9.0

OCCURRENCE OF NITRATES IN DRINKING WATER OF GUJARAT

9.0

OCCURRENCE OF NITRATES IN DRINKING WATER OF GUJARAT

9.1 Introduction

Nitrate concentration in drinking water is considered important for its adverse health effect. The health effects of nitrate are generally a consequence of its ready conversion to nitrite in the body which causes Methaemoglobinemia (Cyanosis) in the infants. Some nitrosamines (N-nitroso compounds) formed by the reaction of nitrate with secondary amines and amides are suspected to be carcinogenic. However research in this field is inconclusive.

In the waste treatment system high amount of nitrate denote the aerobic conditions and high stability of the wastes. Although high concentrations are useful in irrigation but their entry into water resources increase the growth of nuisance algae and trigger eutrophication. This phenomenon interferes with many beneficial uses of water and also disturbs its natural self purification process. Thus high amounts of nitrates are generally indicative of pollution. In many rural and suburban areas sewerless sanitation has become the appropriate method of providing sanitations in the recent time. The effluents from septic tank or cesspool are often rich in nitrogen which affects the ground and surface water.

High nitrate concentration with increasing trend have been reported from many places in Gujarat. This situation is assumed to be the result of increased use of nitrogenous fertilizers, insanitary waste disposal, changes in the land use pattern and geological deposits. Guideline standards by WHO and Bureau of Indian Standards(formerly ISI) are formulated for permissible limits of nitrates in drinking water. Incidence of high amounts of nitrates in Gujarat and findings of the survey work carried out to know the reasons of their excess amount as well as their adverse effects on human health are reported. Methods for removal of excess nitrates are also described.

9.2 Sources

Nitrates are widely present in substantial quantities in soil, in most waters and in plants, including vegetables. 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.

One of the principal uses of nitrate is as a fertilizer, most other nitrogen-containing fertilizers will however, be converted to nitrate in the soil. Nitrates are also used as explosives, as oxidizing agents in the chemical industry, and as food preservatives. The main use of nitrites is as food preservative, generally as the sodium or the potassium salt.

Some nitrates and nitrites are formed when oxides of nitrogen produced by action of lightening discharged or via man-made sources are washed out by rain. Some nitrates in the environment are produced in the soil by fixation of atmospheric nitrogen (bacterial synthesis). They are also produced in the soil as a result of bacterial decomposition of organic material, both vegetable and animal. Sodium nitrate and calcium nitrate are often found in minerals occurring in arid zones and are highly soluble in water. Ammonium is bound on the lattice of silicates in a non-exchangeable form and is released only if the rock gets decayed.

Because nitrates and nitrites are widespread in the environment, they are found in most foods, in the atmosphere and in many water sources. Nitrates in soil and in surface and ground water result from the natural decomposition by microorganisms of organic material such as the proteins in plants, animals and animal excreta. The ammonium ion formed is oxidized to nitrites and nitrates. Nitrification, the conversion of NH_4^+ to NO_3^- has been a very common and extremely important process in water and soil.

Artificial fertilizers, a major source of environmental nitrates, may be composed of a variety of chemicals including Ammonium, Calcium, Potassium and Sodium nitrates and Urea. Consumption of nitrogenous fertilizers in Gujarat is increasing at a faster rate In the last 15 years it has increased five folds. The fact that plants cannot use soil nitrogen completely is of great significance. Nitrogen utilization may vary from 25 to 85% depending on the crop and the agricultural techniques. Thus, to obtain maximum production, a great excess of nitrogen fertilizer must be applied to the soil and the resulting nitrogen run off will be substantially increased. Use of fertilizers containing nitrogen, phosphorous and potassium compounds can also threaten ground water supplies due to leaching. When nitrates reaches ground water, it becomes very mobile because of its solubility and anionic form. They can migrate long distances if there are highly permeable strata.

The recent trend of confining large number of cattle, pigs, and poultry in a limited area has created a new point source of nitrate pollution. Animal wastes from these sources contain large amount of nitrogenous materials that may be converted into nitrates. Animal feeding operations (mostly beef and poultry) represent an agricultural activity that can affect both surface and ground water contaminants of concern which include nitrogen.

Discharges of municipal and industrial wastes are concentrated sources of nitrogen compounds that are to a large extent, released directly into surface waters. Green vegetable especially spinach and cabbage are also rich in nitrates. Industrial wastes, particularly from factories manufacturing nitrogenous fertilizers, processed foods, dairy and meat products contain large quantities of nitrates and many a times, nitrite also. The amount of nitrogen in human wastes is estimated to be about 5 kg per person per year. Even after treatment, half of the nitrogen remains in effluent. Sludge from the treatment plants, septic tanks and cess pools represent another significant source of nitrogen pollution. Solid waste disposal practices, particularly sanitary land fills and dumps may represent a source of water pollution by nitrogen compounds. Nitrate from refuse dumps may release nitrates into ground water(seepage) or contaminate surface water over prolonged period. Nitrates and nitrites are widely used in the production of certain meat products and preservation of fish. This can increase the total intake of nitrates in body. Some medicines also contain compounds of nitrates and nitrites viz. Bismuth sub-nitrate. Average distribution of nitrate contamination from various sources can be represented as under(7):

Commercial fertilizers	31 per cent
Manure	19 per cent
Soil nitrogen	46 per cent
Rains	4 per cent

9.3 Nitrogen Cycle

The continuous interchange between atmosphere and terrestrial nitrogen take place along a number of different pathways including air, water, soil, plants, animals and man. This transfer and transformation of nitrogen is referred to as the nitrogen cycle. The relationship that exists between the various forms of nitrogen compounds and the changes that can occur in nature can best be illustrated by a diagram known as the "Nitrogen Cycle" shown in **Annexure -9.1**.

