POLLUTION STUDIES OF THE REGIONAL OGALLALA AQUIFER AT PORTALES, NEW MEXICO

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INTRODUCTION

Portales, New Mexico, being typical of most localities in the southern High Plains, has been classified as having a semi-arid continental climate (U.S.D.A., 1967). A typical characteristic of this climate is that most of the yearly rainfall occurs during brief heavy thundershowers from May through September. The yearly precipitation averages for Portales have been reported at 16.94 inches while water-loss by evaporation has been set at 92 inches (U.S.D.A., 1967). The deficit between precipitation and evaporation accounts for the fact that most of the agricultural endeavors of the Portales area depend upon irrigation as a source of water. Major application of irrigation water occurs during the relatively hot summer months. Hudson (1962) has shown that in this type of area only 40% of applied irrigation water is used by the crop or stored by the soil. The remaining water was shown to be lost by evaporation or returned to the aquifer. Any water returning to the aquifer would carry with it soluble materials from agriculturally applied chemicals and fertilizers. Continuous cycling of water, even though the rate of consumption far exceeds replenishment, can therefore increase pollution of the aquifer.

Preliminary examination of the aquifer in the vicinity of Portales, N.M., the Ogallala formation indicated the presence of coliform bacteria within a two mile radius of the town of Portales (Taylor, 1970). Coliform organisms are used as indicator bacteria of fecal pollution (A.P.H.A., 1971). The presence of these bacterial organisms in the water at Portales is indicative of recharge of the aquifer. This study examines both chemical and bacterial parameters of the aquifer and extends observations to elucidate any possible seasonal variations and sources of the pollution in the ground water.

Portales, in Roosevelt County, is a part of the Llano Estacado, or "Staked Plains", situated in east-central New Mexico. The Llano Estacado, named by early Spanish conquistadors because of the abundance of yucca stalks protruding above the horizon giving the plains the appearance of being staked, is a part of the High Plains section of the Great Plains province.

Portales Valley is an abandoned stream valley that was once part of the Brazos River before it was pirated by the Pecos River about fifty miles to the west of Portales. The valley runs diagonally (Northwest to southeast) across northern Roosevelt County to where ground water supplies today are obtained from the unconsolidated Ogallala formation of late Tertiary age over most of the area.

Irrigation on a large scale started in Portales Valley about 1910. Before that time many of the farmers irrigated small tracts with water pumped by windmills, and some of the farmers had installed centrifugal pumps driven by gasoline engines. In 1910 the Portales Irrigation Company composed of local farmers and financed by bonds secured by mortgages on irrigated lands, was organized. A central electric power plant at Portales served sixty-nine pumping plants over the area. (Theis, 1930).

This experiment in irrigation ended in failure. During World War I the entire electric plant was dismantled and sold. The reasons for the failure were not clearly defined. Practically none of the farmers had had any previous experience with irrigation and attempts were made to irrigate too much land with too few wells. Some of the wells became dry because the water was being pumped from the valley fill of the Quaternary age and the wells were only 10 to 50 feet deep. The valley fill is of an alluvial origin although aeolian deposits mantle much of the area.

After a period of dry land farming the practice of irrigation began to grow again about 1925 and increased tremendously in the forty-six years that followed. Today, however, most of the wells drilled are around 120 feet deep, protruding well into the Ogallala formation. The Portales Valley Underground Water Basin was originally declared and bound by order number 28 of the State Engineer May 1, 1950 (Galloway and Wright, 1968).

The Ogallala Formation is one of the nation's major aquifers, furnishing agricultural, domestic and municipal water for an area of approximately one-quarter million square miles (Figure 1). This includes 32,000 square miles of West Texas and Eastern New Mexico (Figure 2). The stratigraphic unit extends from the northern High Plains to central West Texas forming a broad plateau which supports an abundance of livestock, and provides a vast amount of agriculture and industry. The livelihood of the Ogallala region depends upon an adequate supply of water, especially for agriculture. This predominantly agricultural area necessitates a complete understanding of the geological, hydrological, chemical and biological factors that control the quantity and quality of the water from this formation. As man increases his demand for water in this area, the need for more data about the aquifer simultaneously increases.

The Ogallala formation was named by Darton in 1905 in Southwestern

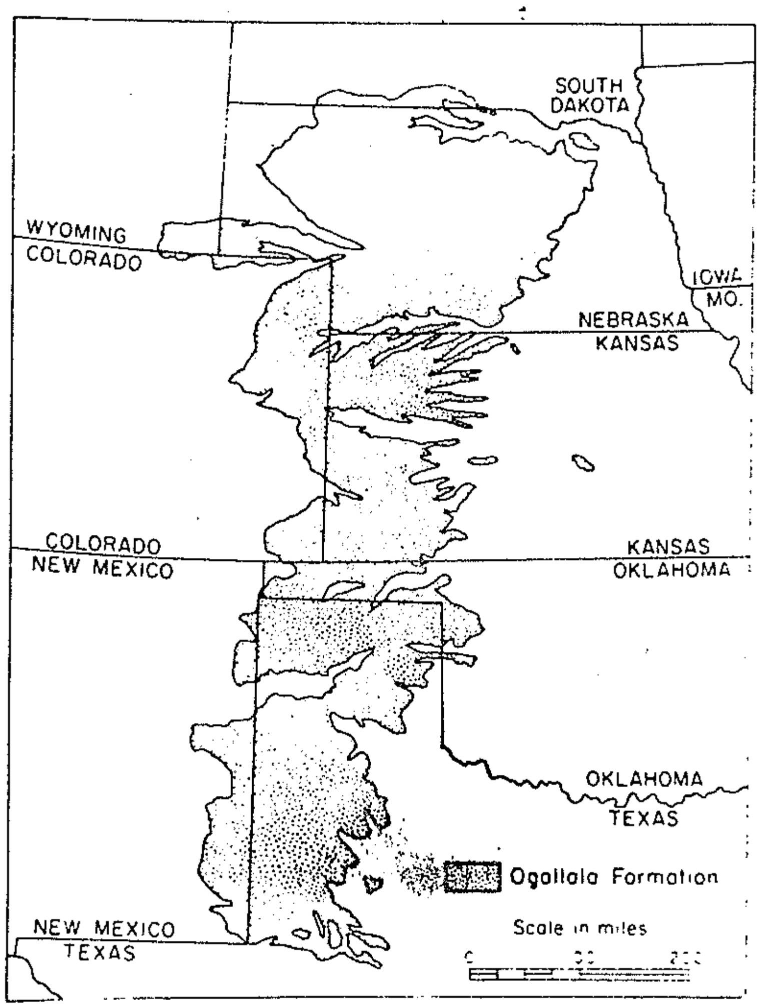


Figure 1. (from Frye)

