SALT FLUORIDATION PLANT TRIAL

AT

PANASAL SALT WORKS

AQUADULCE
PANAMA

April 20th to 24th 1998.

Prepared by: ***Trevor A. W. Milner***
Fluoridation Engineering Consultant
Pan American Health Organization

CONTENTS

ACKNOWLEDGEMENTS

The author wishes to acknowledge the kind assistance of the following persons without which, this report would not have been possible.
Dra Araceli Rodulfo V., Minisrerio de Salud, Panama
Lic. Victoria E Valdes, OPS, Panama
Snr Carlos Ivan Fernandez and the rest of the Staff at PANASAL, especially the laboratory personnel.

1 CALCULATION OF RATE OF ADDITION OF POTASSIUM FLUORIDE

Basis per ton salt
Basis per hour

Target Fluoride concentration in salt is 200ppm as F ion

Weight of F ion required =

$$1 \text{ ton salt} \times \frac{200 \text{ gm F}}{1{,}000{,}000 \text{ gm salt}} \times \frac{1000 \text{ kg salt}}{\text{ton salt}} \times \frac{1000 \text{ gm salt}}{\text{kg salt}} = 200 \text{ gm}$$

Weight of KF required (X ratio of molecular weights)

$$\frac{200 \text{ gm F}}{19 \text{ gm F/gm-mol}} \times 58 \text{ gm KF/gm-mol} = 610 \text{ gm KF}$$

ie for every ton of salt 610.5 gm KF is required to dose salt at a level of 200 ppm F

However give an additional 5% for losses, purity and inaccuracies. ie 1.05 X 610.5 gm KF = 640 gm KF

Hence for target of 200 ppm F, 640 gm KF required per ton of salt

This figure is useful for planning purposes

Time Period	Approximate Production ton	KF required kg
hour	1.5	1
day	30	19.2
month	700	450
year	8500	5440

2 CALCULATION OF DOSING SOLUTION MAKE-UP AND SOLUTION RATE OF ADDITION

In section 1 the rate of KF required per ton of salt production was calculated. Now KF is not added as a dry powder. It is added continuously in solution form. It is therefore necessary to calculate the most convenient solution strength and its rate of addition.

The following factors are balanced in order to come up with the most convenient solution.

Factors influencing higher dosing solution concentration:

I. Desire to minimize the inconvenience of making up solution too frequently

II. Relatively low maximum dosing pump capacity

III. Not adding too much water to process

Factors influencing lower dosing solution concentration

I. Better dispersion in salt

II. Relatively high minimum dosing pump capacity

III. Relatively low solubility of additive.

In the case of PANASAL because addition of Fluoride solution occurs prior to drying, the addition of water is not a big consideration. Another factor to take into account is that the solubility of KF is relatively high at 38%. The main considerations therefore are that of convenience, requiring highly concentrated solution. On the other hand the fact of a high minimum pump rate, requires a low concentration solution. The compromise was struck at about a 10% solution, as with a 20% solution the addition rate would prove too low for the pump minimum capacity when producing at an average production rate.

Average plant production rate = 2.75 ton/hr

$$\text{KF required} = 2.75 \frac{\text{ton salt}}{\text{hr}} \times 640 \frac{\text{gm KF}}{\text{ton salt}} = 1760 \frac{\text{gm KF}}{\text{hr}}$$

Try 25% solution make up, ie .25 gm KF / gm soln

$$\text{Then to add } 1760 \frac{\text{gm KF}}{\text{hr}} \text{ requires } \frac{1760 \text{ gm KF}}{.25 \text{ gm KF/gm soln}} = 7040 \text{ gm } 25\% \text{ soln / hr}$$

Specific gravity of 25% solution was measured = 1.25

Then volume of 25 % KF soln required to dose 2.75 ton salt per hr to a level of 200ppm F
= 7040 $\frac{\text{gm soln}}{\text{hr}}$ X $\frac{\text{1 ml}}{\text{1.25 gm soln}}$ = 5632 $\frac{\text{ml 25\% soln}}{\text{hr}}$ = 93.9 $\frac{\text{ml 25\% KF soln}}{\text{min}}$
Therefore dose rate of 25% KF soln is

5.6 L / hr or 93.9 ml / min
or

1.49 gal / hr or 15 gal /10 hr day.