From this, it will be seen that the atmosphere serves as a reservoir from which nitrogen is constantly removed by the action of electrical discharge, nitrogen fixing bacteria and algae. During electrical storms large amounts of nitrogen are oxidized to N_2O_5 and its union with water produces HNO_3 which is carried to the earth in the rain. The nitrates serve to fertilizer plant life and are converted to proteins.

NO_3^- + CO_2 + Green Plants + Sun Light ------> Protein

Atmospheric nitrogen is also converted to proteins by "Nitrogen fixing" bacteria and certain algae.

N_2 + special bacteria (or Algae) -----> Protein.

Animals and humans are incapable to utilize nitrogen from the atmosphere or from inorganic compounds to produce proteins. They are dependent upon plants, or other animal body. Protein matter is used largely for growth and repair of muscle tissues. Some may be used for body purpose. In any event, nitrogen compounds are released in the waste products of the body during life. At death, the protein stored in the body become waste matter for disposal. The urine contains the nitrogen resulting from the metabolic breakdown of proteins. The nitrogen exists in urine principally as urea which is hydrolyzed rapidly by the enzyme urease to ammonium carbonate.

The ammonia released by bacterial action on urea and proteins may be used by plants directly to produce plant proteins. The "nitrosomonas group" known as the nitrite formers, convert ammonia under aerobic conditions to nitrites and derive energy from the oxidation.

$$2\,NH_3 + 3O_2 \xrightarrow{\text{Bacteria}} 2NO_2^- + 2H^+ + 2H_2O$$

The nitrites are oxidized by the **"Nitrobacter"** group of nitrifying bacteria, which are also called the **nitrate formers.**

$$2\,NO_2 + O_2 \xrightarrow{\text{Bacteria}} 2NO_3^-$$

The nitrates formed may serve as fertilizer for plants. Nitrates produced in excess of the needs of plant life are carried away in water percolating through the soil because the soil does not have the ability to hold them. This frequently results in relatively high concentration of Nitrates in ground waters. Under anaerobic conditions nitrates and nitrites are both reduced by a process called denitrification. Presumably nitrates are reduced to nitrites and then reduction of nitrites occurs.

Reduction of nitrites is carried all the way to ammonia by a few bacteria, but most of them carry the reduction to nitrogen gas, which escapes to the atmosphere. This constitute a serious loss of fertilizing matter in soils when anaerobic conditions develop. Denitrification takes placed in the soil and also at the interface between water and sediment in oceans, rivers, lagoons and lakes. Nitrates from neutral fixation and artificial fertilizers are ultimately used for the synthesis of biological molecules, particularly proteins. Plants and animal waste and dead tissues return fixed nitrogen to the soils. Where part of it is recycled and part returns to the atmosphere, thus completing the "Nitrogen Cycle".

9.4 Routes of Exposure

There are three main routes of exposure of nitrates viz.

(a) Drinking water

(b) Food

(c) Ambient air.

(a) Drinking water :

Because of conventional water treatment and disinfection process do not remove the nitrates to any appreciable extent, the levels of nitrates in tap water is same as that found in the raw water or the source water. Because of oxidation during water treatment, particularly at the chlorination stage, the nitrite levels are slightly reduced in the tap water from that of the source water. Depending on the source providing the water, the nitrate concentration will vary from place to place. For the majority of the world's population, the exposure of nitrates in the treated water is well below 20 mg/L as NO_3 . However in some areas, the levels may be as high as few hundred mg/L of NO_3 .

(b) Food :

The major source of human intake of both nitrates and nitrites is food. Certain vegetables like cabbage, lettuce, potatoes, spinach and several other root vegetables contain relatively high levels of nitrates and small amounts of nitrites.

Nitrates and Nitrites are widely used in the meat processing industry as preservatives. They are also used to impart a reddish colour to meat and to produce characteristic flavour such as that of ham. They are also used in some countries in the processing of fish and cheese.

(c) Ambient air :

Apart from natural sources of oxides of nitrogen and nitrates in the air, other important man-made sources are the products of combustion of fossil fuel (coal, oil, gas). Various chemical industries also contribute nitrates to the ambient air. Inorganic and organic forms of nitrates occur in ambient air, both these and oxides of nitrogen can be inhaled and some will be absorbed by the respiratory system producing a mixture of nitrates and nitrites in the body.

Ultimately much of the oxides of nitrogen and the nitrates in the general air are washed out in rain and deposited on the land and water, some of that which deposits on land will finally percolate to water sources.

(d) Other routes :

Other routes of exposure are industrial exposure and tobacco smoke. Oxides of nitrogen in particular are fairly common in industrial operations. Although aerosols of nitrates and nitrites occur, the levels are generally low.

Oxides of nitrogen and nitrate aerosols are produced in a burning cigarette, but in contrast to food and water, the quantities contributed by smoking tobacco and then being absorbed by the body are regarded as relatively small. Nitrosamines are also reported to be formed in the burning cigarettes.

