THE TREND OF INORGANIC CONSTITUENTS IN TREATED WATER FROM KUCHING WATER BOARD

Supervisor
Dr. LAU SENG

SAMSUDIN B ZAWAWI
MATRIX No. 02 – 03 - 0740

Faculty of Resources Science and Technology
UNIVERSITI MALAYSIA SARAWAK
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SAMSUDIN B ZAWAWI

Faculty of Resources Science and Technology
UNIVERSITI MALAYSIA SARAWAK
2003/2004
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CHAPTER 1

INTRODUCTION

1.0 Introduction

Water has an important role in human life. It affects very much the health of human when consumed low quality of drinking water. Therefore, treated water must be clean and safe for human consumption with respect and comply with the existing guidelines.

Why human needs to drink a lot of water in daily dietary intake? It is simply because human needs water in order to maintain and keep the body system operates normally, such as the blood the blood circulation system in the body. The main component in blood circulation system is blood plasma. Blood plasma is a liquid containing of various soluble substances. About 91 percent of the blood plasma consists of water. Functionally, water is a universal solvent that many soluble substances dissolve in, such as inorganic ions, nutrients, wastes and water protein soluble (Chen, 1979).

Drinking water must be clean and safe, without an unusual and persistent contamination with respect to the parameters of the National Drinking Water Standard, 2000.
This study aimed to assess the quality of the treated water with regards to its compliance to the existing guidelines. This study was also aimed of comparing the level of inorganic constituents between different water treatment plants.

1.2 Background of the Study Area

Sarawak is known for her vast diversity in natural resources e.g. water resources such as river. The availability of water resources in Sarawak is plentiful. Sarawak being the “land of rivers” has 23 major river basins of varying sizes. The catchments topography is generally characterized by an alluvial coastal plain with rises gently towards the interior form mountain ranges. The coastal plain, comprising alluvial deposits and peat swamps are generally low laying with elevation less than 10 meter. Majority of the rivers originate from the mountains along the Malaysian - Indonesian border and meander through vast flood plains as they approach the South China Sea (Ali & Murtedza, 1999).

For example, Sungai Sarawak (Sg. Sarawak) is one of the major rivers. The catchment area covered about 1962 sq.km, and run through a length of 112 km. The main towns located along Kuching and Bau (Ali & Murtedza, 1999)

The average annual rainfall in Sarawak ranges from 3500 to 4000 mm. Rainfall patterns are significantly influenced by monsoons. For the coastal areas in the Kuching – Samarahan Division only about 15 % of the rainfall is recorded in the dry period of the month June - August (Ali & Murtedza, 1999).

The water quality index (WQI) of Sg. Sarawak for 1992 – 1995, indicated that the water quality of the rivers in Sarawak appears to be improving. No river is now categorized as heavily polluted. WQI of Sg. Sarawak/Samarahan for the above period was classified as clean range from 84 - 79 but with respect to the index of suspended
solids (SS) it’s ranges from 74 - 76 which is slightly polluted. Nutrients indicator such as Ammonia - Nitrogen Index, was reported to be in the range from 72 - 93. The incidence of heavy metal pollution in 1995, Arsenic and zinc were detected in Sg. Sarawak but their content does not exceed the permissible limit of 0.046 mg/l (Ali & Murtedza, 1999).

The water authority, Kuching Water Board (KWB) had carried out a study on The Safe Yield’s of KWB’s Raw Water Source at Batu Kitang (Bt. Kitang) in 2000. Several studies related to the water resources have also been done in Sarawak (Ali & Murtedza, 1999). These included:

(i) Kuching Urban And Regional Master Plan Study, 1977
(ii) National Water Resources Study (1982)
(iii) Sarawak Water Resources Study Projects(1995)

Batu Kitang Water Treatment Plant

Batu Kitang Treatment plant is situated near the bank of Sungai Sarawak Kiri about 40 miles from the sea. Raw water is pumped from the river to the treatment plant where it undergoes the conventional treatment process of coagulation, flocculation, sedimentation, filtration, disinfection and pH adjustment. Coagulation is by the alum-lime process and disinfection by chloramines. Fluoridation has been practiced since 1966. The fully treated water is pumped to various reservoirs and service tanks in Kuching for distribution as well as directly into the distribution system.