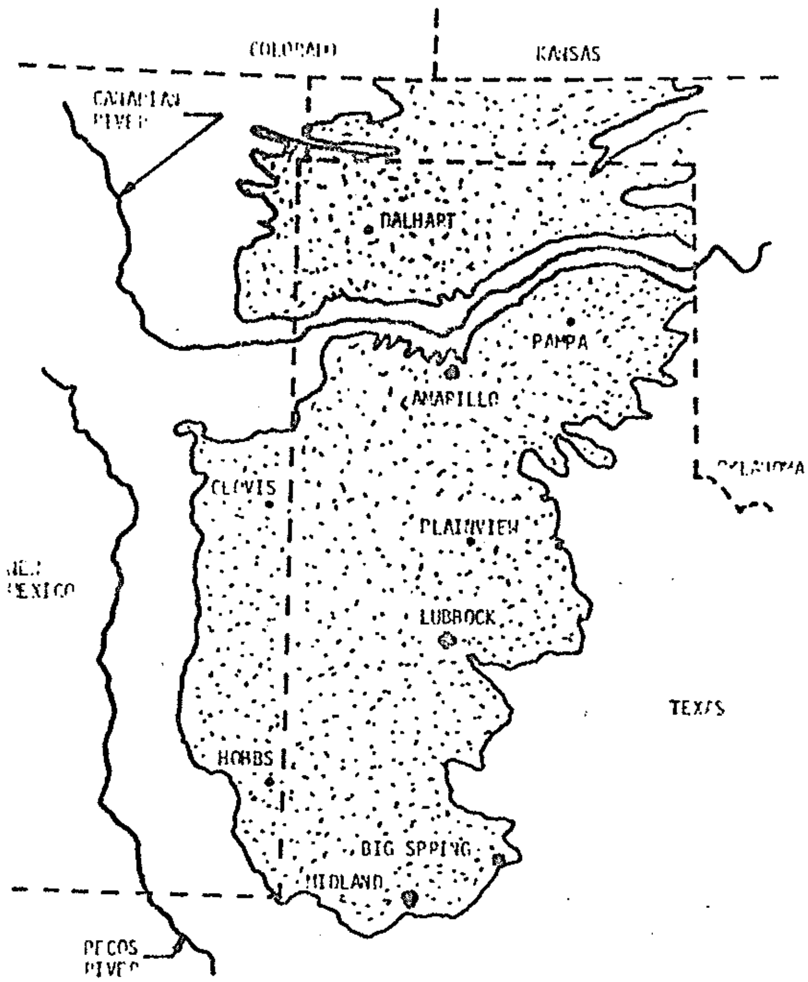


Figure 2. (from Dvoracek and Peterson)

Nebraska. Since then it has been mapped and subdivided extensively. The Ogallala formation extends from southern South Dakota to central western Texas for approximately 800 miles.

The Ogallala was deposited during late Miocene (an epoch of the Cenozoic era) and Pliocene time in pre-existing valley systems across the Great Plains by streams flowing eastward to southeastward from sources in existing mountains (Rocky Mountains). Late Tertiary (a period of the Cenozoic) or early Pleistocene warping placed the alluvial deposits in a position vulnerable to Pleistocene erosion. Erosion modified the landscape in such a manner that the area covered by the Ogallala now forms the plateau between the eroded mountains, foreland, and the central interior plains (Frye, 1970).

The Ogallala, as stated earlier, extends eight hundred miles from southern South Dakota through the Great Plains region to central Texas including almost the entire eastern border of New Mexico. The formation in this entire region is either exposed at the surface or is covered with relatively thin deposits of aeolian sands and silts or by shallow pond deposits. The Ogallala contains significant quantities of sand and gravel and is generally underlain by older rocks of much lower permeability, making it the most extensive and usable aquifer of the Great Plains Province (Frye, 1970).

The Ogallala is isolated from any appreciable water source. Natural recharge of the aquifer from meteoric waters is negligible. Because of it's large surface area and shallow depth, what little water that is accumulated in the soil is soon lost to evaporation. The ratio of withdrawals to recharge is so high that Ogallala water has been recognized as a wasting asset by the Internal Revenue Service which has granted depletion allowance credit to the farmers of the area (Conselman, 1970). Recharge has been variously estimated at as high as 39% (Brunn, 1969), at less than 10% (Dvoracek and Wheaton, 1969), and as low as 0.174% (Clover, 1961).

The ground water of the Ogallala is stored in intergranular pore spaces, solution pores and cavities, fractures and faults. The porosity a granular rock is depends upon the shape, packing size, and degree of sorting of it's components.

Permeability is defined as the measure of the ability of a stratum or rock unit to transmit fluids. Most ground water in the upper parts of the crust comes from precipitation and this water must find it's way from the surface of the ground into the permeable rocks below. The water is pulled downward by gravity; it is pushed down by the weight of the water above it and retarded by surface tension of the water as it clings to the particles of soil through which it must pass. When the water reaches rock, if it is porous and permeable it will continue into the rock; if the rock is impermeable water will either accumulate above the contact or will tend to move laterally downslope along this contact. If the water continues to move downward until it reaches a depth where the rock is not water saturated this downward movement is called the water table. The flow of water in the Ogallala is very slow but moves from high to low elevations at a rate of about fifty to one-hundred feet per year and may under exceptional conditions move as much as several hundred feet per day (Spencer, 1966).

Most ground water of the Ogallala must be pumped to the surface but occasionally water will rise to the surface and flow under pressure. The latter is an artesian condition. Artesian conditions arise from hydrostatic pressure of water trapped or confined within a porous and permeable unit that is both overlain and underlain by impervious units of rocks (aquicludes). Water enters such a unit where it is exposed at the ground surface or overlain by other permeable rocks. The water moves down into the aquifer, gradually fills it, and thereby builds up hydrostatic pressure (Spencer, 1966). Artesian wells once abundant, are presently rare in eastern New Mexico.

The town of Portales acquired its name from the Ogallalas Springs that once prevailed in the area. These natural wells flowed out of the ground through eroded "arches" in the soil that resembled porches, hence the name Portales from the spanish word meaning "porches." Unfortunately, due to the large amount of water used when irrigation practices were begun on a large scale about 1925 the springs quickly dried up (Ford, 1971).

According to hydrologic maps prepared by the United States Geological Survey (1967) the Ogallala aquifer at Portales has an altitude of 3,950 feet, a base altitude of 3,900 feet, and an approximate saturated thickness of fifty feet. According to the same maps, the water table at Portales has declined a total of forty feet between the years 1937 and 1967 leaving a deficit of only ten feet of water in the aquifer.