9.5 Occurrence in water

Fertilizer use, decayed vegetable and animal matter, domestic effluents, sewage sludge disposal to land, industrial discharges, leachates from refuse dumps and atmospheric washout all contribute to these ions in water sources. Changes in land use may also give rise to increased nitrate levels. Depending on the situation, these sources can contaminate streams, rivers, lakes and ground water, especially wells. Contamination may result from a direct or indirect discharge or it may arise by percolation over a period of time, sometimes after many years.

Among the major point sources of nitrogen entry into water bodies are municipal and industrial waste waters, septic tanks, and feedlot discharges. Diffuse sources of nitrogen include farm-site fertilizer and animal wastes, lawn fertilizers, leachate from waste disposal in dumps or sanitary landfills, atmospheric fallout, nitric oxide and nitrite discharges from automobile exhausts and other combustion processes and losses from natural sources such as mineralization of soil organic matter.

Levels of nitrate in water are typically below 5 mg/L but levels exceeding 10 mg/L occur in some small water sources. In chlorinated supplies levels of nitrite are often less but relatively high levels may occur in unchlorinated water. Very high nitrite levels are usually associated with water of unsatisfactory microbiological quality. The levels of nitrates in polluted water are almost invariably very much higher than the levels of nitrites.

Most of the higher levels of nitrate are found in ground water. Nitrates in ground water is usually derived from following sources:

- Geochemical composition of ground water
- Thunderstrom
- Manure
- Organic pool of the soil
- Infilteration of surface run off.

Nitrates in surface waters tend to get depleted by aquatic plants. Increases in the levels of nitrates in water are associated with the application of nitrogen fertilizers. Marked seasonal variations can occur in concentration in rivers and high levels may occur, particularly after heavy rainfall following severe drought periods. The levels in ground water tend to be much more steady during the year.

9.6 Guideline Standards

WHO has suggested 45 mg/L, as the guideline for nitrate (NO_3) concentration. The standards adopted by few countries and organisations are summarised in the table below :

Sr.No.	Country	Nitrate Level (As NO_3 mg/L)
1	Canada	45
2	European standards	50 to 100
3	Poland	45
4	United States	45
5	United Kingdom	50
6	ICMR(India)-1975	20 - 100
7	BIS-India (IS:10500-1991)	45 - 100

It is obvious that variation in standard values adopted by different countries is significant. It is due to the fact that daily intake of nitrate differ from country to country.

9.7 Health Effects

Nitrates in water supplies in concentration more than permissible limit lead to cases of **methamoglobinaemia** in infants and other adverse health effects. Nitrates themselves have no direct effect on health. But they become toxic only under conditions in which they are or may be reduced to nitrites. Otherwise at reasonable concentrations, nitrates are rapidly excreted in the urine. High intake of nitrates constitute a hazards primarily to warm-blooded animals under conditions that are favorable to their reduction to nitrite. Nitrates can be reduced to nitrite with the help of bacteria,

- in water distribution lines
- by means of reduction by bacteria in foodstuffs and drinks
- in the stomach and small intestine
- in dental cavities

Methaemoglobinaemia :

It is a disease which reduces capacity of blood to carry sufficient oxygen for proper functioning of human body. Nitrates don't directly convert hemoglobin to methaemoglobin. Under certain circumstances, nitrate can be reduced to nitrite by the micro-flora in the gastrointestinal tract which then reaches the blood stream and reacts directly with hemoglobin to produce methaemoglobin, with consequent impairment of oxygen transport. Hemoglobin is the oxygen carrier of the blood. In hemoglobin, iron is in bivalent form Fe^{+2} (Ferrous) methaemoglobin is the oxidized product of hemoglobin in which the iron is in the trivalent state (Fe^{+3} ferric). On transition from ferrous to ferric state, the hemoglobin loses its capacity to combine with oxygen.

Nitrite, whether ingested directly or produced by the bacterial conversion during digestion ,is able to oxidize ferrous (Fe^{+2}) ion in hemoglobin to Ferric (Fe^{+3}) and convert hemoglobic the blood pigment which carries oxygen from the lungs to the tissues, to methaemoglobin. Because methaemoglobin is incapable of binding molecular oxygen, the physiological effect is oxygen deprivation or suffocation.

The development of infantile methaemoglobinaemia from nitrate in drinking water depends on the bacterial conversion of nitrate to nitrite and occurs almost exclusively in infants. Methaemoglobin produces a slate-gray (**Blue baby**) appearance of skin and mucous membrane (cyanosis) and the disorder becomes clinically detectable.

Infants are generally more susceptible to the development of methaemoglobinaemia because the infant's total fluid intake per body weight is three times that of an adult. The predominant form of hemoglobin (Faetal hemoglobin) at birth is more susceptible to the development of methaemoglobinaemia. The stomach pH in infants being about neutral (no secretion of juices as in the case of adults which keeps the pH acidic) enables bacterial growth to occur in both the stomach and upper intestine. Infants, in contrast to adults are also deficient in enzymes that can convert methaemoglobin back to hemoglobin.

The stomach pH in infants is less acidic than adults. Many species of entrobacteria are capable of reducing nitrates to nitrite. In infants whose diet is normally carbohydrates, coliform organisms are felt to be primary responsible for the conversion of nitrate to nitrite in the digestive tract. Coliform organisms can grow in the gastric pH range 5 to 7 normally found in the infants. Gastrointestinal illnesses and diarrhea may permit the bacteria responsible for the conversion of nitrates to nitrites to migrate from the lower intestine to the upper intestine and stomach and thus increase the likelihood of nitrite formation prior to absorption in the small intestine. Dietary intake of vitamin-C rich juices or foods has been found to help maintain lower methaemoglobin levels.