Water demands increase very rapidly, since 1957 - 2003, and Bt. Kitang Treatment Plant has been extended and now it has seven (7) Module Treatment plants. These module plants can cater for the water demands of Kuching City and surrounding areas until 2010. Each module was designed for a specific capacity to treat raw water as
in the Table 1.1 below. Bt. Kitang Treatment Plant accounted for 98% of the total water production in 2002 for Kuching Division.

**Table 1.1: Specific Capacity for Each Module Plants as Bt. Kitang Treatment Plant**

<table>
<thead>
<tr>
<th>MODULE PLANT NO.</th>
<th>YEAR OF COMMISSIONED &amp; COMPLETE</th>
<th>SPECIFIC CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module No.1</td>
<td>1957</td>
<td>3 MgD – 4 MgD (1965)</td>
</tr>
<tr>
<td>Module No.2</td>
<td>1968 &amp; 1970</td>
<td>6 MgD</td>
</tr>
<tr>
<td>Module No.3</td>
<td>1976 &amp; 1978</td>
<td>9 MgD</td>
</tr>
<tr>
<td>Module No.4</td>
<td>1983 &amp; 1986</td>
<td>12 MgD</td>
</tr>
<tr>
<td>Module No.5</td>
<td>1991 &amp; 1994</td>
<td>100 Mega Liter per Day</td>
</tr>
<tr>
<td>Module No.6</td>
<td>1998 &amp; 2000</td>
<td>100 Mega Liter per Day</td>
</tr>
<tr>
<td>Module No.7</td>
<td>Yet to be construct</td>
<td>Estimated 100 Mega Liter per Day</td>
</tr>
</tbody>
</table>

(Source: Abstracted from Kuching Water Board. 2002. *Annual Report*)

**Matang Water Treatment Plant**

Matang Treatment plant was originally constructed by the Rajah to supply water to Kuching Town. It is situated in Matang hills some 19.2 km from the Kuching. The water was relatively clear and was distributed untreated. This source was continued to be in use even after the Bt. Kitang plant was commissioned in 1957. In 1960, chlorination was introduced and the possibility of building a treatment plant in the hills was investigated.

Construction of a 2 mega gallon per day (MgD) treatment plant near the Matang dam was commenced in 1964 and the plant was put into operation in March 1966. In 1976, extension works which included the construction of a 1.5 million gallon balancing reservoir commenced and completed in 1977. These extend can increase the capacity to 3.5 MgD. Raw water from the mountain streams was piped to the plant where full treatment similar to that at Bt. Kitang Plant was carried out before it gravitated into the distribution system.
However, production from Matang Treatment Plant was dependent on rainfall and during the dry months the output may fall to as low as 10% of its maximum capacity. To improve the reliability of the water supply, works was commenced in December 1973 on the construction of a 60 million gallon earth storage basin at Matang below the Sg. Sebubut catchment. The storage basin was completed in February 1976. Matang Treatment Plant accounted for 2% of the total water production for Kuching Division in 2002.

1.3 Study Objective

The aim of this study was to assess the quality of the treated water with respect to the level of inorganic constituents in Group II of National Drinking Water Guideline, 2000.

1.4 Hypothesis

This study assumed that the treated water that has been produced and supplied by respective water treatment plant was acceptable and complied with National Drinking water Guideline, 2000.

1.5 Justification of the Study

This study involved important activities to ensure the effectiveness of the treatment that has been done. The activities involved were carrying out of inspections, water sampling and analysis of water.

Variation in the quality of the water supplies can help in detecting the sources of whether they occurred at the source, during water treatment, or in the distribution system. This study intended to provide a range of information and to locate potential problems.
The data obtained may identify failures, anomalies, operator error and deviation from normal that may affect the production and distribution of safe drinking water.

1.6 Definition of Terms

The terminologies listed below were used on this study. There are:

(a) “Water quality” means the quality of the water being measured in terms of levels or concentration of the inorganic constituents and shall be expressed in terms of milligrams per litre (mg/l) or parts per million (ppm) with respect to parameters listed in Table 2.3, Guidelines for Drinking Water, 2000.

