

**IMPACT OF URBANIZATION ON SURFACE AND GROUND
WATER QUALITY- A CASE STUDY**

B K PURANDARA
N VARDARAJAN

**NATIONAL INSTITUTE OF HYDROLOGY
HARD ROCK REGIONAL CENTER
BELAGAVI
2015-2016**

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Water is an Elixir of life. This is next to air and the most important requirement for human life to exist. It is available in various forms such as rivers, lakes and streams etc. The importance of water in human life is so much that the development of any city of the world has practically taken place near some source of water supply. It may also further be noted that the water is available in solid, liquid and gas forms. The occurrence of water in all these three forms is basically important for human beings for comfort, luxury and various other necessities of life.

The use of water by man, plants and animals is universal. As a matter of fact, every living soul requires water for its survival. It is essential for life, health and sanitation. It is the principal raw material for production and for many other uses outside the home and the farm. The man can live without food for about 2 months but he can hardly survive for 3 or 4 days without water. In a similar way, if there is a shortage of water, there will be a decline in farm production, just like a shortage of steel will lead to the decrease in the production of automobiles

In addition to the direct consumption of water at homes and farms, there are many indirect ways in which water affects our daily life. The water plays an important role in the manufacture of essential commodities, generation of electric power, transportation, recreation, industrial activities etc., thus the water can be considered as the most important raw material of civilization because of the fact that without water, the man cannot live and industry cannot operate. With our growing population and industrial developments, the demand of water is also increasing day by day and hence every count has to take preventive measures to avoid man made pollution and contamination of the available water resources.

The water resources are certainly inexhaustible gift of nature. But to ensure their services for all the time to come it becomes necessary to maintain, conserve and use these resources will definitely avoid the chances of water famine for future generation for an indefinite period. It is for this reason that remedial measures will have to be found out in future to increase available water resources and to improve the quality of water.

1.2 VEDIC CONCEPT:

The Vedic civilization was adapted by Aryans who entered India about 2000BC from central Asia (around Caspian sea) They worshipped “PANCHATATWA” as forms of a divine forces. The hymn from the Veda , which is enough to prove the importance of Panchatatwa is

“SADYOJATODBHAVA BHUMI VAMADEVODBHAVAM JALA AGHORAT
AGNIRUTPANNA TATPURUSHAT VAYURUTPANNAHAISHANT GAGANAM
JATAM PANCHABRAHAMAYAM JAGAT”

The Vedas have revealed the mystery of the universe about 2000BC years ago and found out the source of the energy which is driving force in the ecosystem. The driving force of the ecosystem was recognized in the five forms as **Pruthvi, Apo, Agni, Vayu and Akash.**

1.2.1 The hymn from Rig Veda is-

“YA APO DIYA” (those waters which have come from heaven)

“UTA VA SRAVANTI” (or those which flow)

“KHANITRIMA ” (those which come from digging)

“UTA VA YAH SWAYAMJAH ”(or those which of their own accord ooze out as springs)

“SAMUDRATHA”(spreading towards the oceans)

“YAH SUCAYAH PAVAKSTA”(those which are bright and pure)

“APO DEVEEH IHA MAMAVANTU”(may those divine water protect me)

This hymn reflects on the culture of our ancestors and their respect to the nature’s gift. The water available on earth was termed as “APU”. It is sensed by ear, skin, eye and tongue and termed as liquid. It is not having any smell thus it is beyond the reach of nose. When the ‘PRUTHVI’ loses one of its properties of smell, then it loses its independent shape and starts flowing. This water was respected as Divine Gift.

1.2.2 QURANIC CONCEPT: The Holy Quran talks about the creation of human beings from water.

“ALLAH! CREATED EVERY (LIVING) CREATURE FROM WATER, SOME OF THEM GO ON THEIR BELLIES, SOME OF THEM ON TWO LEGS, AND SOME OF THEM ON FOUR, ALLAH! CREATES WHATEVER HE WILLS ALLAH! HAS POWER OVER ALL THINGS ”(QURAN, SURAH AL-NOOR 24:45)

“DO THOSE WHO DISBELIVE NOT SEE THAT THE HEAVENS AND THE EARTH WERE SEWEN TOGETHER AND THEN WE UN-STITCHED THEM AND THAT WE MADE FROM WATER EVERY LIVING THING SO WILL THEY NOT BELIEVE?”(QURAN, SURAH AL-AMBIYA 21:30)

“AND IT IS HE WHO CREATED HUMAN BEINGS FROM WATER AND THEN GAVE THEM RELATIONS BY BLOOD AND MARRIAGE. YOUR LORD IS ALL POWERFUL”(QURAN,SURAH AL-FUQHAN 25:54)

1.3 MEANING OF PURE WATER: The water required for public water supply schemes should be potable or wholesome water, i.e. fit for drinking purposes. It is however not essential to have physically or chemically pure water.

The presence of some minerals in water is required to give some taste to the water i.e. to make it palatable and they also assist in food assimilation. It will be difficult, time consuming and costly to have complete purification of the water.