But 93 ml / min is just at the lowest pump rate, hence if the production rate was reduced overdosing could taker place.

Try 10% KF solution make up.
1760 $\frac{\text{gm KF}}{\text{hr}}$ required to be added.

Then rate of 10% KF solution required, is
$\frac{\text{1760 gm KF / hr}}{\text{.10 gm KF / gm 10\% soln}}$

= 17,600 $\frac{\text{gm 10\% soln}}{\text{hr}}$

Specific gravity of 10% solution was measured = 1.076, therefore volumetric flow rate oof 10% KF solution is:

17,600 $\frac{\text{gm}}{\text{hr}}$ 10% KF soln X $\frac{\text{1 ml}}{\text{1.076 gm}}$ = 16,357 $\frac{\text{ml}}{\text{hr}}$ 10% KF soln

Therefore dose rate of 10% KF soln is

16.4 L / hr or 272 ml / min
or
4.32 gal / hr or 43 gal / 10 hr day

Now PANASAL has at hand 5 gal container s for use in mixing up additives

5 gal X 8.33 X 1.076 $\frac{\text{lb}}{\text{gal}}$ 10% soln = 44.8 lb 10% soln

therefore weight of KF is 44.8 lb X .10 = 4.48 lb

But for ease of measurement and convenience use 5 lbs of KF made up to 5 gal of solution.
ie 5 lb KF in 44.8 lb solution, therefore concentration is 11.2%

For 11.2% solution.
Weight rate of soln required is

$$1760 \frac{\text{gm KF}}{\text{Hr}} \times \frac{1 \text{ gm}}{.112 \text{ gm}} = 15714 \text{ gm } 11.2 \% \text{ solution}$$

Specific gravity of 11.2 % solution is 1.076,
Therefore volumetric flow rate is:

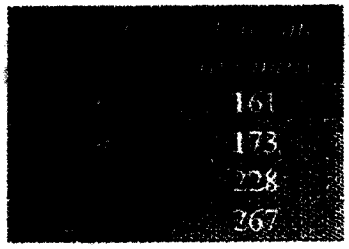
$$15714 \frac{\text{gm } 11.25 \text{ soln}}{\text{hr}} \times \frac{1 \text{ ml}}{1.076 \text{ gm}} = 14604 \frac{\text{ml}}{\text{hr}}$$

Therefore volumetric flow rate of 11.2% KF required to Fluoridate 2.75 ton / hr salt at a level of 200ppm as F is
14.6 L / hr or 243 ml / min
or
3.86gal / hr or 39 gal / 10 hr day.

3 DOSING PUMP SETTING

The PANASAL dosing pump is in fact a liquid egg, in which the pressure of compressed air provides the driving force to pump the Fluoride solution from the container to the spray point. The flow is regulated by the level of pressure that is applied, for a given flow-orifice size.

