# Monitoring Produced and Injection Waters

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The experience that has been acquired over the years in regard to handling of injection and production waters has rendered monitoring distinctly feasible. Approaches to monitoring have varied somewhat, in that some have suggested less frequent examination of a system with more extensive studies in each examination[1] and others the establishment of definite guidelines in regard to the standards to which the interpreter should adhere.[2] On the other hand, the basic concept of monitoring has only scattered controversies; therefore, the author herein presents his concepts of the requirements, and also benefits to be derived.

Monitoring is generally designed as a continuous surveillance to control water handling and quality and hence the author's common usage of "Quality Control Surveillance" as a descriptive nomenclature for monitoring. This continuity of data is classified as an investment in the detection, prevention, and correction of problems as well as the vital aspect of establishing the absence of any problems. The basic objective is to establish the average chemical, biological, and physical conditions of the water involved in the system and then to utilize the resulting knowledge to accomplish maximum efficiency and economy in primary or secondary recovery. The primary value in this approach is in its preventive capacity, in that conditions can be established before any detrimental effects have developed. Simultaneously, the establishment of the absence of any conditions of concern should be assigned its rightful value. The secondary value is to establish a basis for determining the need for and control of corrective measures.

It is extremely vital that care be taken to avoid either excessive or inadequate analytical data in monitoring in order to effectively balance economy with the efficiency of the program. The analytical data that is gathered in any individual examination of a water or waters should be sufficient to allow the detection of any conceivable condition that could develop. It is vital to always take great care not to exclude covering analytical data on those conditions that are not foreseeable. Therefore, at least one point in an injection system should include a very complete study and a second point in the system is distinctly advantageous. Exceptions and other additions will vary widely with the individual circumstances involved in any specific water injection system. The analytical data required in monitoring producing wells and production handling equipment is reduced as compared to data needed for any injection water, as in this case plugging of injection wells is not a condition of concern. However, most all other aspects of the water would need careful consideration.

The extreme variety of injection, disposal, and production systems renders the frequency requirement in examination of the system in a monitoring program extremely variable. In most injection and disposal systems, reasonable quality control can be maintained by examination of a system at two-month intervals. Most any of these type systems deserves at least a quarterly examination of the water and the above-suggested complete data. To exemplify the need for these suggested intervals, a system handling 10,000 bbl/day is examined every two months which means that representative data of chemical, biological, and physical aspects of the water are taken approximately every 600,000 barrels. Though volumes being handled are not always the controlling factor in monitoring, it can still be seen from this example that this would not be an excessively short interval between examinations. Monitoring producing wells involves the need for less frequency. The most vital aspect of monitoring producing wells is to obtain a representative sample and an accurate analysis of the initial water being produced under normal conditions from the individual well. This provides a basis for future studies in allowing an effective comparison thereby revealing changes in the water, the significance of these changes, and their influence on accompanying oil production. There are many exceptions in the case of producing wells, such as chemical squeeze jobs, that require more careful, frequent, and individually designed monitoring.

In the design of a monitoring program, it is extremely vital that reasonable continuity as discussed above is maintained. This continuity is vital in that if it is not followed, there are many misleading possibilities that might occur. Lack of continuity can completely obscure being able to definitely determine whether any condition (good or bad) is continuous, periodic, or temporary. This lack of continuity may then result in failure to detect a serious condition or going into extensive expenditures for a condition that was only temporary. As long as reasonable continuity is maintained, care should be made not to test an excessive number of sample points in any one examination in order to maintain economical feasibility of monitoring. Concentration should be applied to the finished water, such as at the injection pumps and injection wells, and maintain the surveillance from the complete data provided at these points. As long as all possible developments are being monitored at these points at reasonably frequent intervals, any developments back through the system will likely show up at these points. Then when such a condition or conditions do appear that are of sufficient magnitude to be of concern, the investigation in regard to those conditions could be extended back through the entire system to identify the origin and possibilities of correction. There are occasional exceptions to this in such instances as a mixed water system in which the produced water and supply water may require separate monitoring for more specific conditions so that they might be resolved prior to appearing in prominent evidence in the mixed waters. In designing the program, care should be taken not to make any assumptions, such as similarity to nearby systems or wells, detection and correction of a single condition solving future problems, chemical treatment resolving conditions visually apparent, or limiting the study to a specific condition. In specifically referring to the monitoring of producing wells, it is not possible to suggest any design for the extremely varied needs of individual wells. Attempting to design monitoring of producing wells should involve only obtaining an initial record as suggested above; this initial record in conjunction with producing records should be utilized as the basis for any future monitoring of that well.