(b) “Inorganic constituents” mean chemical constituents such as Total Dissolve Solid (TDS), Chloride, Ammonia (as N), Nitrate (as N), Iron, Hardness, Aluminium (Al) and Manganese (Mn). These are inorganic parameters under Group II, set in the guideline.

(c) “Acceptable Value” means recommended standards set out for the maximum or minimum levels of constituents to ensure protection of the health and well being of consumer.

(d) “The level of inorganic constituents” means a concentration of inorganic constituents in drinking water that ensure aesthetically pleasing water and does not result in any significant risk to the health of the consumer.

(e) “Water supply system” means the works and auxiliaries for collection, conveyance, treatment, storage and distribution of the water from the source of supply to the consumer’s tap.
CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter discusses the available literatures related to this study.

2.1 Water Authority

Water supply in Malaysia is now regulated under the Water Ordinance (Chapter 13), 1994. Under the Water Supply Ordinance, Jabatan Kerja Raya Sarawak (JKR) is entrusted to supply portable water for the whole of Sarawak, with the exception of Kuching and Sibu where the water supply are provided by the respective water board (Ali and Murtedza, 1999).

The Kuching Water Board (KWB) and Sibu Water Board (SWB) were established as statutory bodies in 1959 under Water Supply Ordinance, each headed by an Engineer and Manager, with the Director of JKR as the Chairman of the Water Boards. The boards have served the respective municipalities and their immediate environs. The water supply authorities came under the direct control of JKR (Ali and Murtedza, 1999).
2.2 National Drinking Water Quality Surveillance Program

The exact meaning of surveillance in relation to the control of drinking water quality here means the keeping of a careful watch at all time to ensure a consistently acceptable level of drinking water (Guidelines for Drinking Water Quality, 1985). In Malaysia, the Ministry of Health with the co-operation of a new agency namely WHO-PEPAS, Public Works Department and Department of Chemistry, had formulated guidelines for the implementation of an effective, systematic and comprehensive drinking water monitoring program (KMAM) in 1983. Since the introduction and implementation of the KMAM program, many improvements have been made to increase its effectiveness and in facing new challenges and issues so that it is compatible and relevant (Ministry of Health, 2000).

KMAM program cover all public water supplies in the country, which includes;

(i) Urban public supply.
(ii) Rural public water supply.
(iii) Privately owned public water supply.

In the 7th Malaysian Plan, this program was extended to privately owned water treatment system for tourist resort in several states. It is hoped that with this expansion the drinking water quality in the resort area can be improved and promote the development of the tourist industry (Ministry of Health, 2000).

2.3 Water Supply System

Water supply system is defined as system that includes the work and auxiliaries for collection, conveyance, treatment, storage and distribution of water from the source of supply to the consumer tap (National Standard for Drinking Water Quality, 2000).
2.3.1 Source of Water

Sources of drinking water, generally are from surface water, ground water and rain water (Guidelines for Drinking Water Quality, 1985). Here, for this purpose the emphasis was on the surface water.

2.3.1.1 Surface Water

The open accessibility of surface waters and the ease with which they may become polluted has made it necessary for the water from the source should to be disinfected before distribution to consumers. The site of the water supply intake is of crucial importance where industrial waste discharges, drainage run-off from agriculture, etc must be avoided. Surface water intake pipes should be well secured and sited well away from river bank or lakeside. The mouth of the intake tube should not be less than 30 cm below the water surface, to prevent the entry of any floating matter. Intake point should be far enough from the bottom to avoid taking any mud. Even under the worst conditions the intake pump should be sufficiently powerful to resist the force of the current in the river at all times. If electric pump motors are used, they should be fully protected from moisture.

2.3.2 Water Treatment

As surface water, in general, is subjected to contamination, they are often treated and disinfected before distribution to the consumer. Two systems are commonly used.

(i) Slow sand filtration.

(ii) Coagulation followed by rapid sand filtration.

The essential features of both systems are described below:
2.3.2.1 Slow Sand Filtration

Slow sand filtration is a convenient low-cost method of treating surface water that is not highly polluted. During the treatment process colloidal particles are retained and the organic substances are biodegraded. An operational limitation of slow sand filters is the turbidity of the raw water should not exceed 15 NTU (Nephelometric Turbidity Units). With water of higher turbidity, plain sedimentation should be applied prior to slow sand filtration (Figure 2.1).