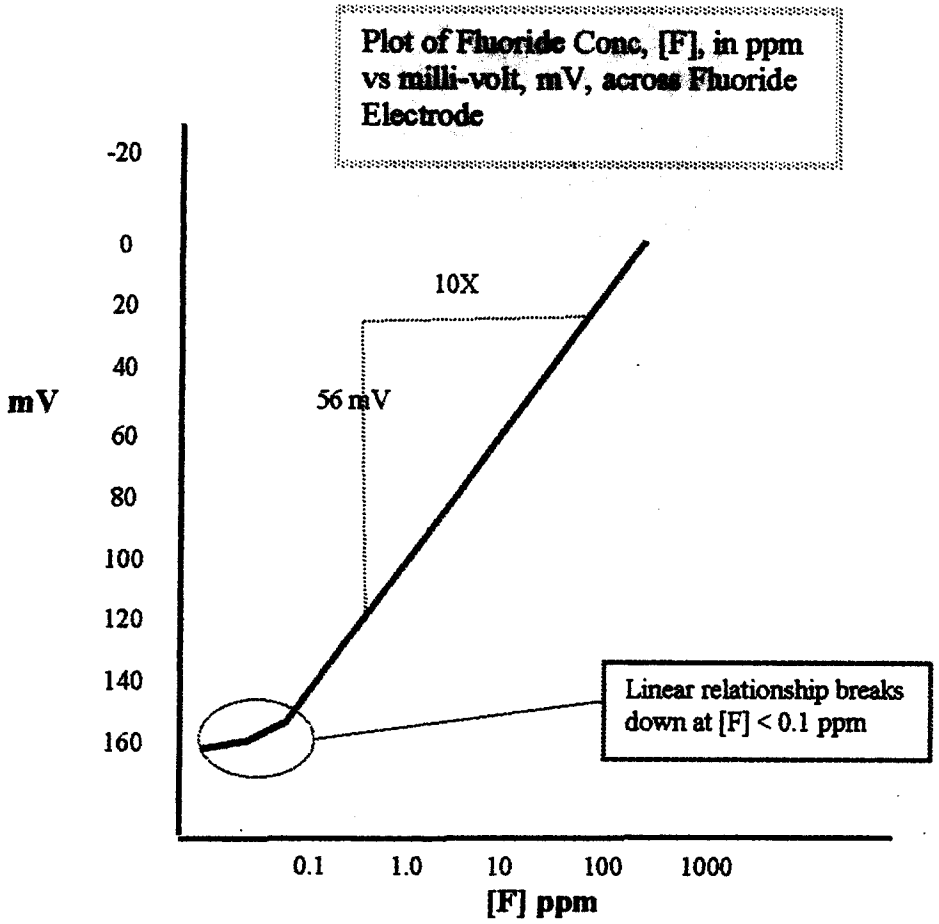
A field check for the present orifice size installed was done. The results are shown below:



4.PRINCIPLES OF MEASUREMENT

The analysis of Fluoride is done using the selective ion meter, which is essentially a millivolt meter with a selective ion electrode. The Orion brand series of pH/selective ion meters are favored for their ease of operation, durability, consistency, reliability and economy.

For Fluoride ions in solution and the Fluoride electrode the following graphs obtains.



Hence by plotting the potential (mV) for solutions of known concentrations, unknown F solutions may be obtained by measuring the mV in the solution and reading the graph..

In the case of the Orion 920A meter, the calculation for the graph is built in electronically. Hence once the machine is calibrated correctly, a direct reading in ppm F may be obtained when measuring a solution of unknown F content.

5. SAMPLE SIZE, COLLECTION AND PREPARATION

For sampling, convenience, tempered by the technical constraints determine the size, frequency and method of sampling and preparation of samples.

(a) Sample Size.
This is required to be as large as possible. For this process, different size salt particles will have different F ion concentrations. The smallest particle sizes will have the highest concentrations, whilst the largest particle sizes will have the lowest F ion concentration.

Hence to have a fully representative sample the sample size should be in the region of 50 gm. In the case of PANASAL it was found that because of their laboratory equipment availability and the time it took for dissolution, it was decided to use a 40gm sample size made up to 200ml.

Calculation of sample dilution.
Solution to be measured = 25 ml..
For the most accurate measurement, F concentration in solution should be about 50 ppm.
Therefore what weight of F in 25 ml will give a concentration of 50 ppm.

$$\text{Weight of F} = 25 \text{ ml} \times 1 \frac{\text{gm}}{\text{ml}} \times \frac{50}{1{,}000{,}000} = 0.00125 \text{ gm}$$

This weight of Fluoride must be provided by the weight of Fluoride from S gm of salt which has a level of Fluoride of 200 ppm.

$$\text{Therefore } S \times \frac{200}{1{,}000{,}000} = 0.00125$$

Therefore S = 6.25 gm.