An effective monitoring program cannot be accomplished without accompanying sampling techniques and procedures that will reflect representative conditions in a water injection or disposal system. The individual who samples these type systems should be thoroughly trained, experienced, and knowledgeable in the chemical, physical, and biological aspects of water. He should also be readily familiar with all aspects of a water-handling system and be able to recognize any condition that might influence any of these aspects of the water. This individual should recognize the extreme significance of sampling and readily know the influence it can have on the ultimate results and know it is a reflection of the conditions of a comparatively massive amount of water. He should be able to readily recognize physical aspects of a system that will influence water handling and quality. It should be clarified in regard to sampling that most producing wells can be sampled without this extensive knowledge and training, but the sampler should note any unusual observations made during the sampling.

There is considerable controversy in regard to the need for and merits of field testing at the time samples are taken. The need for and merits of field testing vary widely, in that they depend heavily on the nature of and circumstances surrounding a particular water system. In a monitoring program, the sampler must be well aware of the conditions that influence the need for field testing. Normally, however, tests that are made in the field involve at least pH, temperature, and filter tests. Also sometimes required is the determination of oxygen and/or hydrogen sulfide. However, the key to effectively representing some sensitive conditions that may appear is to acquire a special air-free sample in a specifically designed container so that the vital preliminary analyses of these sensitive aspects of the water can be made under accurately controlled conditions in a laboratory within a few hours of the sampling. The inoculation of bacterial samples for later counts should be done within a few hours of sampling, but the methods commonly utilized for field inoculation of bacteria are at best very rough estimates and should never be used for accurate monitoring. However, these field-inoculated counts can be a distinct asset as a supplement to monitoring between accurate examinations. There are other determinations that fall in this same category, such as field iron analyses. As related above, several tests need to be made within a few hours from the sampling in order to accomplish accurate monitoring; therefore, injection or disposal waters should not be shipped to a laboratory if it can possibly be avoided. On the other hand, most purposes for analyses of waters from producing wells will allow shipping of a water sample. However, in this respect the more rapidly the sample can be transported to the laboratory, the more information that can be acquired therefrom.

The interpretation of data acquired in monitoring should be made with caution. Prejudging what the conditions are without consideration of all the complete data can be very misleading. An example would be in finding calcium carbonate in an injection system or producing well, and without consideration of other confirming or contradicting evidence, interpreting this as indicating it is the origin of the physical problem that has been observed. This may have been only a minor condition or may have been a deposit that had been in the system for months or years. This shows that interpretation in monitoring involves previous data just as much as it involves the current study that is under observation. This comparison with recent examinations of the system is necessary to reach reliable conclusions. Also in the interpretation of data the possibility of altering the monitoring schedule should be considered, but simultaneously never disregarding the possibility of unforeseeable conditions. The analyst or consultant who makes interpretations will observe the production and injection of water in an entirely different light from other individuals who are also vital to the over-all operation. By necessity, other operating personnel involved must concentrate on his particular primary duties and in most instances must place water quality and related factors in a secondary position. Service and sales companies also necessarily are forced to approach the examination of a produced water or a water injection system as a service or sales potential. This over-all situation renders it vital to engage in concentrated and unbiased monitoring and interpretations therefrom that can then be coordinated with all other aspects of the water or waters to accomplish the maximum economy and efficiency.

