am usually in the regi on at least once a month. My apologies for not being able to accommodate this initial suggested date.

I'm next in the office on Monday and if at all possible will look to provide any relevant additional feedback prior to y our Wednesday meeting. Happy to talk further if that is of use.

Kind regards,

Jill

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My hours of work are Monday to Thursday 8.30am - 5.30pm
>>> "Wes ten Hove" <west@mstn.govt.nz> 24/04/2013 10:59 a.m. >>>

Greetings Jill

Thank you for your contact details. I have copied you in to the various materials. There may be more.
I was hoping to meeting with my Councillors Wednesday 1 May and understand this may not suit you. Any alternat ive will be appreciated, as might be a memo regarding chlorine/public health risk/water standards as a general advis ory.

Best regards

Wes

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Chlorination of Drinking Water and Cancer Mortality in Taiwan

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Received July 30, 1997

Chlorination has been the major strategy for disinfection of drinking water in Taiwan. An ecologic epidemiological study design was used to examine whether chlorination of drinking water was associated with cancer risks. A "chlorinating municipality" (CHM) was defined as one in which more than 90% of the municipality population was served by the chlorinated water while an "nonchlorinating municipality" (NCHM) was one in which less than 5% of the municipality population was served by chlorinated water. Age-adjusted mortality rates for cancer during 1982–1991 among the 14 CHMs were compared to rates among the 14 matched NCHMs with similar urbanization level and sociodemographic characteristics. The results of this study suggest a positive association between consumption of chlorinating drinking water and cancer of the rectum, lung, bladder, and kidney. Although these findings must be interpreted with caution because of limitations in the ecological study design, their public health significance should not be disregarded because chlorination of water is so widely practiced in Taiwan. © 1998 Academic Press

Key Words: **chlorination; drinking water; cancer; mortality; epidemiology.**

INTRODUCTION

The economy and effectiveness of chlorine in killing waterborne organisms has made water chlorination a tremendous public health success worldwide. Chlorination has been the major strategy for the disinfection of drinking water in Taiwan. It is currently added to approximately 75.8% of the nation's drinking water.

A number of epidemiologic studies have been conducted which examine the possible associations between consumption of chlorinated drinking water and cancer mortality or incidence (Page *et al.*, 1976; Kuzma *et al.*, 1977; Cantor *et al.*, 1978,1987; Wilkins and Comstock, 1981; Young *et al.*, 1981,1987; Bean *et al.*, 1982; Gottlieb *et al.*, 1982; Lawrence *et al.*, 1984; Carpenter and Beresford, 1986; Cech *et al.*, 1987; Zierler *et al.*, 1988; Flaten, 1992; Morris *et al.*, 1992; McGeehin *et al.*, 1993). These studies consider a wide range of populations and regions but have been mainly carried out in the U.S. Most studies have shown positive associations between chlorinated drinking water and colorectal and bladder cancer. This has been attributed to trihalomethanes (THMs), a carcinogenic organic halogenated byproduct of water chlorination (Reuber, 1979; Dunnick and Melnick, 1993; IARC, 1987).

The present study was carried out because few epidemiological studies have been conducted outside the U.S. (Carpenter and Beresford, 1986; Flaten, 1992). The study reported here was designed to explore further the association between cancer mortality and the use of chlorinated water.

MATERIALS AND METHODS

Selection of Study Municipalities

Taiwan is divided into 361 administrative districts, which will be referred to herein as municipalities. They are the units that were subjected to statistical analysis. Excluded from the analysis were 30 aboriginal townships and 9 islets which had different lifestyles and living environments and Taipei city (including 12 municipalities) because of its distinctly more urban character and higher population than other Taiwan municipalities. This elimination of unsuitable municipalities left 310 municipalities for the analysis.

The current Taiwan water system is rather simple. Residents obtain their drinking water either from the public drinking water supply systems served by the Taiwan Water Supply Corporation (TWSC) or from nonmunicipal sources. The major sources of municipal water supplies are almost all

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surface waters and are often treated with chlorine. The nonmunicipal sources are mainly privately owned wells (groundwater) and are often unchlorinated.