Therefore weight of sample could be 6.25 gm made up to 25 ml of solution, or a multiple thereof will give the desired range in the solution for accurate measurement. As stated sample size needs to be as large as possible. Therefor 40 gm in 200 ml is an acceptable sample make -up.

(b) Conversion Factor.
The result obtained for the measurement of the [F] in the solution will have to be converted to [F] in the salt.
Hence: For 40 gm salt made-up to 200 ml then if the Fluoride concentration in soln is **Fsoln**, then Fluoride concentration in salt, **Fsalt** is given by

$$\textbf{Fsalt} = \frac{\textbf{Fsoln}}{1{,}000{,}000} \times 200 \times \text{s.g.} \times \frac{1{,}000{,}000}{40}$$

or

$$\textbf{Fsalt} = \textbf{Fsoln} \times 4 \times \text{s.g.}$$

(c) Frequency of Sampling

When just starting or after an upset condition, sampling and analysis should be done every 15 mins. The plant reaction time is relatively fast, less than 10 mins.

Once the target Fluoride level has been achieved, and plant operations are smooth, then sampling every 4 hours is asufficient.
In addition one sample per day from packaged salt in warehouse should be done.

Method of sampling
Sample from dryer exit
Ensure proper flushing of sample point, so that a representative sampler is taken.