Havens (U.S.G.S., 1966) reports that the annual recharge on 1,400,000 acres in Lea County, New Mexico, about forty miles south of Portales, during the period 1949 to 1960 was about 95,000 acre-feet or about 0.8 inch with a decline during the same period of approximately fifty feet. These are alarming figures. What will happen to these areas if the withdrawals continue to exceed the recharge until the water is totally depleted?

Several plans are presently being drawn up to recharge the Ogallala from sources distant to it. One plan is to build a canal from the Mississippi River to the eastern edge of New Mexico with recharge stations at several intervals in Texas and New Mexico. However, this would mean that the water would have to be pumped from an altitude of almost sea level to an altitude of over 4,000 feet. This project would be tremendously expensive.

Another project plans to build a series of canals from Canada for recharge by an agreement with the Canadian government.

If and when the Ogallala is recharged from any source we must take pains not to fill it with water full of chemical and bacterial pollutants.

BACTERIOLOGY

All methods used in this study are in accordance with the procedures approved by the United States Public Health Service as published in Standard Methods for the Examination of Water and Wastewater by the American Public Health Association (A.P.H.A., 1971).

Bacterial pollution of water is indicative of the degree of contamination of the water with wastes from human or animal sources. The coliform group of bacteria is used to indicate the pollution of water with wastes and thus the potability of water for domestic and dietetic uses. The group of coliforms belong to the family of bacteria known as Enterobacteriaciae.

The most common system of coliform detection now used and accepted by the A.P.H.A. is the membrane filter technique or Millipore filter system, a commercial brand of the membrane system (A.P.H.A., 1971). The membrane filter technique provides a direct plating method for the detection and estimation of coliform densities in a given volume of water, usually a 100 ml. sample. It is an effective and rapid method for the detection of bacteria from the coliform group and thus for the presence of pollution. The U.S.P.H.S. standard for coliform organisms states that no more than four may be in a 100 ml. sample of water for it to be considered potable.

The Millipore membrane filter system operates by passing a 100 ml. sample of water through a 0.45 micron pore size filter and bacteria that are larger than 0.45 micron are "trapped" on the filter. The filter is then placed on media, incubated, and examined for visible colonies. Coliform organisms are approximately 0.5 micron wide and 2-3 microns long. The colonies, which grow from one organism develop a characteristic color and provide a direct count of the coliforms within twenty-four hours.

Presently two media are used for identification. M-Endo broth-MF (Difco Co.), red in color, allows coliform growth of bright red colonies with a green metallic sheen. This media is for the detection of "total coliforms" which means that they may or may not be specifically from a fecal source. These organisms are incubated at 35° C. for twenty-four hours.

The other media used is "M-FC" broth (BBL Co.) which is blue in color. After the organisms are collected on the filter, and the filter placed on the "M-FC" media, the organisms are incubated at 44.5° C. ± 0.5° for twenty-four hours. A feature of the technique is that the petri dish containing the test filter is sealed and submerged in a water bath during the incubation period. The medium depends on the use of a high incubation temperature for its selectivity because it relies on heat shock to prevent overgrowth of the membrane by non-fecal strains. The indicator system in the medium is such that fecal coliform colonies appear blue in color and other organisms which grow will be gray to cream colored.

All laboratory items are sterilized before use to prevent extraneous contamination of the test samples. The filters from Millipore Corporation are sterile, the supplied petri dishes and the filter funnel apparatus are sterilized by use of ultraviolet light. All other glassware is sterilized by autoclaving. The ultraviolet light is a wavelength of 2537 Angstroms which is the effective killing wavelength for bacteria. With the above precautions and routine control tests it is assured that no contamination enters the samples from our laboratory.

The coliforms are mostly common inhabitants of the flora of the intestinal tract of man and animals. They belong to the Tribe Escherischia, and include the three genera, Escherichia, Klebsiella, and Aerobacter. All the coliforms are lactose fermentors meaning they are capable of fermenting the sugar lactose into lactic, succinic, formic, and/or acetic acids and 2,3-butylene glycol. They also ferment lactose with the production of CO_2 and H_2 gases. Coliforms are gram negative rods or bacilli, are facultative anaerobes, meaning they can survive and reproduce with or without the presence of oxygen, and do not form spores.

Escherichia coli strains make up the major part of the normal flora of the large intestine. Certain serologic strains, however, can produce illness such as gastroenteritis, particularly in infants (Frobisher, 1962). An example is summer diarrhea or infantile diarrhea which can be quite severe and occasionally fatal in young infants. Occasionally the organism invades the blood and the meninges resulting in a meningitis in young children.

Another type of illness produced by *E. Coli* is a urinary tract infection which may be caused by many different strains of the organism. It is most frequently seen in females and patients with obstructive genitourinary lesions.

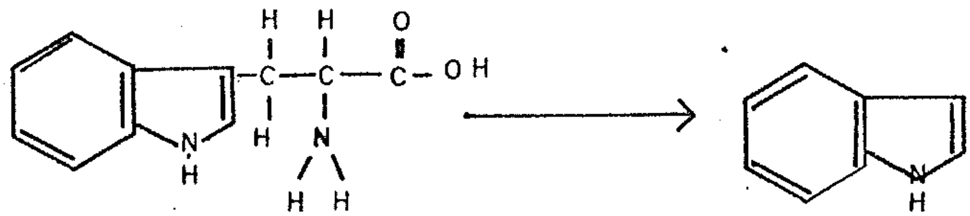
Aerobacter are not usually too harmful but may be found in the urogenital tract of man and are potentially dangerous. Diseases of unknown origin may be caused by Aerobacter.

Of the Klebsiella genera, the most detrimental strain is *Klebsiella pneumoniae*, commonly called "Friedlander's bacillus" which is not an enteric organism. Lesions due to this organism may occur in any part of the body but its most frequent manifestation is a highly fatal type of pneumonia. The organism is frequently isolated in sinusitis, pharyngitis, liver abscesses, peritonitis, endocarditis, and others. *Klebsiella pneumonia* is not susceptible to the action of penicillin. Organisms of the Friedlander group also have been isolated from a tumor-like growth on the oral mucosa of man called rhinoscleroma.

Occasionally a colony growing on a plate is suspected of being a coliform but without the metallic sheen. To confirm the colony as a coliform it is placed in a test tube with a screw cap called a fermentation tube, containing Brilliant Green Bile Broth that has lactose as one ingredient. The tube has a small, hollow, glass tube sealed at one end inverted in it. If the colony is a coliform the small inverted tube will be filled with gas within the next twenty-four hours from the fermentation of lactose in the media. If still in doubt, the cells may be gram stained and examined under a microscope.