In this study, an individual municipality was classified as a chlorinating municipality (CHM) if more than 90% of the municipality population was served by chlorinated water. In all, 156 of the 310 municipalities satisfied this criterion. A nonchlorinating municipality (NCHM) was defined as one in which less than 5% of the municipality population was served by chlorinated water, i.e., more than 95% of the residents of these 15 municipalities obtained their drinking water from unchlorinated water sources. In all, 15 municipalities satisfied this definition. These 15 NCHMs provide a unique opportunity to investigate the issue of chlorination.

Mortality from cancer has been found to vary between regions in Taiwan (DOH/ROC, 1993), and several studies have examined the variation in cancer rates across urbanization gradients (Greenberg, 1983; Miller *et al.*, 1987; Swoboda and Friedal, 1991). To take into account the possible confounding effect resulting from differing urbanization levels, the urbanization level of the nonchlorinating municipalities should be the same as that of the chlorinating municipalities. The assignment of urbanization levels was based on the urban–rural classification of Tzeng and Wu (1986). This urbanization index has been applied to our previous studies (Yang *et al.*, 1996,1997a). Each municipality in Taiwan ($n = 361$) was assigned to an urbanization category from 1 to 8. Municipalities with the highest urbanization score, such as the Taipei metropolitan area, were classified in category 1, while mountainous areas with the lowest score were assigned to category 8.

More specifically, each NCHM was matched with one CHM with the same urbanization level. Among the 15 NCHMs, one was excluded as there was no appropriate municipality for matching. If a NCHM had more than one appropriate CHM for matching, a random sampling method was used to select one for matching.

Data Collection and Mortality Analysis

Information concerning both the number of deaths and the midyear population by sex, age, and calendar year during 1982–1991 was obtained from the Bureau of Vital Statistics of the Taiwan Provincial Department of Health, which is in charge of the death registration system in Taiwan. The International Classification of Disease, Injury, and Causes of Death [9th revisions (ICD-9)] is used to code the cause of death, and the system has been completely computerized since 1972.

Average annual cancer mortality rates per 100,000 population were calculated for males and females for each municipality of the two chlorination groups, 1982–1991. As the age distribution was not similar among the municipalities of the two chlorination groups, the age-standardized rates were computed by the direct method, using the world population in 1976 as the standard population (Waterhouse *et al.*, 1976).

Statistics

The age-standardized rates for various cancer sites were calculated first among residents in the individual chlorinating and nonchlorinating municipality. The mean age-standardized rates in all CHMs and all NCHMs were then calculated. The ratios of the mean age-standardized mortality rates from various malignant neoplasms for CHMs and the mean rates from all NCHMs represent the relative cancer risk in the CHMs compared to the NCHMs (standardized rate ratio, SRR). For the SRR the null hypothesis (H_0: SRR = 1) was tested, and the 95% confidence interval of the SRR was calculated according to the method of Rothman (1986).

RESULTS

The sociodemographic characteristics of the CHMs and NCHMs were generally similar except for a higher population and a higher percentage of population using the chlorinated water among CHMs (Table 1).

Average annual age-adjusted cancer mortality rates per 100,000 population and ratios of the age-adjusted mortality rates (SRR) for 1982–1991 by cancer site and sex for the CHMs and NCHMs are listed in Tables 2 and 3. A significant relationship was observed for cancers of the rectum, lung, bladder, and kidney in both males and females and for cancer of the liver in males. Mortality rates for cancers of the esophagus, stomach, colon, pancreas, prostate, brain, breast, cervix uteri and uterus, and ovary were not associated with the use of chlorinated water.

DISCUSSION

The major findings of this study suggest that there was a significant association between municipal (chlorinated) drinking water in Taiwan and mortality from certain cancers. Before evaluating the

TABLE 1

Some Characteristics of Two Groups of Taiwan Municipalities, Grouped According to Chlorination Practice

	14 CHMs[a]	14 NCHMs[b]
Total population (1989)	463,657	397,588
Mean population	28,399	33,118
Population density (per Km^2)	611.2	600.4
Percentage of population served by chlorinating water	96.1	1.5
White-collar, %[c]	25.4	24.8
Blue-collar, %[d]	24.6	22.2
Agriculture, %[e]	50.0	53.0

[a]Chlorinating municipalities.
[b]Nonchlorinating municipalities.
[c]Professional, technical, administrative, superintendents, clerical, sales, and service workers as a percentage of total employed (aged 15 and over) population.
[d]Producers, transportation operators, and laborers as a percentage of total employed population.
[e]Farmers, loggers, grazers, fishermen, hunters, and related workers as a percentage of total employed population.

meaning of these findings, consideration first must be given to the design of the study.