The utilization of data acquired in a monitoring program involves a very complex interpretation of interrelated results. These data can be utilized to provide a very large number of implications and indications; and in the case of injection and disposal systems, a large number of conditions can be revealed. There are commonly many sources of evidence to be observed in establishing the presence and origin of a single condition. For example, air contamination produces several resulting conditions that can be used as indicators. On the other hand, a single piece of evidence may indicate the possibility of more than one condition. This renders it necessary to carefully coordinate all the pieces of evidence disclosed in order to establish what condition they are indicating in the system. The primary conditions that need to be examined and considered to render the program effective in most systems include chemical and physical properties, biological properties, and physical inspection.

*Chemical and Physical Properties*

1. Evaluation of the rate and type of corrosiveness. Contrary to common opinion, a reasonably accurate prediction of corrosiveness can be acquired by an experienced person with accurate and adequate analyses.
2. Observation of indicators of corrosion. A variety of possibilities is involved in detection of these indicators, such as the use of iron in limited circumstances, (Fig. 1).
3. Amount, nature, and size of particles in filtrable solids that can cause plugging, (Fig. 2)
4. Development of excessive bottom sediments in both tanks and lines, (Fig. 2)
5. Development of excessive oil-water interface material on top of lines and vessels, (Fig. 3)
6. Slug conditions that originate from water wells, production, or handling vessels
7. Observation of scale crystals in the water, indicating scaling in injection system
8. Detection of scale crystals, abrasives,

or corrosion products from production
9. Detection of abrasive particles originating from water wells or supply lines
10. Development of evidence of deterioration of cement or other linings
11. Detection of any precipitation occurring in the system
12. Detection of lubricants suspended in the water
13. Observation of compatibility of waters and/or chemicals that may be involved in the system
14. Detection of air contamination and effects resulting therefrom, (Figs. 4 & 6)
15. Detection and evaluation of scaling tendencies in various areas of the system, (Fig. 5)
16. Perpetually evaluating the efficiency of any treatment for scale or corrosion
17. Continuous evaluation of amount of any chemical treatment that is being applied to establish insufficient or excessive treatment
18. Efficiency of oil separation
19. Detection of contamination
20. Evaluation of varying temperature and its influence on other aspects of the water
21. Composition of deposits or sediments
22. Composition of filtrable solids
23. Coordination of chemical properties and treatments with biological properties

*Biological Properties*

1. Potential plugging of injection wells due to the numerical mass of bacteria or other living organisms
2. Observation of slime developments and their tendency toward fouling and plugging, (Fig. 7)
3. Observation of accumulation of slime on top of the water in vessels
4. Continuous use of bacterial activity as conclusive indicator of periodic or continuous air contamination or inefficiency of chemical treatment to remove oxygen, (Fig. 6)
5. Evaluate the potential restriction of water well production by slime.
6. Observation of incompatible conditions resulting from products of bacterial activity
7. Maintain observation over the efficiency of inorganic and organic bactericides and evaluate their economical feasibility and possible detrimental effects.
8. Coordination of bacterial properties and treatment with chemical properties

*Physical Inspection*

1. Observe and record any aspect of sampling that may influence outcome of study.
2. Observation of design and its influence on retention time
3. Nature and location of tank inlets and outlets
4. Sequence of vessels
5. Inspection of equipment for depositions or corrosion
6. Observation of cross-connections where two waters are involved
7. Observation of accumulations that might be forming at sample points
8. Observation of accumulations on top of the water in vessels
9. Observation of accumulations on tank bottoms
10. Inspection of filters
11. General observation of line conditions such as exposure of lines to weather, length of supply or distribution lines, vibrations involved, etc.
12. Search for any minor condition that might be of concern such as open hatches, open or closed gas or water lines, water level in tanks, temperature of heater-treater, etc. that might influence water quality.