If it is desired to differentiate between the specific members of the coliform groups, a series of tests known as the "IMViC" test is used.

The "I" stands for the Indole test and differentiates whether the coliform in question has the ability to convert the amino acid tryptophane to the indole ring as a by product of bacterial metabolism.



Tryptophane   Indole ring

The "M" stands for the methyl red test. Methyl red is an acid indicator and when added to the media will remain red if the organisms are producing acid but will turn yellow if the organisms are not.

The "V" is the Vogas Proskauer test which checks the organisms ability to form acetyl-methyl-carbinol in the presence of 10% potassium hydroxide.

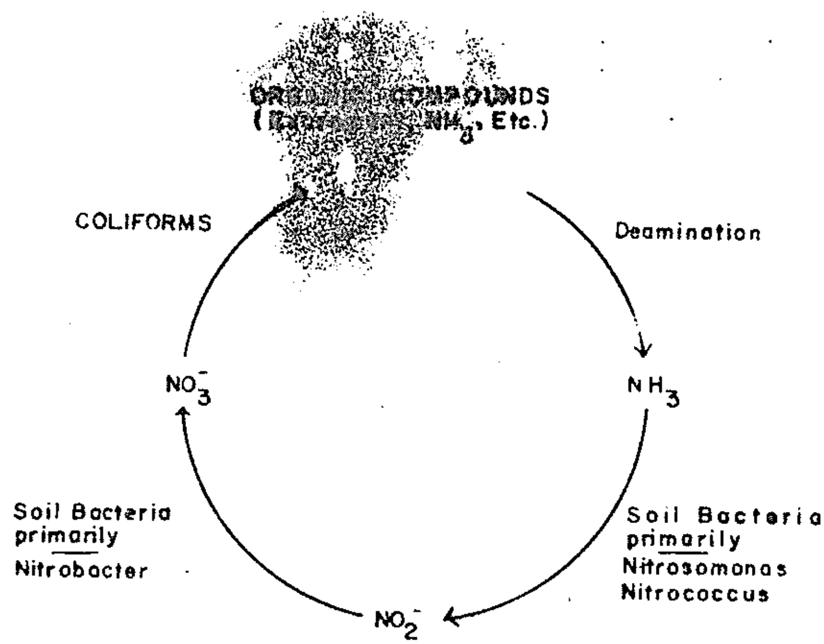
The "C" stands for the citrate test to determine if the organisms can utilize citrate as its sole source of carbon. The "i" is simply a memnomic device.

There is no need to key out the species of the organisms in question as it would be highly impractical and very time consuming. A known species is not required to indicate whether or not the water is potable.

CHEMISTRY

Chemical analyses of the water include nitrate, phosphate, sodium, potassium, calcium, pH (acidity or alkalinity), total hardness, conductivity and total dissolved solids.

Nitrates are the most highly oxidized phase in the nitrogen cycle of bacteria and normally reach important concentrations in the final stages of biologic oxidation (figure 3). The conversion of ammonia to nitrate (nitrification) is brought about by highly specialized soil bacteria of the Nitrobacteraceae Family. Nitrification takes place in two steps. In the first step ammonia is oxidized to nitrite; in the second, nitrite is oxidized to nitrate. Soil fertilized with manure, or manure on feedlot surfaces is converted from organic nitrogen to nitrate through ammonification and nitrification. A large number of the irrigated fields in the Portales area are fertilized with ammonia which can be oxidized by the soil bacteria to form nitrates. Nitrates are water soluble and are not complexed by soil, therefore they are easily leached from the soil and transported by water (Stanier, Doudoroff and Adelberg, 1970). These characteristics of nitrate often result in their attaining excessively high levels in ground waters. In excessive amounts nitrates are a good indication of pollution, not only chemical but also organic matter such as fecal material. In excessive amounts, nitrates contribute to an illness known as infant methemoglobinemia. Because of the almost always strict milk diet of babies, their stomach and small intestines are less acidic than those of adults. This allows bacteria which convert nitrate into nitrite to survive in the upper portions of the digestive tract. If water with high concentrations of



THE NITROGEN CYCLE

Figure 3.

nitrate is given to such infants, these bacteria may convert the nitrate to nitrite, (Wagner, 1971). When hemoglobin is treated with certain oxidizing agents such as nitrites, methemoglobin is formed. This brown pigment differs from hemoglobin and oxyhemoglobin in that the iron is in the oxidized ferric form. Methemoglobin is a combination of heme (ferriprotoporphyrin) and globin. It does not combine with oxygen and there is little or no methemoglobin in normal blood. Methemoglobin is not toxic as such, but its presence in the blood stream simply means a proportional reduction in the oxygen-carrying capacity of the blood resulting in the anemia. Methemoglobinemia is the disease which is commonly referred to as "blue babies" (Oser, 1965).

The condition of Methemoglobinemia has been observed when the nitrate ranges from 66-1100 ppm in the water supply of infants and accordingly a limit of 45 ppm of nitrate has been imposed on drinking waters by the U.S.P.H.S. as a means of averting this condition. The nitrate concentrations of most drinking waters usually falls below 10 ppm (mg/l). However a higher amount is undesirable and may indicate fecal and/or chemical pollution. At a range of 45 ppm or above, the water is reaching the danger level as far as methemoglobinemia is concerned.

Standards set for drinking water can only be enforced on municipal water supplies. Rural wells used only by the occupants are the responsibility of the owners of the wells. Often undue illness occurs from privately owned wells because of the neglect of the owners to insure against non-potable water.

One method which is considered the fastest and most accurate for the determination of nitrates in the water is the "Brucine-Sulfate