Carcinogenicity :

Since ingested nitrates can be readily converted to nitrites, either in the mouth or elsewhere in the body where the acidity is relatively low (high pH), it is possible that nitrosamines, some of which may be carcinogenic will be produced. It has been shown that the formation of nitrosamines may be increased in individuals with bladder infections and people suffering from achlorohydria (a condition of low stomach acidity). In the case of bladder infections, it is probable that the nitrosamines produced there would be absorbed into the blood. However there are no direct evidences of higher carcinogenicity in man.

Other health effects :

Studies relating to congenial mal-formations and cardiovascular effects to nitrate levels in drinking water have not produced consistent results. Some animal studies indicate that chronic exposure to high levels of nitrates can reduce the intrathyroid iodine pool and thus render the gland more sensitive to goitrogoens. However, whether or not exposure to nitrates is an etiological factor in human goitre remains to be determined.

9.8 Nitrates levels in Gujarat

Gujarat is one of the advanced states in the country having production of Agricultural and Industrial goods. So far as the agricultural activities are concerned, obviously due to advancement in crop patterns and techniques, the use of chemical/biological fertilizers is more. Similarly due to heavy industrialization, the disposal of industrial effluent will also pose a threat of increased nitrate levels in receiving waters and onto land. In addition to that Gujarat has got four major fertilizer manufacturing factories.

They are;

- Gujarat State Fertilizers Co. Ltd. (GSFC) at Bajwa in Baroda District.
- IFFCO fertilizers at Gandhidhan (Kandla) in Bhuj District.
- Gujarat Narmada Valley Fertilizers Co. Ltd.(GNFC) in Bharuch District.
- IFFCO Fertilizers at Kalol (NG) in Mehsana District.

S.M Vaijanapurkar of Gujarat Water Supply & Sewerage Board, Gandhinagar has studied the problem of nitrate occurrence in Gujarat in 1990-91 for his ME(PH) dissertation studies, (BVM College, V.V.Nagar). The author of this thesis provided him useful guidance during his studies. He has reported that out of the 19 districts of the State, as many as 8 districts were affected by excessive amount of nitrates in water. They were Bharuch, Vadodara, Panchmahals, Kheda, Mehsana, Sabarkantha, Banaskantha and Surendranagar. Based on his study observations, he has divided the State in four zones as under varying effects of nitrates concentration.

9.8.1 Agriculturally potential zone

Kheda, Mehsana and Sabarkantha districts fall under this zone where nitrate concentration is exceedingly high. The probable reason he has put for this is the increased use of nitrogen fertilizers in agricultural practice.

9.8.2 Arid Zone

Panchmahals, Banaskantha and Surendranagar districts fall under this zone. Here rainfall is less and as a result agricultural production is also less but due to geological formations, nitrate content in water is reported to be high.