Mortality data have been widely used to generate epidemiologic hypotheses, despite their inherent limitations (Morgenstern, 1982). The completeness and accuracy of the death registration should be evaluated before any conclusion based on the mortality analysis is made. In Taiwan, it is mandatory to register all deaths at local household registration offices and since the household registration information is verified annually through a door-to-door survey, the death registration is very complete. Although causes of death may be misdiagnosed or misclassified this problem has been minimized through an improvement in the verification and classification of causes of death in Taiwan since 1972. Furthermore, malignant neoplasms have been reported to be one of the most unequivocally classified causes of death in Taiwan (Chen and Wang, 1990). Because of their fatal outcome, it is believed that in recent years in Taiwan, all cancer cases from the studied municipalities have had access to medical care regardless of geographical location. The completeness and accuracy of death certificate registration is thus believed to be comparable.

Problems inherent in aggregate studies, including the "ecologic fallacy," are well known. However, the degree to which this fallacy is a problem varies from study to study. It was a distinct problem in the early water-cancer studies when associations between consumption of surface water and rates of cancer were looked for by comparing the proportion of county or parish residents supplied by surface water sources with cancer mortality rates for the total county or parish. In our study, the effects of drinking water chlorination on cancer mortality were investigated using an "extreme points contrast" in order to maximize the inherent power of the design

TABLE 2

Mean Annual Age-Adjusted Mortality Rates per 100,000 Population and Ratios of Age-Adjusted Mortality Rates (SRR), 1982–1991, among Males in Chlorinating Municipalities (CHMs) to Those in Nonchlorinating Municipalities (NCHMs) by Cancer Site

Cancer site (ICD 9)	14 CHMs	14 NCHMs	SRR (95% CI)[a]
All sites (140–208)	135.66	103.09	1.32 (1.18–1.46)[b]
Esophagus (150)	4.44	3.34	1.33 (0.83–2.12)
Stomach (151)	15.20	11.89	1.28 (0.98–1.67)
Colon (153)	5.00	4.65	1.08 (0.75–1.54)
Rectum (154)	3.45	2.43	1.42 (1.23–2.25)[b]
Liver (155)	36.45	29.37	1.24 (1.01–1.52)[b]
Pancreas (157)	2.81	1.88	1.49 (0.93–2.40)
Lung (162)	26.33	16.44	1.60 (1.39–1.85)[b]
Prostate (185)	2.14	1.81	1.18 (0.78–1.78)
Bladder (188)	4.85	2.60	1.86 (1.54–3.50)[b]
Kidney (189)	1.73	0.69	2.51 (1.27–4.94)[b]
Brain (191)	1.62	1.47	1.10 (0.58–2.09)

[a]95% confidence interval.
[b]$P < 0.05$.

TABLE 3

Mean Annual Age-Adjusted Mortality Rates per 100,000 Population and Ratios of Age-Adjusted Mortality Rates (SRR), 1982–1991, among Females in Chlorinating Municipalities (CHMs) to those in Nonchlorinating Municipalities (NCHMs) by Cancer Site

Cancer site (ICD 9)	14 CHMs	14 NCHMs	SRR (95% CI)[a]
All sites (140–208)	74.93	70.75	1.05 (0.95–1.18)
Esophagus (150)	0.52	0.81	0.64 (0.20–2.09)
Stomach (151)	7.16	5.85	1.22 (0.95–1.58)
Colon (153)	4.22	5.13	0.82 (0.59–1.14)
Rectum (154)	2.22	1.56	1.42 (1.13–1.98)[b]
Liver (155)	10.55	8.69	1.21 (0.90–1.64)
Pancreas (157)	1.87	1.53	1.22 (0.73–2.05)
Lung (162)	12.04	6.16	1.95 (1.45–2.59)[b]
Breast (174)	4.54	3.61	1.26 (0.89–1.77)
Cervix uteri, Uterus(179–180)	13.28	9.52	1.39 (0.88–1.86)
Ovary (183)	0.94	0.92	1.02 (0.47–2.23)
Bladder (188)	2.90	0.74	3.92 (1.08–4.28)[b]
Kidney (189)	1.54	0.70	2.20 (1.84–5.78)[b]
Brain (191)	1.25	1.57	0.80 (0.49–1.31)

[a]95% confidence interval.
[b]$P < 0.05$.