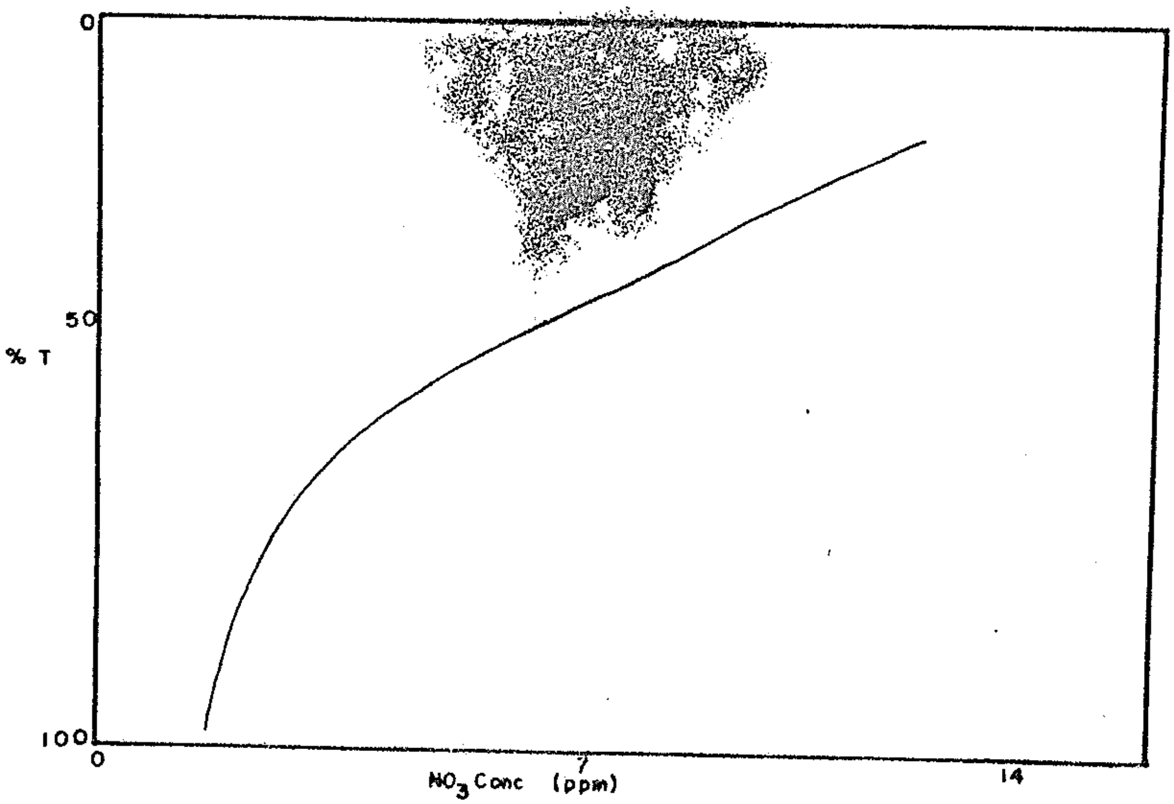


Figure 4.

Sulfanilic Acid" method as approved and listed by the U.S.P.H.S. (A.P.H.A., 1971). Briefly, two mls. of the sample is mixed with one ml. of brucine sulfate and sulfanilic acid mixture to which 10 ml. of concentrated sulferic acid is added. A yellow color is formed when the above reagents react with nitrates and placed in the dark for color development to occur. A set of standards is prepared using a range of 1 - 10 ppm nitrate nitrogen and a standard curve plotted using a Spectronic 20 color spectrophotometer at a wavelength of 410 millimicrons (Figure 4). The curve is not straight when plotting transmittance versus concentration and does not obey Beer's law but a smooth curve is obtained and the unknown concentrations can be determined from the standard curve. As many as 20 samples can be analyzed for nitrate at one time with this method. If residual chlorine is present in the sample it must be corrected for by the addition of sodium arsenite which precipitates the residual chlorine. Any strong oxidizing agent or reducing agent will also interfere with the tests.

Calcium, sodium, potassium, total hardness, pH, conductivity, and total residue are not used in this study as an indication of pollution per se. However, there may be a correlation between the concentrations of the ions, the pH, and total hardness and the amount of bacterial contamination found in the water samples. These conditions could be the factor that controls the environment of the organisms, their existance and reproduction.

Calcium, sodium, and potassium are analyzed on a Beckmann flame spectrophotometer and total hardness with the use of pHydrion water hardness testing paper, similar to litmus paper. Conductivity is measured on a conductivity bridge.

The pH of the water is measured with a Leeds and Northrup pH meter. The pH (hydrogen potential) of water is a limiting factor to the growth of micro-organisms. If the pH of the water becomes highly acidic or alkaline, the organisms cannot survive.

Orthophosphates applied to agricultural or residential cultivated land as fertilizers are carried into surface waters with storm runoff. Organic phosphates are formed primarily in biological processes; hence, they are contributed to sewage in body wastes and food residues, or they may be formed from orthophosphates in biological treatment processes or by life in the receiving waters. The method used is the approved Aminonaphtholsulfonic Acid method for Orthophosphate (A.P.H.A., 1971). The phosphate concentration is determined from a standard curve, which obeys Beer's Law, with the use of the Spectronic 20.

SAMPLING AREA:

Samples of water are taken from twenty-two well sources on a weekly interval. The sampling schedule consists of two mile radii extending to ten miles distance from Portales, with the entire circle of testing area having a diameter of twenty miles (Figure 5).