Figure 2.1: Schematic Representation of Slow Sand Filtration Plant

2.3.2.2 Coagulation and Rapid Sand Filtration

Treatment plants of coagulation and rapid sand filtration type are normally the most used system for public water supply. They are capable of treating highly turbid surface water. The turbidity is controlled by the use of added coagulants, flocculation, sedimentation and filtration through a sandbed. A schematic
representation of a typical plant is given in Figure 2.2 below:

![Diagram of Coagulation And Rapid Sand Filtration Plant](image)

Figure 2.2: Schematic Representation of Coagulation And Rapid Sand Filtration Plant

The coagulant added by means of a feeder and mixer (disperser) which must be checked for correct and efficient performance. In the flocculator, large flocs are produced, and later settle in the sedimentation tank. If this sedimentation process is incomplete, problem of overloading will occur in the subsequent filtration. Turbidity of not more than 10 NTU after sedimentation ensures proper filtration. However, a quick and efficient check consists of measuring the turbidity of the water downstream of the filter and it is essential that this finished water should comply with the guideline value of 5 NTU.
The complexity of the treatment steps required a process control laboratory that can carry out some basic tests. Equipment and facilities should be available for standard jar test and certain chemical and physical determinations e.g. pH and turbidity.

2.3.3 Disinfection

The importance of the disinfection of water supplies in controlling microbial contamination cannot be overemphasized. Good quality water at source, can be polluted during collection, processing, storage, or distribution its stages. A policy of proper disinfection of water supplies, normally using chlorine, will minimize the risk of waterborne diseases.

Chlorine releasing products and chlorine itself are the most widely used reagents for the disinfection of water supplies. In places where the water source is not considered safe and protected an effort must be made to introduce disinfection as soon as possible to minimize health risks. Therefore, a sufficient residual chlorine concentration should be established before the water leaves the water treatment plant. For the example, in surface water systems where slow or rapid sand filter is used chlorination is generally performed after filtration. This also refers as post-chlorination.

In some cases, chlorine is added as the water enters water-storage reservoir. Whatever method is used, the chlorine or the chlorine-releasing substance must be in contact with water for at least 30 minutes.

2.3.4 Storage Reservoir

Storage reservoir (tank) normally used for storing water to cope with period of maximum demand on the water-supply system. Such reservoir can however, be absolute
breeding places for microorganisms if there is no proper protection against external contamination. The adequate protection of reservoir and to make sure the access by humans or animal, etc. to the inside is made impossible.

   The opening of any overflow, clean-out or vent pipe should face downwards to prevent the entry of rain, and should be protected by a screen to prevent the entry of birds, insect, rodent, etc. The cover of the reservoir should fit firmly in place and should be at an inclined angle to prevent entry of rainwater. There should be an inspection manhole, likewise protected against the entry of humans or animals.

2.3.5 Distribution Network

   The distribution network is define here as the piping system through which the water is conveyed from the water treatment plant to the users. There are unfortunately many ways in which such networks may be polluted. Pollutants, including sewage, can be in filtrate into if it there are defects in the system. As long as the positive pressure of water exists in the distribution main, pollution should not arise. However, a drop in the water pressure will increase the risk of infiltration of potentially polluted water. Some other potential risks that could pollute water are a cross-connection failure to disinfect distribution system or parts of such system after repairs have been carried out and back-siphonage is not uncommon.

2.4 Water Quality

2.4.1 Application of Guideline Values

   Guideline values for drinking water quality are given in volume 1 of the Guideline for drinking water quality, which also explains how these values are to be interpreted (Guidelines for Drinking Water Quality, 1983). A guidelines value represents
the level (a concentration or a number) of constituents that ensures aesthetically pleasing water and does not result in any significant risk to the health of the consumer. The quality of water defined by the guideline values will be classified as is such that suitable for human consumption and for all usual domestic purposes, including personal hygiene, if the standards are met. When the guideline is exceeded the cause should be investigate with a view to taking remedial measures (Guidelines for Drinking Water Quality, 1985).