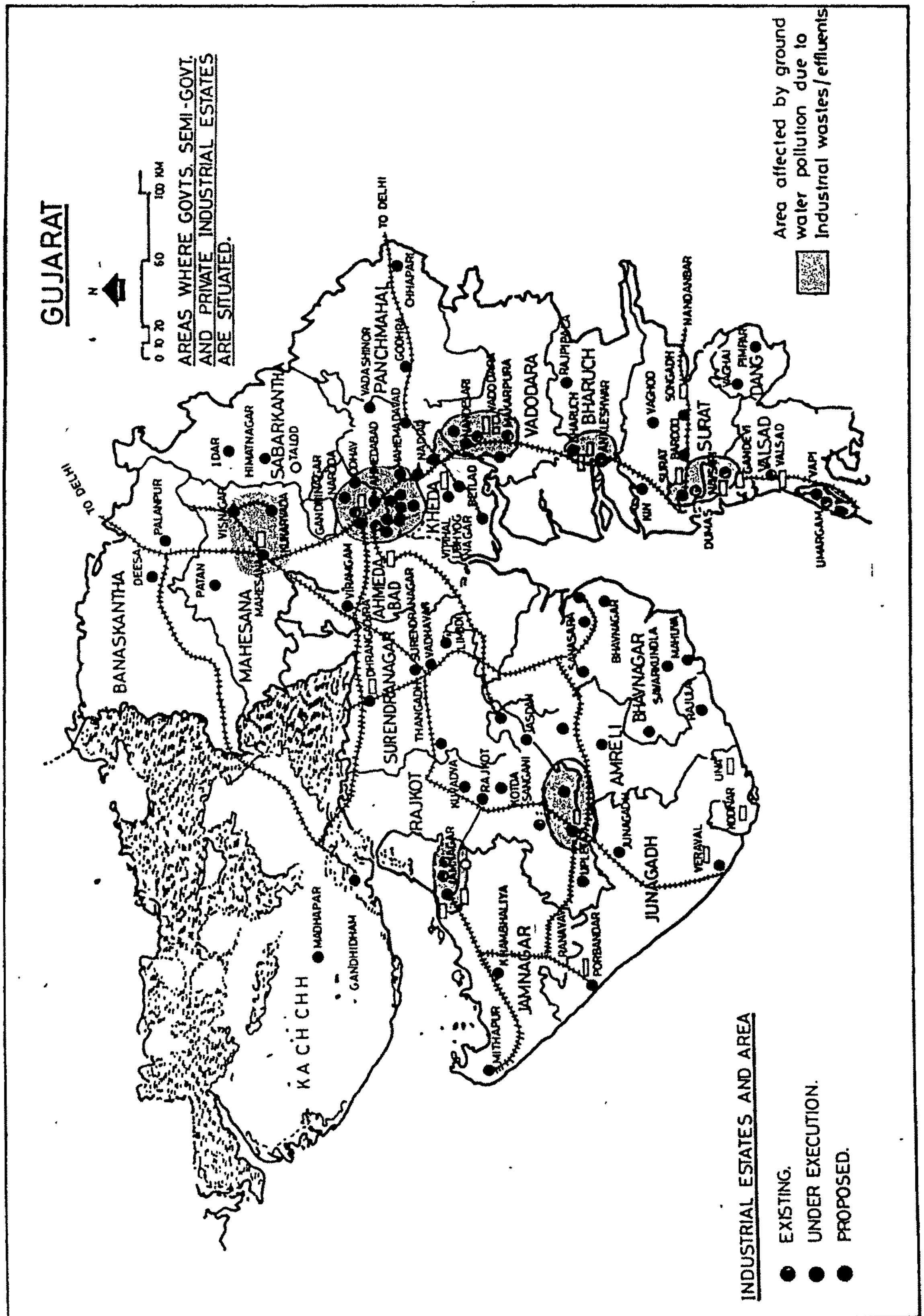
9.8.3 Canal rich area

In Surat, Valsad and Dangs districts of South Gujarat, nitrate content in water is observed to be low. The area is receiving higher percentage of rain fall (average 75 cm). Also surface irrigation is more. So surface runnoff in this area is more . Hence nitrate and other pollutants get washed away. Also use of nitrate fertilizers is reported to be less here.

9.8.4 Salinity Zone

Districts of Saurashtra and Kutch regions are having the effect of salinity due to coastal lines. Nitrate problem in these areas is considerably low.

Highest amounts of nitrates reported by Mr. Vaijanapurker in the districts having excessive nitrate concentrations are as under :


GUJARAT
AREAS WHERE GOVTS. SEMI-GOVT. AND PRIVATE INDUSTRIAL ESTATES ARE SITUATED.
0 10 20 60 100 KM
N
TO DELHI
Area affected by ground water pollution due to Industrial wastes/effluents
INDUSTRIAL ESTATES AND AREA
EXISTING.
UNDER EXECUTION.
PROPOSED.
BANASKANTHA
SABARKANTHA
MAHESANA
PANCHMAHAL
AHMEDABAD
KHEDA
VADODARA
BHARUCH
SURAT
VALSAD
DANG
SURENDRANAGAR
RAJKOT
AMRELI
BHAVNAGAR
JAMNAGAR
JUNAGADH
KACHCHH
PALANPUR
DEESA
PATAN
IDAR
HIMATNAGAR
GANDHINAGAR
VIRAMGAM
GODHRA
NANDANBAR
VAPI
UMARGAM
MADHAPAR
GANDHIDHAM
MITHAPUR
PORBANDAR
VERAVAL
THANGADH
MAHUVA

Sr.No.	Districts	NO_3 (in mg/l)
1	Vadodara.	239.0
2	Banaskantha	354.0
3	Bharuch	122.0
4	Kheda	385.0
5	Mehsana	131.0
6	Sabarkantha	465.0
7	Surendranagar	260.0

The regional office of Central Ground Water Board (CGWB) working at Ahmedabad has also published a map of Gujarat in 1988-89 showing areas with excessive amount of nitrate (more-than 45 mg/l) in various districts. (See **Annexure-9.2**) The map shows that all over the state effect of excessive amount of nitrate in ground water is spread.

Mr Vaijanapurkar during his ME(PH) dessertation study has reported the status of villages having excessive Nitrate (more than 100 mg/l). Similarly the Gujarart Water Supply and Sewerage Board has also carried out a survey of all villages in Gujarat and identified villages having excessive Nitrate (more than 100 mg/l) **Table 9.1** gives the number of villages having excessive Nitrate in all districts of Gujarat State. The table shows that district of Banashkantha, Bharuch, Kheda; Mehsana, Panchmahals, Sabarkantha, Vadodara and Panchmahal are having more number of affected villages.

The auther has also carried out an extensive survey of 39 locations spread over the entire state covering all types of sources in use. The result of Nitrate contents in these villages/ towns are given in **Table 9.2.** This study has revealed that except for a few sources perticularly in Sabarkantha and Mehsana district the Nitrate levels are well within the permissible limits. This indicate that the water supply authorities are taking all precautions to provide drinking water with low Nitrate to the people in Gujarat.

9.9 Case studies

9.9.1 Fertilizer factory effluent at Vadodara

The case study of pollution of ground water due to discharge of effluent from Gujarat State Fertlizer Company in Vadodara district is eleaborately narrated in the chapter No.10 on case studies. So it is not repeated here. However as will be seen from the conclusions drawn in that chapter that prevalence of nitrate in the drinking water sources of the State is not due to discharge of factory effluents or any other extraneous pollution but due to some inherrent characteristics of the soil as well as the excessive use of nitrogenous fertilizers and chemicals in the agricultural activities.