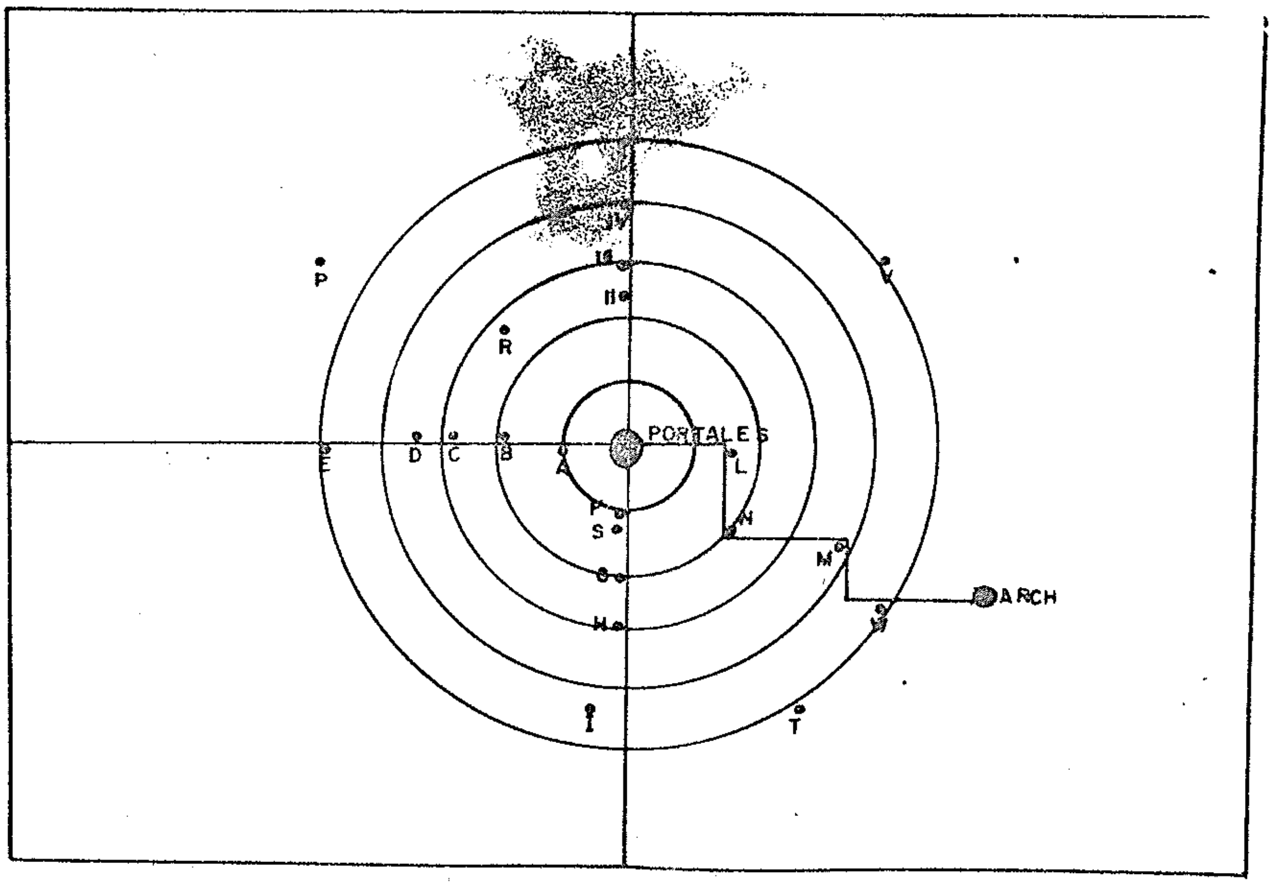


Figure 5.

RESULTS AND DISCUSSION

It has been found that during the summer months practically all wells sampled showed a gradual accumulative decrease in nitrate concentration and with any appreciable amount of rainfall showed a dramatic decrease in nitrate concentration. One well, which has an unusally high concentration of nitrate, decreased from 226.82 ppm on June 1 to 166.60 ppm on August 27. Another well, initially 36.77 ppm on June 1, decreased to 7.97 ppm on August 27. A third well, with a normally small amount of nitrate throughout the year decreased from 7.54 ppm on June 1 to 4.40 ppm on August 27. The graph in figure 6 illustrates the decrease in nitrate concentration with respect to rainfall.

However, five wells of twenty-two sampled increased in nitrate concentration throughout the three months. One sample increased from 3.99 ppm on June 1 to 38.54 ppm on August 27.

The summer months are the time of year in Portales when irrigation is at its maximum and a large amount of water is pumped on the fields. The U.S. Weather Bureau Substation at Portales recorded almost 10 inches of rainfall from June to August. This amount of water added to the aquifer, both meteroic and irrigated could possibly dilute the concentration of nitrate in the ground water.

Most nitrogen fertilizer is applied to the fields in this area during the pre-planting season and very little applied during the summer months. The accumulative effect of rainfall during the summer may have diluted the nitrates that were carried into the water table during the spring. The absence of fertilization in the agricultural regions during the summer could account for this decrease in nitrate concentration.

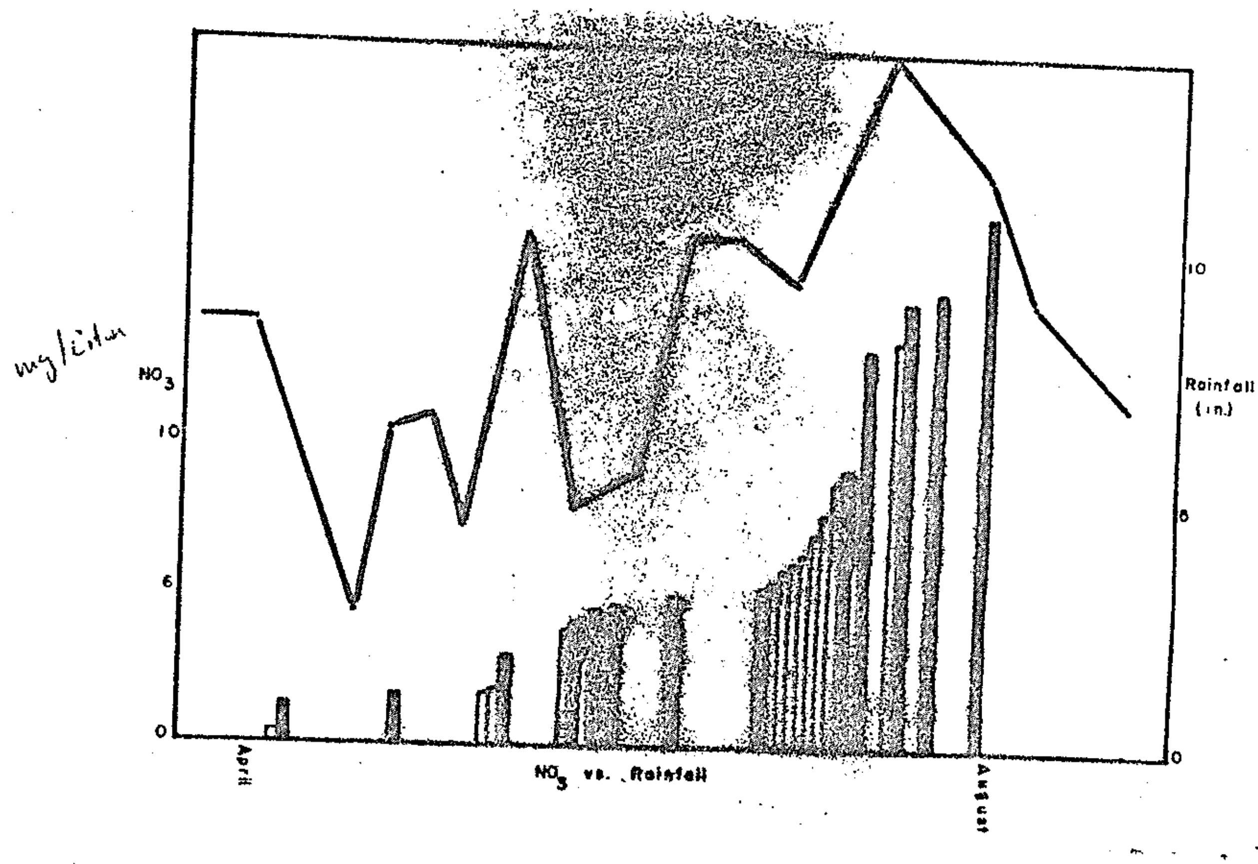

mg/liter
NO3
10
6
0
April
NO3 vs. Rainfall
August
10
Rainfall
(in.)
6
0

Figure 6.

One must also consider that the nitrate concentration of the soil capable of being carried into the water table with accompanying rainfall is also decreased during the growing season by utilization of nitrates by plants.

