I - INTRODUCTION

General Introduction

Adequate clean water supplies for domestic purposes has long been a critical factor in public health protection and ecomomic development in most parts of the world, particularly in the developing countries. In the northeastern part of Thailand, the problem is particularly acute during the prolonged dry months of the summer season, during which time temporary surface water sources such as ponds become dry. With inadequate water for domestic needs, health condition may become serious, domestic animals weaken and in some instance families and livestock have been forced temporarily to other localities where water is available. Ground water in this case become of great importance as a valuable resource to furnish a supply of water.

Ground water sources explorations have been extensively done in this part of the country be the Ground Water Resources Development of Northeastern Thailand Project. Unfortunately, many of these sources although producing a good yield of water contain excessive amounts of minerals. One of the most common constituents in the ground water in this part of the country which renders them unsatisfactory for use is iron, which is found to be very high in most sources as indicated in Appendix. Some of these sources of good yield may have to be abandoned because of the high iron content, unless a good treatment plant can be provided. It follows therefore that, as the water consumption of the population in this region increases, more and more ground water sources of high iron content will have to be used and an economical and efficient method of iron removal is ungently needed.

The USPHS Drinking Water Standard and W.H.O. International Drinking Water Standards recommended the limitation of iron content in public water supplies to be 0.30 mg/l. Since iron is essential for proper nutrition, this limit is of no sanitary significance, It is however undesirable from an aesthetic standpoint, as it is well known that it tends to stain clothes, laundry and plumbing fixtures and tends to cause deposits on food during cooking. Iron also renders the water unattractive in appearance, forms deposits in main, and favors the growth of iron bacteria, known as Crenothrix, which are discharged periodically in objectionable masses or import taste to the water. In addition, Crenothrix can cut down available flow rate in a pipe line. The recommended limit of 0.3 mg/l for iron is apparently based on aesthetic and taste consideration rather than on physiological effects. In rural areas of Thailand, the appearance, odour, and taste of a ground water with high iron content has often resulted in villagers preferring to use a contaminated surface water.

Origin and Appearance of Iron in Groundwater

Iron is one of the chemical constituent of shale, sandstone and alluvial deposits. Under reducing conditions, insoluble iron is converted from its insoluble higher valence state to its soluble divalent state. In general, iron is soluble in acid water and insoluble in alkaline water. It is dissolved from the soil or from vegetation by carbonic acid or by organic acids resulting from the decomposition of vegetation, other organic materials or from volcanic deposition.

Usually iron appears to exist as ferrous salts, ferrous bicarbonate and ferrous carbonate. In addition to these salts found in groundwater, ferrous sulphate is also present when the source is in a swampy area. Iron may also be present in water as organic complexes. These complexes are formed as a result of the combination of iron with negatively charged organic matter called ligands. The resulting complexes have the iron in the center, surrounded by organic units. Generally they are more difficult to oxidize than inorganic compounds because of the organic "protective shell". These complexes and chelates are commonly referred to as organically bound iron.

Generally, iron bearing waters when they emerge from the ground will appear clear and colorless. But, after a time, upon aeration or upon removal of the pressure under which it exists in the ground, these water will undergo a change in physical as well as chemical characteristics. Iron in soluble ferrous form will be oxidized to the insoluble ferric state. This often results in the formation of brown precipitates and a condition commonly referred to as "red or rusty water" which is unattractive in appearance. It can be seen from Fig I. and Table I. that although iron is present in the ground waters in many part of Thailand, the most serious are observed in the Northeast of the 15 Northeastern provinces, only three have wells with iron concentration as low as in the range of 2.1 mg/l. The other provinces were found to be over 4.0 mg/l to as high as 36 mg/l iron concentration. According to the records of chemical analyses of ground water reported by the DEPARTMENT OF MINERAL RESOURCES (1966), it was found that most of the ground waters in Northeastern Thailand are devoid of dissolved oxygen. Carbon dioxide which is often associated with iron - bearing waters, was found to range zero in some wells to as high as 366 mg/l in a well in Surin Province (Well No. A. 11, S.10). High iron content is also commonly associated with a high concentration of hardness, and some wells in Northeastern Thailand exhibited total hardness, more than 1,000 mg/l expressed as $CaCO_3$. Manganese was reported to be relatively low compared with iron and other constituents. The major constituents which were found in high concentrations in the ground waters in this area were Ca^{++}, Mg^{++}, K^{+}, Fe^{++}, HCO_3^{-}, $So_4^{=}$, Cl^{-} and $PO_4^{\equiv}$.