9.9.2 Case study of Sabarkantha district

Sabarkantha is one of the districts in Gujarat which shows excessively high amounts of nitrates. Moreover it is the district showing highest value of nitrartes (as high as 531 mg/l). So it was decided to investigate the problem of high nitrate in drinking water by carrying out a detailed survey of the district. The study was devided into three aspects.

- Chemical analysis of various sources such as public well/bores, private wells/bores and river waters.
- Chemical analysis of stone sample for river bed to check the source of high nitrates in water.
- Health effects on humanbeings and particularly infants.

a) **Chemical analysis of various sources:**

In the chemical analysis of various public and private sources as well as two rivers (Hathmati at Himatnagar and Meshwo at Harsol) the following observations were recorded (August 1981).

Sr No	Source	Phosphate	Nitrate	Chloride	Total Hardness	Calcium	Magnasium
1	Public Well at Mota Chikhala (Depth 11.5 m)	Nil	186	284	230	26	39
2	Private Bore at Mota Chikhala (Depth 120 m)	Nil	138	138	172	18	30
3	Hathmati River at Himatnagar	Nil	54	54	216	54	19
4	Meshwo River at Harsol	Nil	48	48	176	35	21

The above results indicate that the nitrate content at higher depth is less as compared to shallow depth. This can prompt us to conclude that the high amount of nitrate at shallow depth may be due to leaching of nitrate from fertilizers used in agricultural practice. The agricultural activities in the areas was reported to be potentially high and obviously the use of nitrate fertilizer was also high.

b) **Chemical analysis of stone samples:**

The chemical analysis of stone sample from riverbed of of Hathmati at Himatnagar has revealed that the stone does not contain high amount of nitrate. The value reportes was 36 mg/l only. Hence the possibility of leaching of nitrate from the river bed stone strata to the ground waters on both banks was ruled out.

c) **Health effects :**

In the health survey, the civil surgeon of the district as well as leading paediatricians of the area were contacted to know about the prevalence of methaemoglobinaemia in the district. It was revealed that no such incidence is reported with either the civil hospital or the private dispensories.

d) **Conclusion :**

From the study it could be concluded that the local soil strata do not contain the inherent nitrate contents. But it is presumed that the excessive amount of nitrate is coming from agricultural use of fertilizers. It could also be concluded that the high amount of nitrate has no adverse effect on the health of humanbeings including infants. The reasons for this are not known and is a subject of clinical research.

9.10 Preventive Measures

Based on the medical studies done on nitrate poisoning and experiences gained in different countries to prevent cases of methaemoglobinaemia, following recommendations are made, towards public health action and medical treatment.

- Breast feeding of babies minimises the chances of their suffering from methaemoglobinaemia to a great extent. If that is not possible, cows milk should be used. The milk should be free from bacterial contamination.
- In areas where water supply has high nitrates, use of tinned milk or food for babies must be banned.
- The babies should be provided food containing ascorbic acid or vitamin-C such as orange, juice, as it increases the immunity to the disease.
- Green vegetables, especially spinach and cabbage should not be given to babies in any form.
- Addition of 0.5 to 1.0% lactic acid as the final concentration to infant feed prevents the disease.
- The medical authorities should be cautioned of the risks of the disease, where these exists. They should not give drugs containing nitrates and nitrites to babies, especially in case of diarrhoeal diseases.

- As soon as the case of the disease is detected, the nitrate should be eliminated from the diet of infants and the diseased baby should be given injection of methylene-blue.
- Educational programme and demonstration should be given to mothers and pediatricians telling them effects of high nitrates in water.

9.11 Treatment Technologies

When nitrates are excessive in drinking water sources, they pose problem to the authorities who supply water to the communities. As water having nitrates in excess to permissible limit cannot be supplied to the communities, the authorities have to think of some other alternatives. For supply of water with reduced nitrate content for drinking purposes, following alternative measures can be considered.

9.11.1 Source Developmnet

- Procurement of water from other sources totally or partially
- New tapping of ground water with low nitrate content by constructing new wells in nitrate free zone or tapping of water from higher depth.

9.11.2 Hydro-technical methods

- Biological methods including autotropic denitrification with hydrogen and neterotrophic denitrification with organic substrate.
- Sub soil denitrification
- Physico-chemical methods such as ion-exchange and desalination
- Elimination by high nitrate consuming vegetation.

9.11.3 Dilution

- Dilution by mixing eith nitrogen free water can also be cosidered if possible.

No treatment for removal of nitrates from drinking water is known to be practised in Gujarat or even in India. However due to its increasing trend, time may come when we have to think of some economically viable treatment.

So far follwoing four methods have received attention for removing nitrates from water.

9.11.4 Chemical reduction :

The possibility of reducing nitrates chemically using ferrous hydroxide has been experimented. The reduction was found to require the presence of 1 to 5 ppm of cupric or silver ions as catalyst. The optimum pH involving the precipitation of the iron as ferrous hydroxide was found to be about 8. However, this method was not economical and attractive. Very close control of treatment conditions made the process unfeasible.

9.11.5 Biological denitrification

It has been extensively studied in its application to the purification of waste waters and sewage effluents. In the presence of an organic substrate, denitrifying bacteria can reduce nitrates to nitrogen gas. The most frequently used substrate is methanol because it is both cheap and effective.

In this process both nitrite and nitrate are reduced to gaseous nitrogen in an anaerobic environment. The micro organisms use the oxygen out of Nitrate and Nitrite for the purpose of carbon oxidation. Methanol, an oroganic carbon source is used as hydrogen donor. (oxygen acceptor).