The monitoring of individual producing wells normally involves less extensive analytical data. Chemical analyses of the initial water are vital and then, possibly, annual analyses may be made as a follow-up to the initial record. Also, the main influence on monitoring of producing wells should involve changes in total fluid production, oil-water ratio, etc. Average circumstances in the individual producing well involve the following factors as those of primary significance that warrant observation:

1. Establishment of chemical characteristics of natural connate water from the well
2. Evaluation of corrosiveness in a producing well through chemical analyses
3. Iron in oxygen and hydrogen sulfide-free waters for corrosion control, (Fig. 1)

4. Observation of scaling tendencies, (Figs. 5 & 8)
5. Observation of tendencies for depositions that tend to obstruct total fluid production, (Fig. 8)
6. The zone from which the water or waters are originating, establishing casing leaks, communications, etc.
7. Incompatibility involved between two zones or two producing wells from different intervals
8. Per cent breakthrough injection water, (Fig. 8)
9. Compatibility of the water with acid or other chemical treatments planned
10. Abrasives*
11. Emulsions*
12. Bacterial corrosion or fouling*
13. Presence of treating chemical*

* These are normally included only when the need is indicated.

## REFERENCES


1. Bilhartz, Harrell L.: Standardized Method to Monitor Injection Water, *Petr. Engr.*, The Petroleum Engineer Publishing Co., pg 65-74, August 1968.
2. Wright, C. C.: Rating Water Quality and Corrosion Control in Waterfloods, Waterflooding Systems Design and Operation (compiled and reprinted from The Oil & Gas Jour.), The Petroleum Publishing Co., pg 12-14, September 1964.