During these same three months it is observed that the coliform count in practically all wells examined showed a marked increase. The increase in return flow to the aquifer could easily carry these organisms into the aquifer. Although some soil bacteria convert ammonia to nitrates the coliform organisms convert nitrates to nitrites and finally to ammonia. Presently in vitro studies in the laboratory are underway to observe the conversion of nitrates to ammonia, quantitatively with the use of E. Coli. It is hoped to demonstrate in what quantity the nitrates are converted to ammonia by the coliform organisms.

If nitrate concentration versus coliform density is plotted on a graph (figure 7) it is evident that there is an inverse relationship between coliform density and nitrate concentration. This relationship holds true for practically all wells examined whether the initial nitrate concentration is abnormally high at all times, normal (less than 10 ppm), or contains only trace amounts of nitrate. During the summer months of this study wells that have here-to-fore never contained coliform contamination have proven contaminated.

With the coliform increase it is interesting to note that a feedlot sampled regularly increased from no coliforms on June 1 to 140 colonies per 100 ml. on August 27. The amount of excrement on the feedlot surface obviously contains a similarly high amount of coliforms. With increased rainfall the organisms could have been carried into the water table at the feedlot. It is interesting to note that at the same time the coliforms

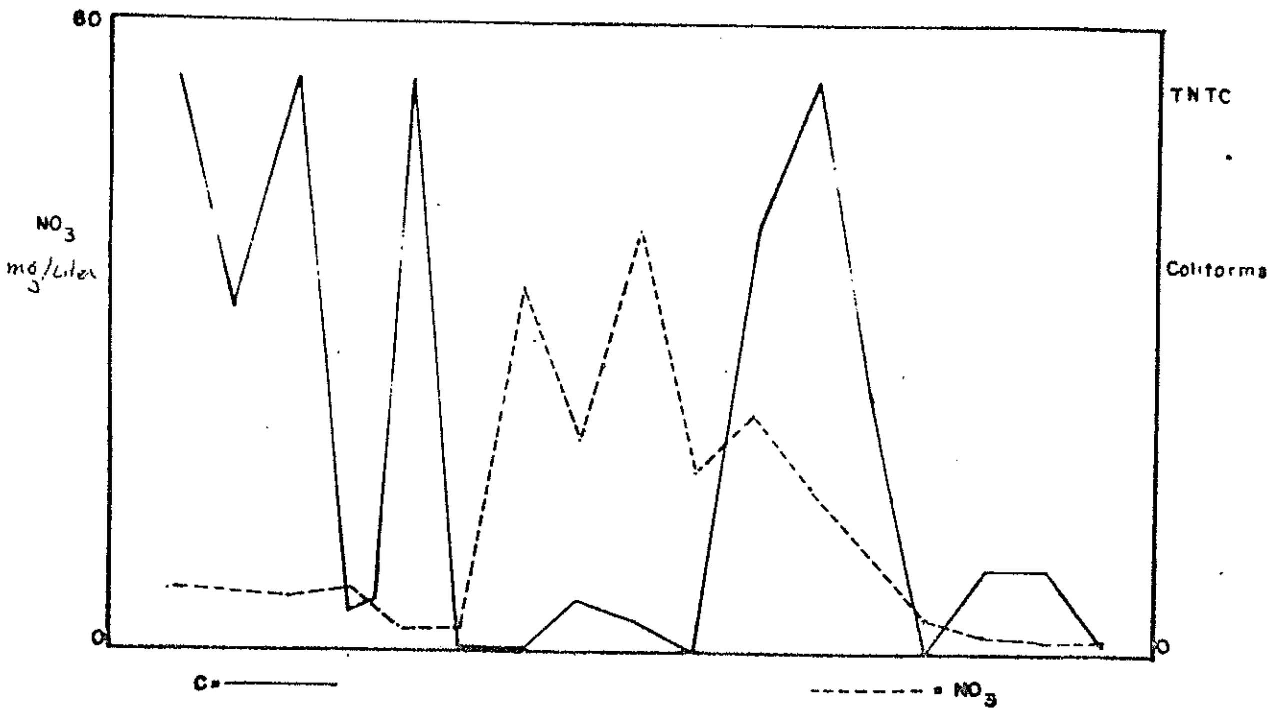


Figure 7.

increased the nitrate concentration in the water sampled at the feedlot decreased. Certainly it could be expected that if urea, which is converted to nitrate by soil microbes, is being carried back into the aquifer from the feedlot, the concentration of nitrates would be high. However, if our hypothesis proves true that that bacteria contained in the water table were converting the nitrates to nitrites, then the observed results could be understood.

One well, where nitrate concentration has reached a high of 248.00 ppm on April 9 and a low of 166.60 on September 8 is an exception to the normal nitrate concentration in the remainder of the wells examined. The owner of the well had owned a dairy herd until recently and kept them in stables near the well entrance. The well is situated out of the Portales Valley and drilled into the Triassic formation. It has been observed that in the Triassic, chemicals tend to accumulate in "pools" (Galloway, 1971). Although the well has shown the previously noted inverse proportion between nitrates and coliform density which existed in the other wells observed during the summer months, the extraordinary high nitrate concentration can be attributed to the nitrate accumulation in pools at this location through the years when the dairy herd was maintained. Another well distant to any livestock sampled on the same farm about one mile away from the high nitrate well, showed, for example a nitrate concentration of 6.202 ppm on the same day as the well near the herd showed a nitrate concentration of 226.82 ppm. It must also be considered that domestic wells distant to any type of livestock show fluctuation in nitrate concentration and coliform densities among each other. This could be due to nitrate and coliforms being "washed" from cesspools and septic tanks back into the well water supply. This possibility must not be overlooked since cesspools and septic tanks in some areas are the only apparent sources of pollution by fecal organisms. It is unlikely that the fluctuations were due to the flow of the water table because all wells sampled vary highly in data obtained. It is also improbable because the water table at Portales flows at such a slow rate (50 feet per year), and is slowed even more during the summer by heavy irrigation practices (Spencer, 1966).

It has been demonstrated that wells never having been found to contain bacterial contamination do fluctuate in nitrate concentration in the summer months. This means that although there is a definite correlation between nitrate concentration and bacterial contamination these two factors may also be considered independently of each other. The three wells in figure 8, having contained no or little coliforms show a striking similarity in nitrate fluctuation during the summer months indicating that nitrate fluctuation when considered in the absence of coliforms is similar in all wells. The three wells are approximately ten miles distance from each other in difference directions.

It can be concluded that the increase in coliform densities is most probably due to increased rainfall and irrigation and that decrease in nitrate levels is in part, at least, due to nitrates being converted by coliforms to ammonia in the water table and to a lesser degree by dilution of nitrates by rainfall.