$3O_2 + 2CH_3OH \text{ -------->} \ 2CO_2 + 4H_2O$

$6NO_3^- + 5CH_3OH \text{ -------->} \ 2H_2CO_3 \xrightarrow{\text{Bacteria}} 2N_2 \uparrow + 6HCO_3^- + 8H_2O$

In a generalised form

$$NO_3 + 5H^+ \xrightarrow{\text{Bacteria}} 1/2\,N_2 + H_2O + OH^-$$

9.11.6. Ion-exchange

It is the only method which is currently used to remove nitrates from water in the treatment plants. Some basic anion exchange resins are nitrate selective and can reduce the nitrate concentration substantially. Ion exchange appears to be simple in use and offers good reproducibility.

9.11.7 Desalination

As nitrates are often associated with high Total Dissolved Solids, the statandard technology applied for desalination are Reverse Osmosis and Electrodialysis can also be applied for this work with some limitations.

It must be kept in mind that the cost of such treatment will be high and it will vary according to place and solution and will be quite uneconomic for small supplies. Hence treatment should be considered as a last resort.

9.12 References

1) **Occurrence of Nitrate in Drinking Water of Gujarat State** - by S.M. Vaijnapurkar, ME(PH) thesis at BVM Engg. College, V.V. Nagar- 388120.

2) **Nitrates and Nitrites in the Environment - An overview** - By S.P. Pande et.al. Journal of IWWA - July-Sept.1986.

3) **Nitrate and Nitrite** - Chapter 13 of WHO guidelines on drinking water.

4) **Nitrate and Nitrite** - from a book on "Quality criteria for water".

5) **Nitrate - A serious threat to Ground water pollution** - By K.R. Bulusu et.al. Journal of IWWA - April-June 1990.

6) **Ground water pollution by Onsite waste water systems** - By T Viraraghavan - Journal of IWWA - April-June 1990.

Table : 9.1
Districtwise villages having high amount (>100 mg/l) of Nitrate

Sr No	District	Total Villages	Villages Having highNitrate (>100 mg/l)	
			A (1989-90)	B (1992-93)
1	Ahmedabad	656	2	3
2	Amreli	595	6	None
3	Banashkantha	1375	66	8
4	Bharuch	1123	23	35
5	Bhavnagar	876	7	85
6	Dangs	311	None	None
7	Gandhinagar	98	None	None
8	Jamnagar	750	10	20
9	Junagadh	1148	5	6
10	Kheda	973	34	98
11	Kutch	948	8	None
12	Mehsana	1089	82	8
13	Panchmahal	1895	36	54
14	Rajkot	856	8	12
15	Sabarkantha	1384	37	20
16	Surat	1190	6	22
17	Surendranagar	651	56	1
18	Vadodara	1651	26	36
19	Valsad	822	3	8

Source :

A As reported by Mr S M Vaijanapurkar in his ME (PH) dissertation thesis from BVM Engineering College, Vallabh Vidyanagar - 1990-91

B As revealed in the Survey carried out by GWSSB, Gandhinagar under Rajeev Gandhi National Drinking Mission in 1992-93