## MONITORING CORROSION BY WATERS WITHOUT OXYGEN OR SULFIDE

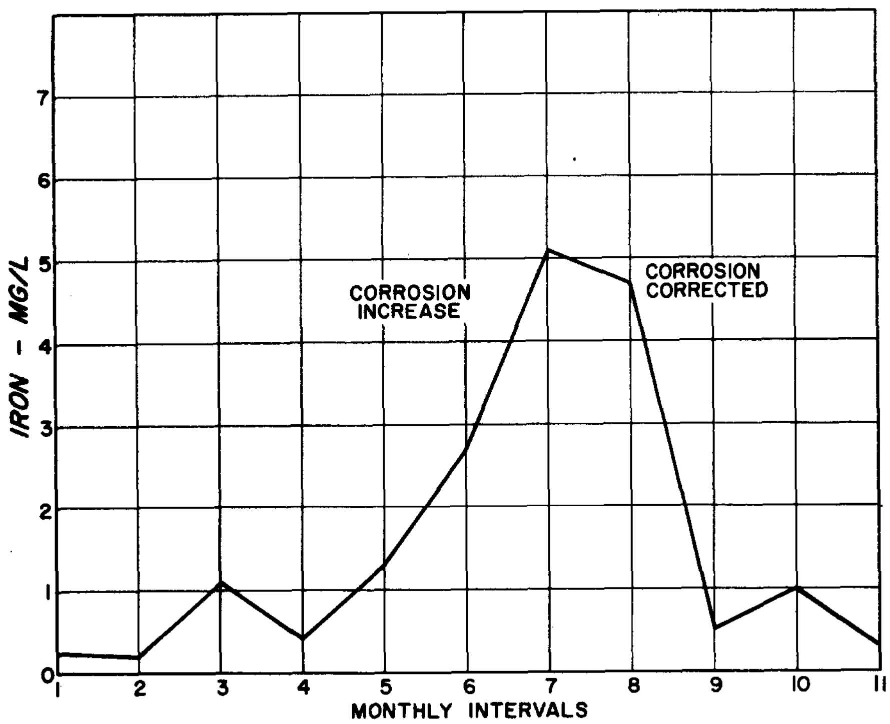


FIGURE 1

## MONITORING EXCESS BOTTOM SEDIMENTS IN VESSELS AND INJECTION LINES

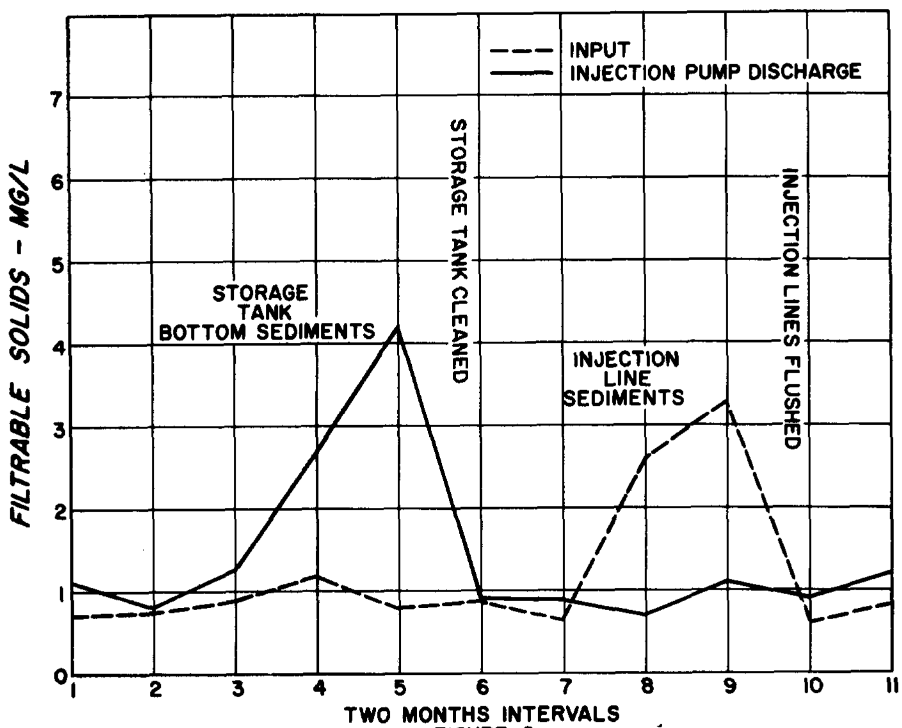