To date only a slight trace of phosphate contamination of two wells in the entire area has been found. The reason for this is probably due to the affinity of the soil in the region for the phosphate ion.

On August 11, 1971, three samples showed an acidic pH of 6.8. This data was tripled checked because the Portales Valley water is famous for being alkaline. Until this date of August 11, all samples had been alkaline and no acidity had been observed. During the summer in the Portales area vast amounts of pesticides, especially some relatively water soluble

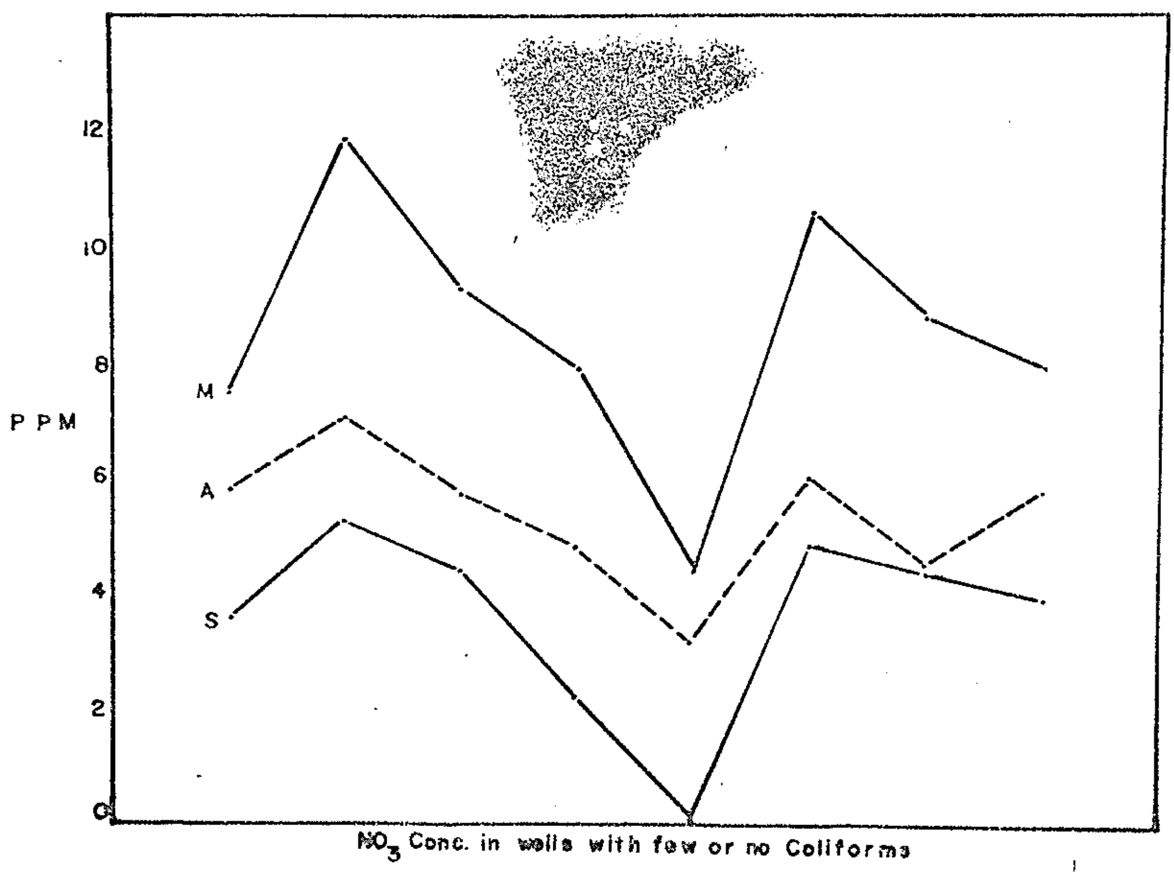


Figure 8.

systemics are commonly applied to the fields. Pesticides such as "Disyston" and "Sevin" which are commonly used hydrolyze acids in water. Is it not possible that with an increasing amount of rainfall some of this pesticide may have been carried back into the water table in high enough concentrations to give the water an acidic nature? At the present time this is merely a hypothesis with no actual data to confirm the suspicion. Soil and water samples of the area are no awaiting analyses for pesticides to confirm or negate the probability of the pesticides being carried into the water table. The pesticide information will be interesting to observe with respect to the data already obtained on the permeability of chemicals and bacteria.

CONCLUSIONS

Although this study will not be complete for several months, it is apparent that pollution of the Regional Ogallala Aquifer at Portales does occur. This pollution may be due to only one factor but more likely is a combination of several factors; mostly man made.

The bacterial contamination of the aquifer may be due to cesspool and septic tank pollution, to feedlot surfaces and run-off or to other factors not yet discovered. Certainly large amounts of rainfall in this semi-arid area appear to contribute to the seepage of bacteria into the water supply.

The high nitrate levels mentioned in this study may be attributed to "percolation" of nitrates into the water table accompanying heavy rainfall. There is a possible parallel between the Portales Valley of New Mexico and San Joaquin Valley of California with reference to nitrate contamination. In 1966 a water company in the San Joaquin Valley informed its customers that its water was considered unsafe for infants due to the fact that it contained more than 45 ppm nitrate (U.S.P.H.S. standard) and could cause infant methemoglobinemia. This problem came about in the San Joaquin

Valley because of certain irrigation practices. The Valley was similar to Portales in that it was very fertile although the rainfall was inadequate for agriculture, so irrigation wells soon provided the requisit water. After a number of years of intensive irrigation and pumping the water level fell. At the same time leaching of both natural and artificial sources of nitrate produced an enriched zone of nitrates deep in the soil. In 1951 the Friant-Kern Canal bringing water from the Sierra Nevada was opened. The water table began to rise again because of the plentiful surface source of water, the subsequent reduced demands from wells, and, of course, drainage from the irrigated fields. When the groundwater reached the enriched nitrate zone in the soil, the nitrates dissipated into the water and began to contaminate the wells used for drinking supplies (Wagner, 1971).

Is it not possible that a parallel condition will occur in the Portales Valley when recharge from distant sources, which seems inevitable does occur? The nitrate concentration in almost all wells sampled in the study area of Portales are above 10 ppm and six of the wells are above 45 ppm.

The Portales Valley, as well as many other areas of the Southwest, depend upon ground water for their very existence. If the Portales Valley is to continue to exist and prosper the pollution, or contamination, of its water, whether intentional or not, must cease. New Mexico is one of the few states where overpopulation is not yet an alarming figure. When more people begin to settle in New Mexico water will be a more vital factor than ever before. If the water is becoming unfit for New Mexico's sparse population of today, how will it ever sustain life for an abundance of people in the future.

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