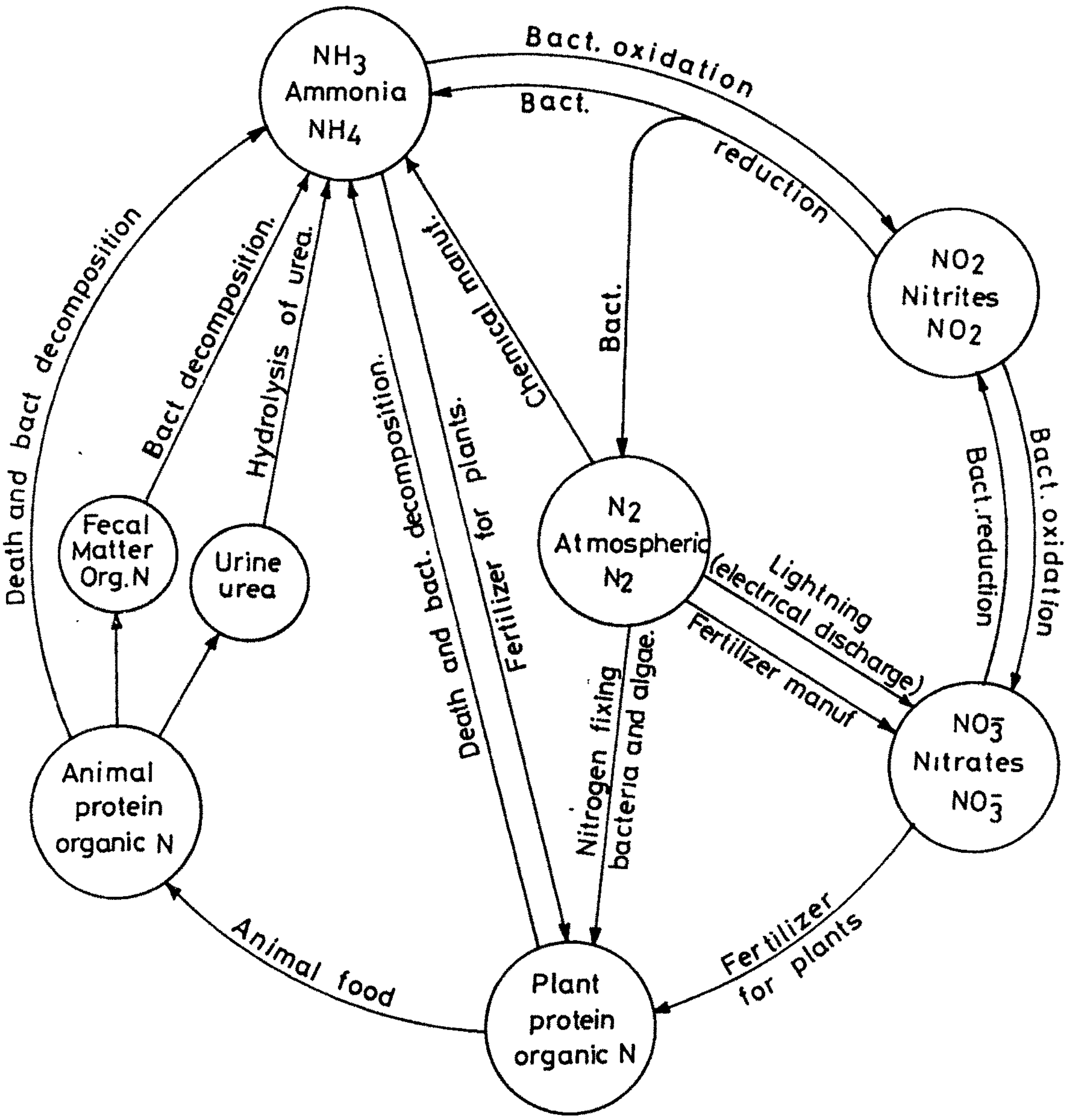
Table : 9.2

Nitrate content (in mg/l as NO_3) observed in the study carried out by the author (1987-88)

Sr No	Location	Village/ City	Taluka	District	NO_3 (mg/l)
1	Milrampura	Walli	Khambhat	Kheda	4.4
2	Lake Water	Saputara	Ahwa	Dangs	2.2
3	Hand Pump	Malegao	Ahwa	Dangs	6.7
4	Satrunji Dam Site	Gariadhar	Palitana	Bhavnagar	17.7
5	Nimeta Head Works	Ajawa	Vaghodia	Vadodara	5.0
6	ESR	Jangaral	Patan	Mehsana	33.2
7	Head Works	Mehsana City	Mehsana	Mehsana	65.4
8	ESR on GH Road	Gandhinagar	Gandginagar	Gandhinagar	1.6
9	Head Works	Kevadia	Rajpipala	Bharuch	2.2
10	WT Plant	Jamnagar	Jamnagar	Jamnagar	3.3
11	Sabarmati Scheme	Vataman	Bavla	Ahmedabad	1.3
12	Mahi French Well	Vadodara City	Vadodara	Vadodara	3.9
13	Tap Water	Amreli City	Amreli	Amreli	10.0
14	Dhadhodar Head Works	Barwala	Dhandhuka	Ahmedabad	31.0
15	Scheme Head Works	Vaghania	Lilia	Amreli	33.2
16	CZBT Head Works	Palej	Bharuch	Bharuch	7.8
17	Dam Site	Ukai	Songadh-Vyara	Surat	Nil
18	Head Works	Kalol City	Kalol	Mehsana	63
19	Head works (HW)	Akhol	Deesa	Banashkantha	22.2
20	Santalpur Scheme (HW)	Shihori	Shihori	Banashkantha	6.65
21	Dudheshwar (HW)	Ahmedabad	Ahmedabad	Ahmedabad	16.0

Table II Continued

22	SZBT Head works	Ankleshwar	Ankleshwar	Bharuch	3.5
23	Varachha (HW)	Surat City	Surat	Surat	3.5
24	River -Damanganga	Silvas	Dadara Nagar	Dadra Nagar	Nil
25	. ESR - Kalyanbag	Valsad-City	Valsad	Valsad	1.77
26	Tap Water	Pij	Nadiad	Kheda	45
27	Tap Water	Bhuj City	Bhuj	Bhuj	16.4
28	RWSS - Banni (HW)	Khavda Fatak	Bhuj	Bhuj	2.2
29	RWWS - Shilakha(HW)	Kumbharia	Rapar	Bhuj	1.1
30	ESR	Godhara City	Godhara	Panchmahal	5.1
31	Tap Water (Nyari Zone)	Rajkot City	Rajkot	Rajkot	0.11
32	Tap water (Aji Zone)	Rajkot City	Rajkot	Rajkot	0.11
33	Tap water	Dabhoi Town	Dabhoi	Vadodara	4.4
34	Private Hand Pump	Idar Town	Ider	Sabarkantha	84
35	ESR in Mun. Gardan	Himatnagar	Himatnagar	Sabarkantha	99
36	Public Well	Kapurai	Dabhoi	Vadodara	2.2
37	Artisen Well	Dholera	Dhandhuka	Ahmedabad	Nil
38	Kalubhar Head Works	Ranghola	Lathi	Amreli	Nil
39	Umara Head works	Jambusar	Bharuch	Bharuch	8.86



THE NITROGEN CYCLE.

Annexure 9·2

MAP OF GUJARAT SHOWING DISTRIBUTION OF FLUORIDES AND NITRATES IN GROUND WATER FROM PHREATIC AQUIFER

PERIOD 1987 TO 1988