FIGURE 2

## MONITORING OIL-WATER INTERFACE ACCUMULATION

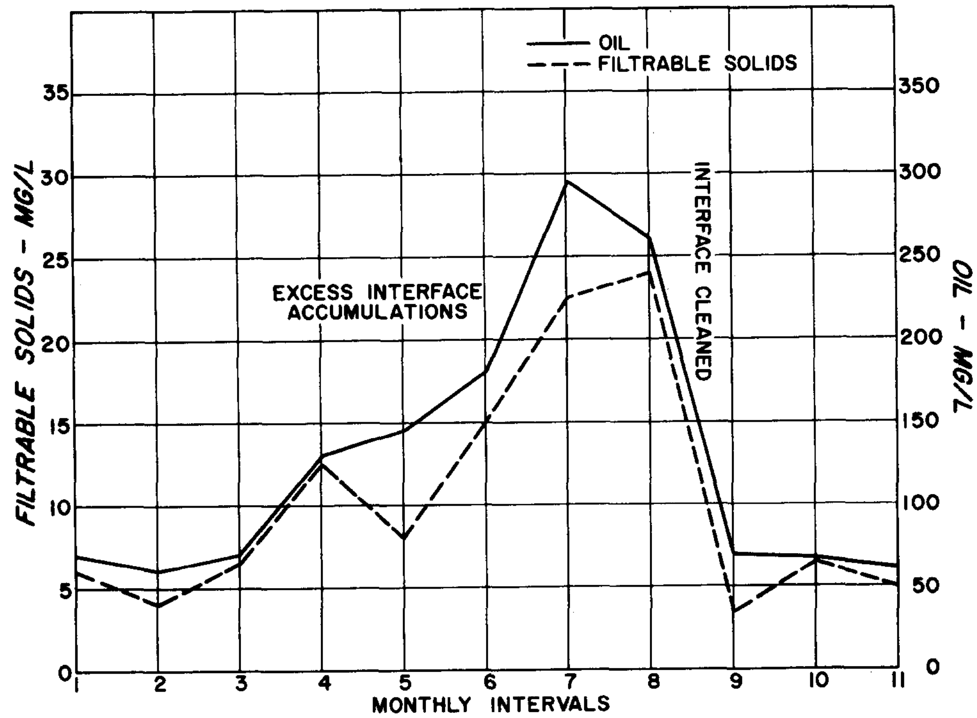


FIGURE 3

## MONITORING AIR CONTAMINATION IN HIGH SULFIDE WATERS

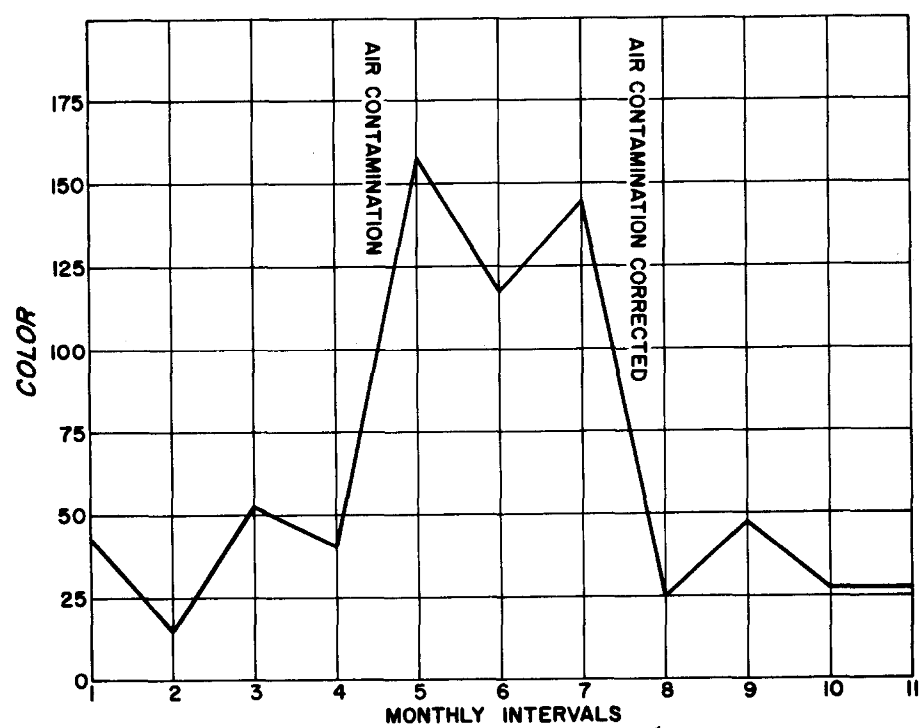