(Miettinen, 1985; Rothman, 1986). This method was applied to our study of cancer mortality and residence near petrochemical industries (Yang *et al.*, 1997b). The percentage of the population served by chlorinated water in the CHMs and NCHMs were 96.1 and 1.5%, respectively. Also, the municipalities selected for this study were rural municipalities and it is likely to preclude much of the resident's budget being allocated to bottled water, thus reducing the likelihood of water coming from a source other than the home. In line with this assumption, we expect that persons living in the CHMs do in fact drink water from the public supply and residents living in NCHMs do in fact drink water from the private wells (nonchlorinated water). Thus, the importance of one problem associated with ecologic analyses is reduced.

Migration is especially important in cancer studies, since the latency period is probably very long. The migration that does occur will result in a reduction of the strength of the geographical association between the disease and the studied factor (Polissar, 1980; Bentham, 1988). Taiwan's population is rather stationary compared with those of most other Western countries. It was reported that more than 90% of rural residents lived in the same municipality in which they were born for their entire life (Wu *et al.*, 1989). Thus, the migration problem is probably minor.

Since the measure of effect in this study is mortality rather than incidence, migration during the interval between cancer diagnosis and death must also be considered. During this period, the cancer diagnosis may influence a decision to migrate and possibly introduce bias. If there is a different trend toward migration between the CHMs and NCHMs due to proximity to medical care, for example, a spurious association between chlorinated water and cancer death would result. Since each NCHM was matched with one CHM with the same urbanization level, this possibility should be minimized.

Potential exposure to industrial pollution for the population not necessarily working in the cancer risk industrial plants but living nearby may be another confounding factor. In this study, we used the percentage of a municipality's total population employed in the chemical and petrochemical industries as an indicator of a resident's exposure to air emissions from industrial plants (Yang *et al.*, 1997b). The workers employed in chemical and petrochemical industrial plants constituted only 0.36% of the CHMs' population, while for the NCHMs this value was 0.39% (MOE/ROC, 1989). This result suggests that industrial pollution was unlikely to have an effect on cancer mortality.

The bladder and the rectum both serve a similar physiological function, storing concentrated excretory products. One might speculate that the epithelial tissue at both sites is exposed to high levels of chlorination by-products and is therefore at increased risk for the development of neoplasia. Our study is in accordance with many past studies (Page *et al.*, 1976; Cantor *et al.*, 1978, 1987; Kuzma *et al.*, 1977; Moriris *et al.*, 1992; Flaten, 1992; McGeehin *et al.*, 1993). The lung is a biologically plausible target organ, since it is a major excretory route of ingested chloroform (Fry *et al.*, 1972) and a site of considerable enzymatic metabolism of toxic compounds (Becker, 1975). Our finding is consistent with previous studies (Cantor *et al.*, 1978; Jolley *et al.*, 1978). Kidney and liver have been suggested as target organs on the basis of experimental animal study (Reuber, 1979), and cancer of these organs has been reported to be associated with the use of chlorinated water (Wilkins *et al.*, 1979). The same holds for cancer of the kidney in both males and females in Taiwan and cancer of the liver for males. It seems biologically implausible for chlorinated by-products like trihalomethanes to affect cancer risk for one sex only. Also, a sex-specific effect in this direction is not consistent with the hypothesis that women may be more routinely exposed to domestic water sources than men. Alcohol drinking has been found to be associated with liver cancer (Yu *et al.*, 1983; Oshima *et al.*, 1984; Tsukuma *et al.*, 1990; Chen *et al.*, 1991). There is unfortunately no information available on alcohol consumption patterns for individual municipalities. If alcohol drinking were more prominent in the CHMs, one would expect liver cancer excesses in both male and female residents. Our results, however, indicate that excess liver cancers were restricted to men. Since the CHMs and NCHMs were reasonably homogeneous for several socioeconomic indicators, there is no reason to expect sex differences in alcohol drinking between the CHMs and the NCHMs. Therefore, the possibility that this is a chance finding should be considered.