6. PANASAL Pictorial

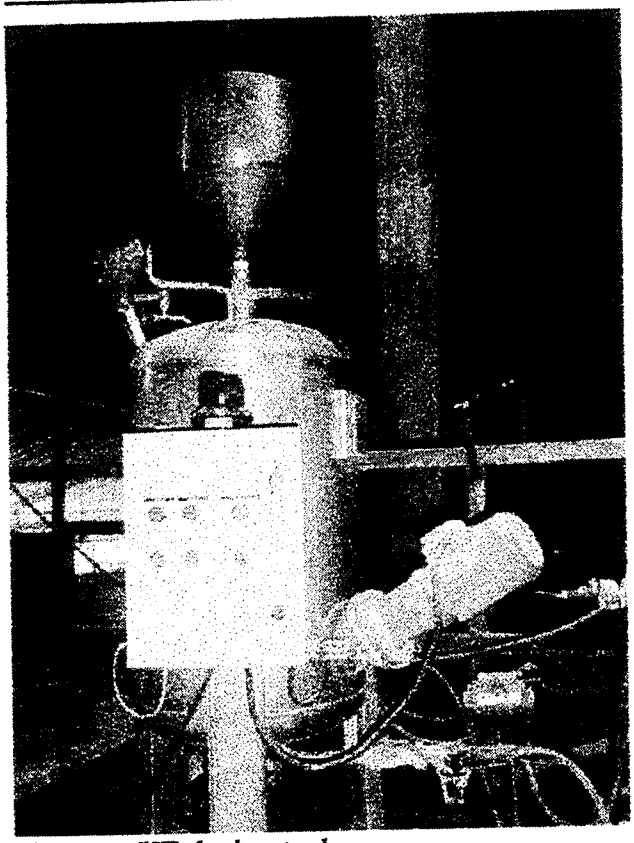


Figure 1: KF dosing tank

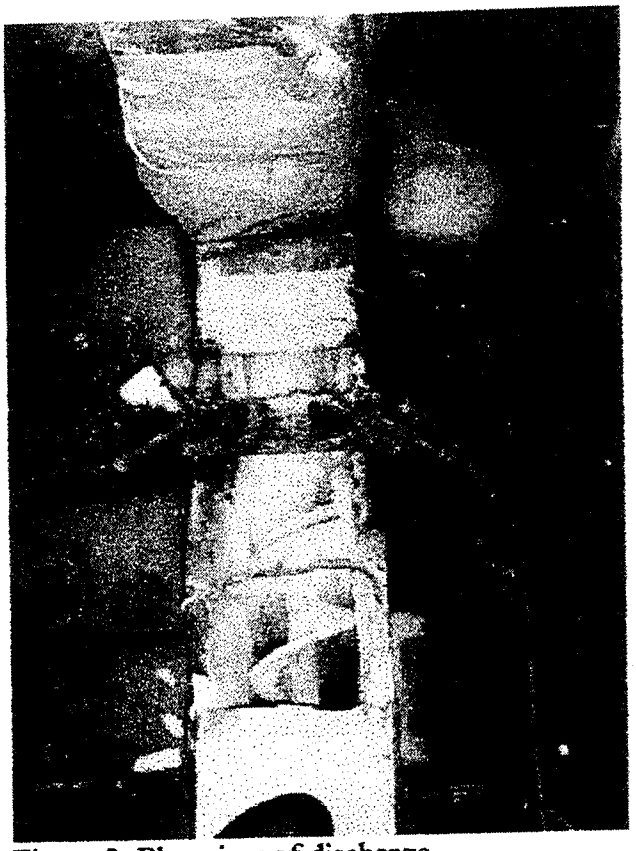


Figure 2: Plan view of discharge screw from centrifuge showing KI and KF addition points

Figure 3: Some of the Ministry of Health & PANASAL team

7.RESULTS OF PLANT TRIAL

On Wednesday April 22nd and Thursday April 23rd, solution of Potassium Fluoride was added while salt processing was in progress. This exercise gave valuable experience in the addition of fluoride under plant conditions. Unfortunately there were problems with the plant breaking down, (unrelated to the fluoride addition), and hence an extended run did not materialize. The results are shown below.

Wednesday April 22nd .Addition of Fluoride started art 2:00pm

Sample #	Time Taken	Result [F]ppm
1	2:30	22.3
2	2:45	4.7
3	3:00	0.11
4	3:30	0.08

In this case the fluoride solution ran out prior to the start of sampling. So by the time sampling started the concentration had started to drop. The lesson learnt here is that at least 3 to 4 batches of solution must be made up prior to the start of dosification so that the solution may be replenished. Also to avoid the inconvenience of mixing many batches per day a storage vessel, or large mixing vessel for Fluoride solution is required. One has been identified in PANASALS workshop. It is a stainless steel tank of capacity about 100 gals.

Thursday April 23rd . Addition of Fluoride started at 9:15am, halted at 9;50pm, restarted at 3:45pm, and ran out shortly thereafter..

Sample #	Time Taken	Result [F]ppm
1	9:30am	116
2	9:45am	155
3	4:00pm	143.7
4	4:15pm	28.6
5	4:30 from packer	193

In this case a plant breakdown caused by a sheared screw-shaft halted production. Again after addition started at 3:45 pm the solution ran out shortly after. Sample #5 was taken at the packaging machine and shows that the fluoride concentration had attained target values of 200 ppm before the dosing solution ran out.

8. CONCLUSIONS AND RECOMMENDATIONS.

There should be now major problems to implement on a full time basis a program of salt fluoridation at PANASAL in Panama. The main problem that this consultant foresees is simply the personnel getting used to the regime and protocols of analysis of the salt for fluoride. This will come with time and practice. The plant and laboratory personnel were found to be fully competent in all aspects of the operation and analysis of salt fluoridation. They will therefore learn quickly as they correct the inevitable mistakes that will be made in the implementation of a new program such as this.

The main recommendations are as follows:

1. That the addition point of potassium fluoride to the salt remains as in the plant test, at the screw conveyor discharge from the centrifuge to the dryer.
2. That the solution concentration of fluoride remain in the range of about 10 to 15 % KF bty weight.
3. That the main sample point for salt be as determined during the plant trial, at the dryer discharge.
4. That the sample size for analysis be as used during the plant trial, 40gms.
5. That sample frequency be every four hours during steady state operations, and as necessary during start-up and upset conditions. Also daily sampling of finished salt in the warehouse is recommended.
6. That a larger mixing tank for potassium fluoride makeup be installed. This tank should be in the order of 50 to 100 gal capacity.