FIGURE 4

## MONITORING SEASONAL VARIATIONS IN CARBONATE SCALING TENDENCY

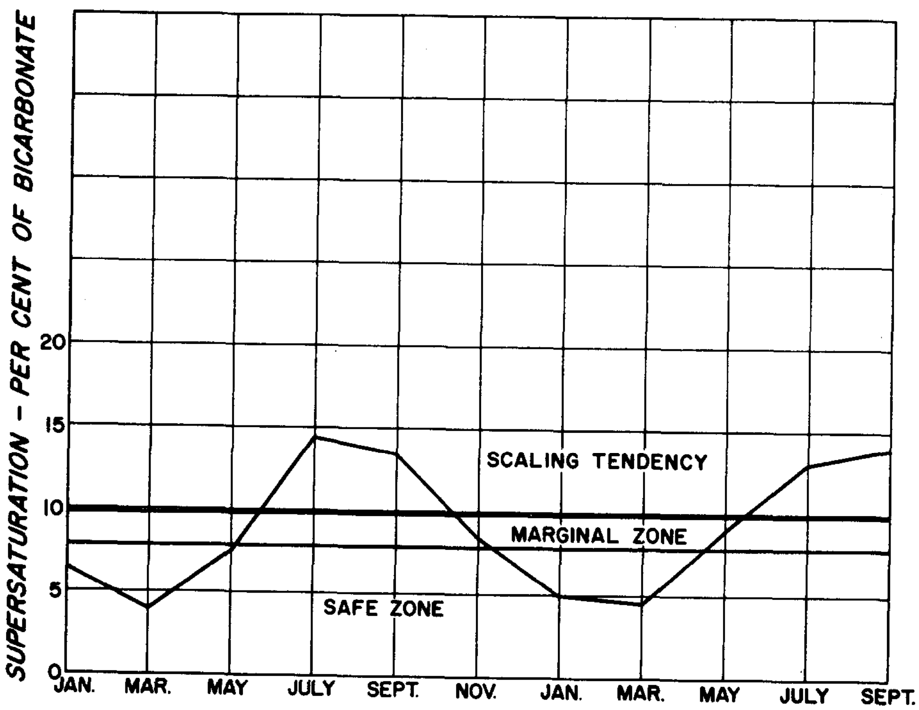


FIGURE 5

## BACTERIAL INDICATIONS OF AIR CONTAMINATION

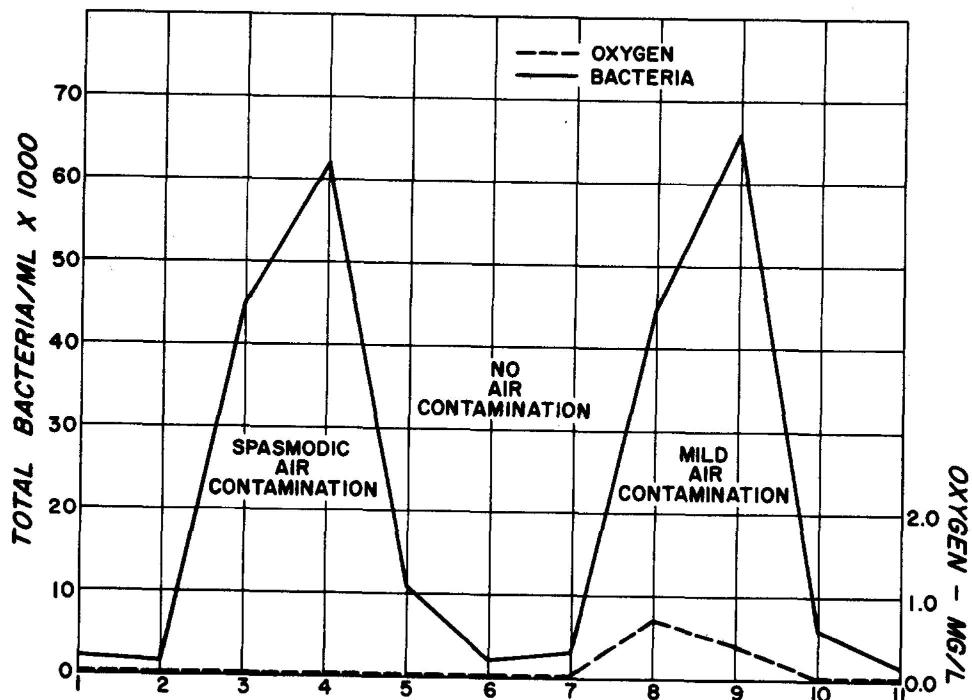