The associations between exposure to chlorinated water and mortality from rectum, lung, bladder, and kidney cancer for both sexes were significant in this study. These results were not readily explained by confounding due to degree of urbanization, sociodemographic characteristics, or industrial pollution. The most important potential confounders not adjusted for in this study are diet and smoking. If consumption of a diet high in fat and low in fiber or smoking rates were associated with consumption of chlorinated water, one could argue that the observed association is confounded by dietary factors or

smoking. There is unfortunately no information available on the smoking and dietary patterns for individual study municipalities. Since the CHMs and NCHMs were reasonably homogeneous for several socioeconomic indicators, this possibility would have tended to be diminished. In addition, if diet were responsible for the observed association with rectal cancer, we would expect to see the same association with colon cancer (Morris *et al.*, 1992). Also, there is no reason to expect differences in smoking patterns between CHMs and NCHMs in the present study. Therefore, the marked differences in these associations tend to refute the contention that smoking and diet are explanatory factors for observed associations.

In conclusion, the results give some support to indications from other epidemiological studies that chlorination of drinking water may be associated with cancer of the rectum, lung, bladder, and kidney. Due to inherent methodological limitations in ecological studies like the present one, the results could not provide sufficient evidence to establish a causal relationship. However, the public health significance of a cancer risk associated with consumption of chlorinated drinking water may be substantial. Our findings are in no way intended to suggest that the disinfection of drinking water with chlorine should be abandoned. However, it should not be forgotten that the primary public health concern for drinking water supplies is still waterborne infectious disease transmission, against which chlorine provides very effective protection. Therefore, these findings should provide an impetus to identify, develop, and implement disinfection strategies that are not associated with adverse health effects.

ACKNOWLEDGMENTS

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COST/BENEFIT COMPARISON

Pathogen control by oxidation v filtration

This report looks at the wider financial costs to the Masterton community of using chlorine for pathogen control in drinking water.

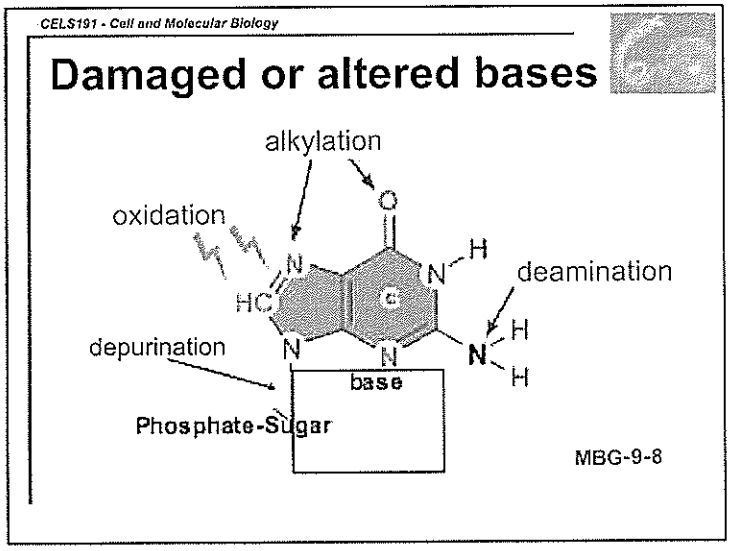
These costs should be considered along with the respective costs of three water treatment options:

1) Chlorination in the treatment plant and/or residual chlorination in the reticulation system.
2) Filtration to 3 micron absolute without chemical dosing but with increased water testing.
3) As 2 above with point-of-use filtration to 1 micron absolute.

The wider financial cost is that cost associated with the treatment of residents with oxidation induced carcinomas. That cost does not include the associated costs of welfare support, lost earning potential or family and social costs.

Oxidation affects DNA, leading to mutation and cancer.