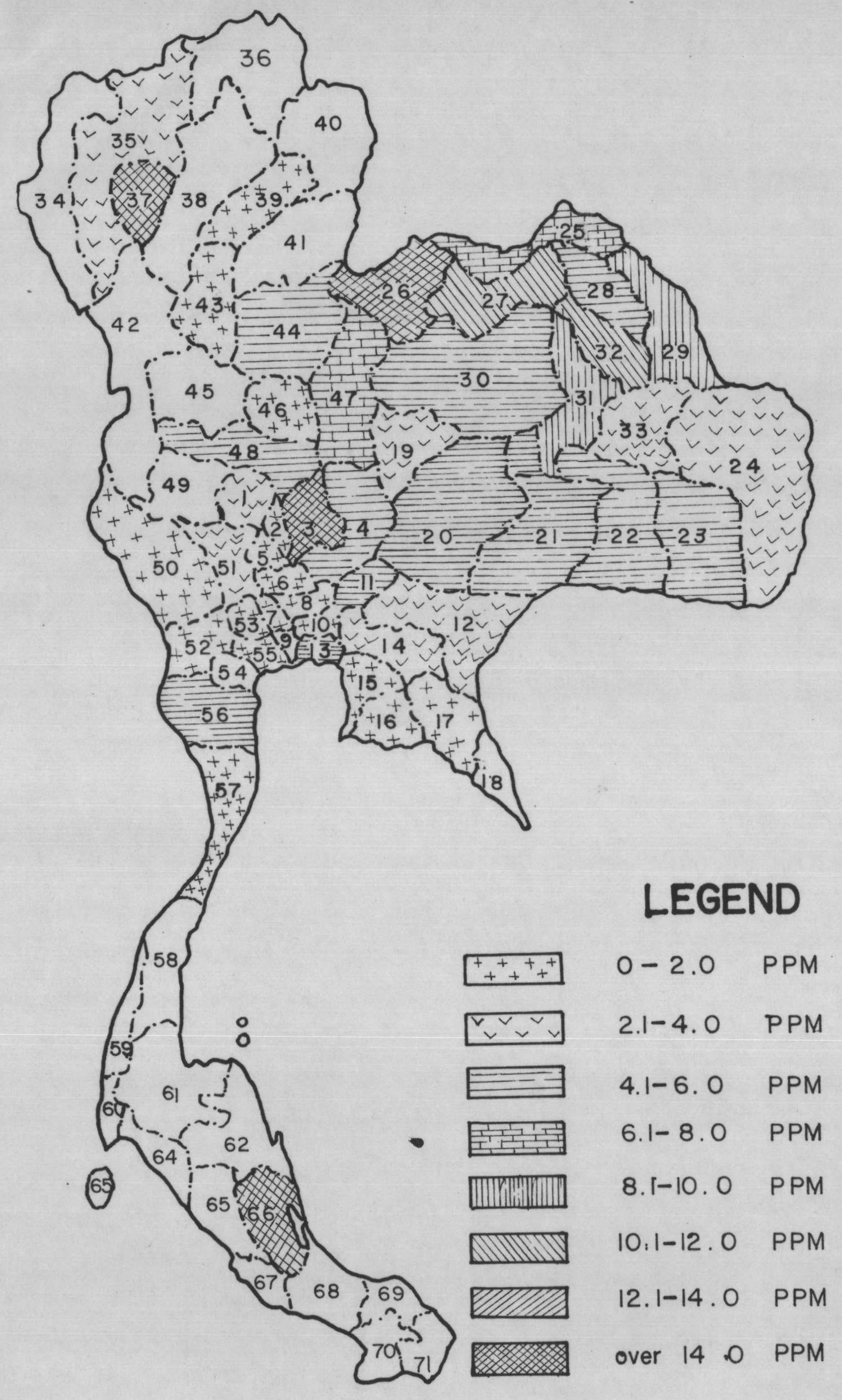

Fig. I Map Showing Iron Concentration in Ground Water in Thailand.