FIGURE 6

## MONITORING BACTERIAL SLIME DEVELOPMENT

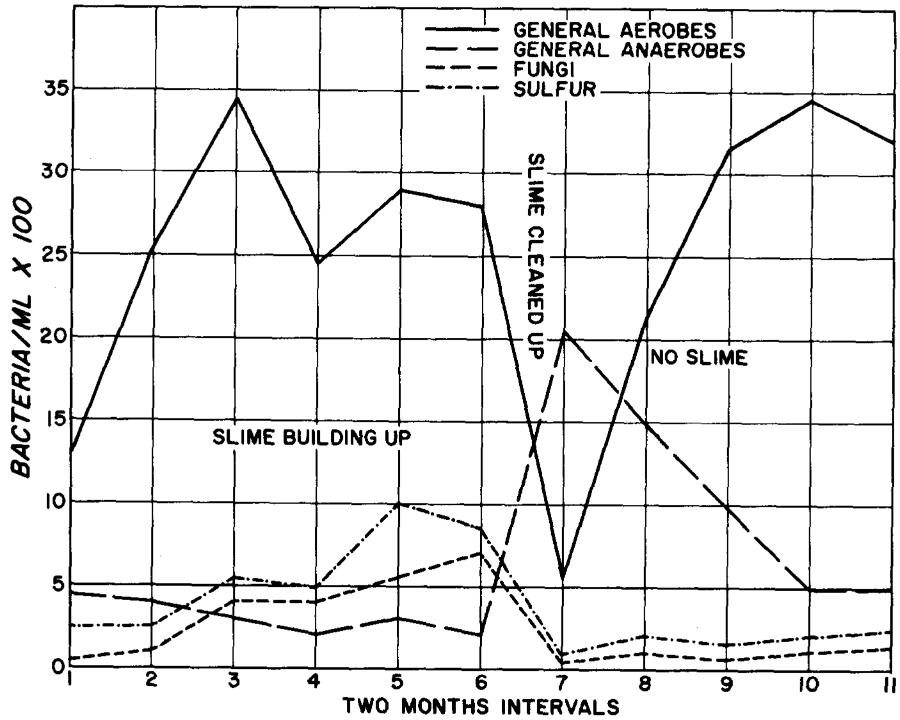


FIGURE 7

## MONITORING BREAKTHROUGH WATER AND GYPPING TENDENCY

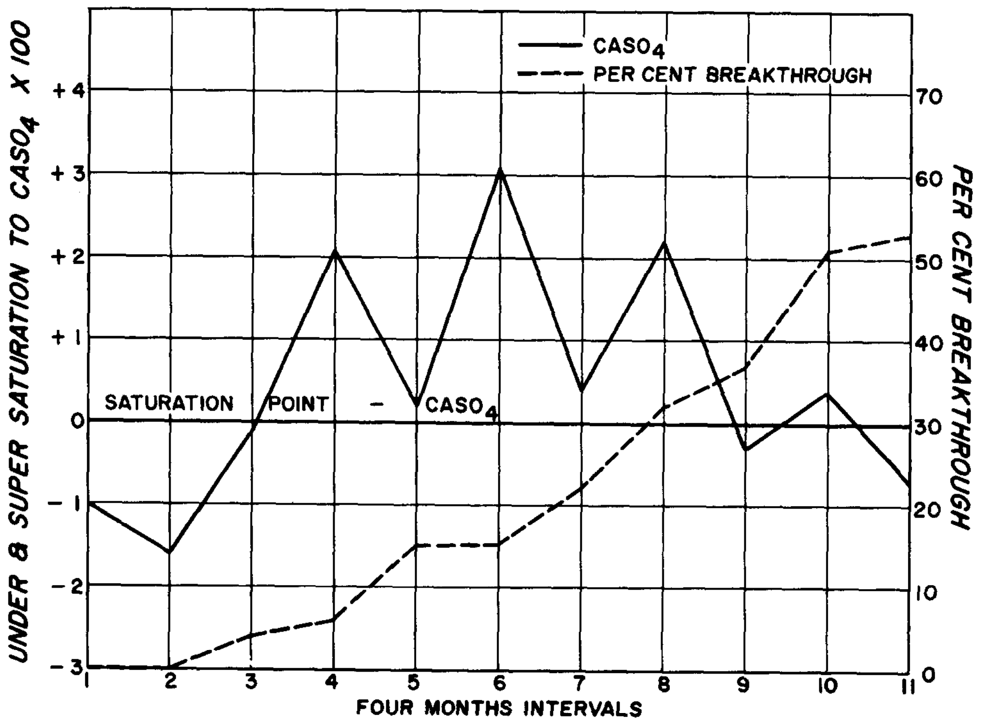


FIGURE 8