Oxidation is one of several factors which can act on different parts of DNA and lead to mutation:



Source: Dr. Richard Macknight, HUBS Lecture 24, (2008)
Department of Biochemistry,
Otago School of Medicine

Oxidation means that a guanine component of DNA has an electron removed as a result of DNA being modified by a reactive oxygen species (ROS). The most common types of ROS are:

1) Superoxide Radical $O_2^{\bullet}$
2) Hydrogen Peroxide H_2O_2
3) Hydroxyl Radical $^{\bullet}OH$
4) Hypochlorous Acid HOCl
5) Alkoxyl Radicals/ Peroxyl Radicals RO / ROO
6) Organic hydroperoxides ROOH
7) Peracid RC(O)OOH

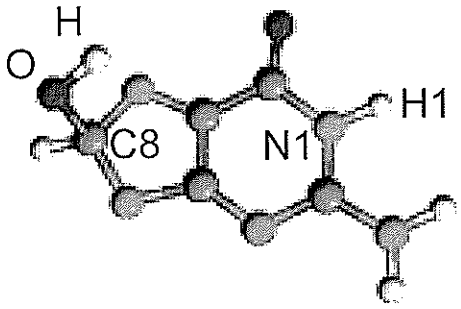
Source: Wenjie Ye, PhD thesis, (2008)
"Oxidative Damage to Guanine DNA caused by Reactive Oxygen Species,'
Gillings School of Global Public Health,
University of North Carolina.

Hypochlorous acid (No.4 above) is formed by the addition of chlorine to water. The simplest equation showing this dissociation is:

$$Cl_2 + H_20 \leftrightarrow HOCl + HCl \leftrightarrow 2H+ + Cl^- + OCl^-$$

Source: National Diploma in Drinking Water Assessment, (2002)
Unit Standard 18453,
Otago Polytechnic

After oxidation a chemical group is added into the electron "hole" formed by oxidation. This is frequently seen as the formation of 8-OxoG where an hydroxyl is added at C8 after oxidation by an external agent:



Source: Robert N. Barnett, Angelo Bongiorno, Charles L. Cleveland, Abraham Joy, Uzi Landman, and Gary B. Schuster, (2009)
"Oxidative Damage to DNA: Counterion-Assisted Addition of Water to Ionized DNA"
Schools of Physics and Chemistry & Biochemistry,
Georgia Institute of Technology, Atlanta, Georgia 30332

After mutation this molecule forms a stable base pair with adenine which evades the immune proof reading system and leads to cancer.

There is a correlation between chlorinated water supplies and cancers. These are primarily cancers of the:

Lung
Bladder
Rectum
Kidney

Other cancers affected are cancers of the:

Stomach
Liver
Pancreas
Breast
Uterus

Source: Chun-Yuh Yang, Hui-Fen Chiu, Ming-Fen Cheng and Shang-Shyue, (1997)
"Chlorination of Drinking Water and Cancer Mortality in Taiwan"
School of Public Health, Kaohsiung Medical College, Kaohsiung, Taiwan
Department of Pharmacology, Kaohsiung Medical College, Kaohsiung, Taiwan
School of Public Health, Kaohsiung Medical College, Kaohsiung, Taiwan

These cancers are carcinomas, that is, cancers of epithelial cells primarily of the mucous membrane linings and secreting glands.

> Source: William A. R. Thomson, MD
> "Black's Medical Dictionary."

Further, this effect is amplified by pH adjustment toward alkaline when lime is used.

> Source: N. W. Revis, P. McCauley, R. Bull, and G. Holdsworth, (1985)
> "Relationship of drinking water disinfectants to plasma cholesterol and thyroid hormone levels in experimental studies" (chlorinated water/hypercholesterolemia/hypothyroidism)
> Oak Ridge Research Institute, 113 Union Valley Road, Oak Ridge, TN 37830
> United States Environmental Protection Agency, 26 West St. Clair Street, Cincinnati, Ohio 45219

And further, this effect is evidenced by a shift in carcinoma incidence towards those persons in their 50s.

> Source: Barry Borman, (1982)
> "A Cancer Atlas of New Zealand"
> National Health Statistics Centre, Department of Health, Wellington

The average cost of treatment per carcinoma patient is around $20,372 per annum [1] of which $3,555 is Pharmac funded [2] drugs. This is a mean annual cost and does not reflect the actual cost of successful treatment nor associated social costs.

The current mean yearly number of patients diagnosed with cancer and living in the Masterton urban area is 138 [3] . The incidence of cancer prior to chlorination and lime adjustment was not more than 36 [4] persons annually for the same population, so the mean registrations attributable to waterborne ROS are 102 persons annually.

The mean cost to the Masterton urban community for medical treatment related to continued chemical dosing is $2,077,944 annually.

Stephen Butcher May 2013

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3. "Cancer_mastertondoms_1978-2008" (Excel worksheet) Ministry of Health, Wellington.
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