Legend of Fig. I

1 Chainat
2 Sing-Buri
3 Lopburi
4 Saraburi
5 Ang-Thong
6 Ayuthya or Ayudhya
7 Nonthaburi
8 Pathum-Thani
9 Thonburi
10 Bangkok
11 Nakhornayok
12 Prachinburi
13 Samutprakan
14 Cha-Choengsao
15 Cholburi
16 Rayong
17 Chanthaburi
18 Trat
19 Chayaphum
20 Nakhornratsima
21 Buri-Ram
22 Surin
23 Srisaket
24 Ubonrat-Thani
25 Nong-Khai
26 Loei
27 Udron-Thani
28 Sakonnakhon
29 Nakhorn Phanom
30 Khon-Kaen
31 Maha Sarakham
32 Kalasin
33 Roi-Et
34 Mae-Hongson
35 Chiengmai
36 Chieng Rai
37 Lamphun
38 Lampang
39 Prae
40 Nan
41 Uttaradit
42 Tak
43 Sukho-Thai
44 Phitsnuloke
45 Kamphaengphet
46 Pichit
47 Phetchbun
48 Nakhorn Sawan
49 Uthai-Thani
50 Kachana-Buri
51 Suphanburi
52 Ratburi
53 Nakhonpatom
54 Samutsongkhram
55 Samutsakhorn
56 Phetburi
57 Prachaup-Kiri-Khan
58 Chumphorn
59 Ranong
60 Phang-Nga
61 Surat-Thani
62 Nakhornsri-Thamrat
63 Phuket
64 Krabi
65 Trang
66 Phatalung
67 Satun
68 Song-Khla
69 Pattani
70 Yala
71 Nara-Thiwat

Table I - The Iron Concentration in various ground water wells in Thailand.

Province	Well depth ft.		Total Fe, mg/l	
	Range	Average	Range	Average
North-east				
LOei	100-191	133	1.5 - 36.0	14.3
Udorn	100-515	224	0.0 - 23.0	10.4
Nongkhai	100-480	139	0.0 - 21.0	6.5
Chaiyapoom	100-1004	270	2.0 - 10.0	3.9
Khonkhaen	90-331	198	0.0 - 17.0	5.4
Nakornpanom	65-845	158	0.0 - 28.0	9.8
Sakornnakorn	70-1045	233	0.0 - 23.0	5.0
Kalasin	90-526	151	1.2 - 41.0	11.3
Roi-ed	90-300	161	1.0 - 7.0	3.9
Mahasarakam	80-500	219	0.02- 20.0	8.1
Surin	67-1050	329	0.6 - 15.0	6.7
Buriram	94-1015	275	2.5 - 16.0	6.0
Srisaket	100-356	179	0.5 - 14.0	6.4
Ubol	60-1010	246	0.0 - 14.0	4.0
Nakornrasima	55-1500	337	0.0 - 24.0	4.1
South				
Prachaupkirikhan	140-750	420	0.0 - 1.0	0.4
Songkhla	50-240	194	1.9 - 90.0	22.3
Chumporn	-	-	-	-
Surat-thani	-	-	-	-
Nakornsrithamraj	-	-	-	-

Table I (Cont'd)

Province	Well depth ft.		Total Fe, mg/l	
	Range	Average	Range	Average
Pattalung	-	-	-	-
Trang	-	-	-	-
Puket	-	-	-	-
<u>North</u>				
Chiengmai	152-330	216	1.0- 4.8	2.8
Lamphun	135-345	133	212-120.0	47.0
Prae	246-400	335	0.1- 2.3	0.8
Uttaradit	50-250	138	2.0- 25.0	8.0
Petchaboon	152-350	186	0.6- 21.0	8.0
Sukhothai	60-260	146	0.6- 3.3	1.9
Pitsanuloke	185-270	219	1.8- 5.8	4.7
Kamphaeng Phet	-	-	-	-
Tak	-	-	-	-
Chiengrai	-	-	-	-
Lampang	-	-	-	-
Nan	-	-	-	-
Mae-Hongson	-	-	-	-
<u>Central</u>				
Nakonsawan	131-287	218	0.2- 6.5	5.0
Pichit	150-310	225	0.8- 2.3	1.5
Chainat	35-231	120	0.4- 7.0	2.7
Lopburi	66-320	189	0.0- 80.0	30.0
Saraburi	100-258	159	0.0- 42.0	5.9

Table I (Cont'd)