Thus, in developing a national drinking water standards based on the guidelines, it will be necessary to take into account of a variety of geographical, socio economic, dietary and industrial condition. In the case of Malaysia, drinking water quality required to follow the National Drinking Water Quality Standard, 2000. The value given considered as long term goals to be complied with at all times and in all supply system (Guidelines for Drinking Water Quality, 1985).

Table 2.1: Drinking Water Quality Standard

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Max Acceptable Value (mg/L)</th>
<th>Source of Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dissolved Solid (TDS)</td>
<td>1000</td>
<td>WHO2</td>
</tr>
<tr>
<td>Chloride</td>
<td>250</td>
<td>WHO2</td>
</tr>
<tr>
<td>Ammonia (as NH₃)</td>
<td>1.5</td>
<td>WHO2</td>
</tr>
<tr>
<td>Nitrate (as N)</td>
<td>10</td>
<td>WHO3</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3</td>
<td>WHO2</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.5 – 0.7</td>
<td>MAL</td>
</tr>
<tr>
<td>Hardness</td>
<td>500</td>
<td>WHO3</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>0.2</td>
<td>WHO2</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.1</td>
<td>WHO2</td>
</tr>
</tbody>
</table>

2.5 Description of Inorganic Constituents

The descriptions of inorganic constituents listed in National Standard of Drinking Water Quality, 2000 (see Table 2.1) are provided in the following sub-sections.

2.5.1. Nitrate and Nitrite

2.5.1.1 Sources

Both the nitrate and nitrite are considered together because their conversions are from the same source. Concentrations in water are expressed as mg/litre for nitrate-nitrogen (nitrate-N) and nitrite-nitrogen (nitrite-N) (Guidelines for Drinking Water Quality, 1984). Nitrates are widely present in substantial quantities in soil, most waters and in plants including vegetables (World Health Organization, 1978). Nitrites also occur fairly widely but generally at very much lower levels than nitrate (World Health Organization, 1978). Nitrates are products of oxidation of organic nitrogen by the bacteria present in soils and in water where sufficient oxygen is present. Nitrites are formed by incomplete bacterial oxidation of organic nitrogen (Guidelines of Canadian Drinking Water Quality, 1980).

One of the principle uses of nitrate is a fertilizer, most other nitrogen-containing fertilizer will, however be converted to nitrate in soil. Nitrates are also used in explosives as oxidizing agents in the chemical industry, and as food preservatives (Guidelines of Canadian Drinking Water Quality, 1980). The main use of nitrites is as food preservatives, generally as sodium or the potassium salt (World Health Organization, 1978). Some nitrates and nitrites are formed when the rain washes out the oxides of nitrogen produced by the action of lightning.
discharge or via man-made sources (Guidelines of Canadian Drinking Water Quality, 1980). Nitrates and some nitrites are also produced in the soil as the result of bacterial decomposition of organic material, both vegetable and animal (Guidelines for Drinking Water Quality, 1984).

2.5.1.2 Occurrence in Natural Water

Organic fertilizer for decay plant. Fertilizer use decayed vegetable and animal matter, domestic effluents sewage sludge disposal to land, industrial discharge, leachate from refuse dumps, and atmospheric washout are contributing nitrates and nitrites to the water sources (World Health Organization, 1978; International Standing Committee on Water Quality and Treatment, 1974; National Research Council, 1977). Changes in land use may also give rise to increased nitrate levels. These sources can contaminate the streams, river, lakes and groundwater, especially wells (International Standing Committee on Water Quality and Treatment, 1974). Contamination may result from a direct or indirect discharge, or it may arise by percolation over a period of time, sometimes after many years. The levels nitrates in polluted water almost invariably very much higher than levels of nitrites (National Research Council, 1977).

Levels of nitrate in water typically below 5 mg/L of nitrate - N, but levels exceeding 10 mg/L occur in some small water sources. In chlorinated supplies, levels of nitrate are often less than the limit of detection, i.e., < 0.005 mg/L of nitrate - N (Guidelines of Canadian Drinking Water Quality, 1978; International Standing Committee on Water Quality and Treatment, 1974; National Research Council, 1977) but relatively high levels may occur in unchlorinated water. Very