Province	Well depth ft.		Total Fe, mg/l	
	Range	Average	Range	Average
Singhburi	170-354	225	0.2- 1.0	0.3
Supanburi	144-187	165	1.4- 5.0	3.8
Ayudhaya	167-365	245	0.1- 1.0	0.4
Pratumthani	248-365	293	0.2- 0.8	0.5
Nontaburi	565-720	596	1.0- 2.1	1.5
Bangkok	400-713	590	0.1- 1.3	0.8
Thonburi	481-670	559	0.1- 4.8	1.0
Samutprakan	403-903	689	0.5-11.0	5.2
Samutsakorn	355-542	472	0.1- 1.6	1.0
Angthong	112-174	143	0.1- 0.2	0.2
Rachaburi	130-660	305	0.2- 1.8	1.0
Petchaburi	200-850	562	0.3-17.0	5.0
Nakornpatom	302-645	401	0.1- 0.7	0.3
Kanchanaburi	113-215	165	0.2- 2.8	1.5
Utai-thani	-	-	-	-
Samutsongkam	-	-	-	-
<u>East</u>				
Cha-Choengsao	295-580	483	1.8- 3.8	2.8
Rayong	45- 84	66	0.8- 3.3	2.0
Cholburi	141-160	145	0.3- 2.4	1.3
Prachinburi	80-215	135	0.0- 7.0	2.2
Chantaburi	74- 75	74	0.8- 1.2	1.0
Nakonnayok	80-320	152	1.0- 9.0	5.5
Trat	-	-	-	-

Note: See APPENDIX B for additional data on individual wells.

Principles of Deferrization

Iron exists in water as iron hydrate which is soluble and unoxidized. It is usually accompanied by mineral salts, carbon - dioxide or other gases, and often manganese. It can be removed from most groundwaters low in manganese and vegetable organic matter by simple aeration followed by filtration through sand or even fine gravel. Various methods of iron removal have been reviewed by HAUER (1950), CONNELLY (1950),ENGELBRECHT, O'CONNOR, and GHOSH (1965), but the most widely used one seems to be the conventional method which consists of three basic unit processes, namely oxidation, sedimentation, and filtration. The principles on which the conventional method is based required that the iron which exists in ground water, mainly in the form of soluble ferrous iron, is converted by oxidation to the insoluble form of ferric iron which is then removed by sedimentation and sand filtration. Hence the oxidation process may be considered as one of the most important parts of the treatment. WESTON (1914) stated that if the water was properly oxidized beforehand the type of filter, whether slow or rapid, seems to have less importance in removing the iron.

Purpose of Study

It was the objective of this research to investigate the capability of using patassium permanganate ($KMnO_4$) for iron removal in water supply and to study the oxidation reaction of soluble ferrous iron to insoluble ferric form.

The Jar test was performed for determination of optimum potassium permanganate dosage required.

A laboratory - scale filtration unit accommodated with an overhead oxidation - flocculation unit were developed for determination of the following conditions:

a) Actual Potassium permanganate dosage required for a given iron concentration of composite ground water.

b) Treatment Efficiency

c) Coliform bacteria removal efficiency

d) Comparison of treatment efficiency when using both local anthracite and burnt rice husk filter media.

Such a simple combined oxidation - flocculation - filtration unit was expected to operate conveniently by unskilled workman in rural area.

Scope of Study

The study was divided into two parts:

1. Coagulation by means of jar test

The composite sample of ground waters around Bangkok area were analysed for the determination of total alkalinity, total hardness, pH and total iron. In performing the experiment in this part, optimum permanganate dosage, behavior of floc or precipitate formation, color, turbidity, total alkalinity, total hardness, pH, dissolved and total iron after coagulation and clarification were determined by means of jar test.

2. Filtration

An open - gravity filter was designed for experimental runs and local filter media - granular anthracite and burnt rice husk were selected as filter media for removal of insoluble iron form. The definite depth of filter media was fixed with anthracite or burnt rice husk and using gravel as a supported medium. The quantity of flow entering the top of filtration unit was varied whilst potassium permanganate dosage was also varied according to the concentration of soluble form of influent. The total iron concentration of influent and effluent were analysed in order to determine the efficiency of treatment. Total alkalinity, total hardness, pH and MPN of coliform bacteria were also determined.

During filtration head loss was measured in order to determine range of filter run for specific filter media.