The impurities in water are to be removed to a certain extent only. So that it does not prove harmful to the public health. The term wholesome water is used to indicate the water which is not chemically pure, but does not contain anything harmful to the human body i.e. the water in which there are no pathogenic bacteria, no toxic substances and no excessive organic matter. Thus the wholesomeness is a must while the palatability of water is desirable. The term pure water is a relative term and it has to be interpreted in relation to the use of water. The concept of pure water, potable water or wholesome water with relation to various uses of water is understood.

The total quantity of water in the world is estimated to be about 1386 million cubic kilometers. About 96.5% of this water is contained in the oceans as saline water. Some of the water on land amounting to about 1% of the total water is also saline. So the fresh water available is around

2.5% out of this 68.6% is in the form of polar ice in a frozen form in the polar regions and on the mountain tops and glaciers. 30.1% is in the form of ground water. Only 1.3% is available as surface water in the form of rivers, lakes and marshes etc....

Over the oceans about 9% more water evaporates than that falls back as precipitation. Correspondingly there will be excess precipitation over evaporation on the land mass. It is interesting to note that less than 4% of this total river flow is used for irrigation and the rest flows down to sea. Indian sub-continent, the long term average runoff for India is about to be 46%. India's largest river, the Brahmaputra and the second largest the Ganga flow into the Bay of Bengal with a mean annual average discharge of 16,200 cubic meter per sec and 15,600 cubic meter per sec respectively.

1.4 WATER IS PRECIOUS AND SCARCE RESOURCE

Only a small fraction (about 3%) is fresh water. India is wettest country in the world, but rainfall is highly uneven with time and space (with extremely low in Rajasthan and high in North-East) On an average there are only 40 rainy days Out of 4000 BCM rainfall received, about 600 BCM is put to use so far. Water resources are over-exploited bringing more and more water quality issues in various parts of the world and also in our country. The environmental consequences of industrialization and intensification of agriculture have, for a long time, been neglected and unfortunately still are in many parts of the world. Global Environment Outlook report (2000) produced by the United Nations Environment Program (UNEP) included the following statistics:

- Already one person in five has no access to safe drinking water
- Polluted water affects the health of 1.2 billion people every year, and contributes to the death of 15 million children less than 5 years of age every year
- Three million people die every year from diarrhea diseases (such as cholera and dysentery) caused by contaminated water
- Vector-borne diseases, such as malaria, kill another 1.5 – million people per year, with inadequate
- Water management a key cause of such diseases.

1.5 THE NEW PARADIGM OF WATER QUALITY

- In water resources management water quality plays an increasingly important role, just as important as that of water quantity.
- In fact, as pollution of surface, coastal and groundwater increases, it has become essential to adopt an integrated approach encompassing both water quantity and quality (Fig.1.1).

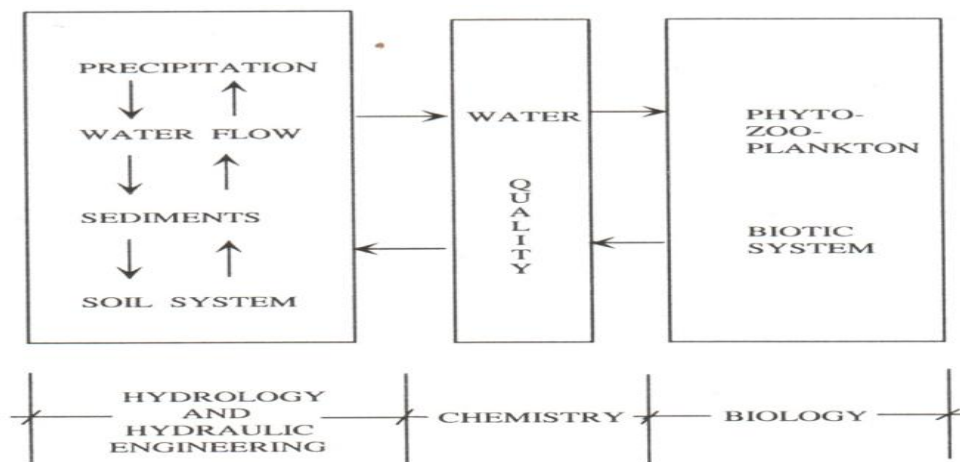


Fig.1.1: The New Paradigm Of Water Quality

1.6 GROUND WATER POLLUTION

Ground water is an economic resource and more than 85% of the public water supplies are obtained from wells. Ground water supplies for rural areas have certain advantages over surface water. The supply is invariably close at hand, the water is of more uniform character and relatively free from harmful bacteria, and can be developed at a small capital cost in a short time. Ground water may become contaminated due to improper disposal of liquid wastes, defective well construction and failure to seal the abandoned wells. These provide possible opening for the downward movement of water into subsurface formation without the process of natural filtration. Contamination may also take place through movement of waste water through large openings such as animal burrows, fissures on rock, coarse gravel formation or manmade excavations. Contaminated ground water may appear clear and yet contain pathogenic organisms. Bacteria from liquid effluents from septic tanks, cess pools, pit privies etc., are likely to contaminate shallow ground water aquifers. Sewage effluents discharged

directly into water-bearing formations through abandoned wells or soil absorption systems contaminate the ground water.

The depth of the water table below ground level is a governing factor in determining pollution since, as the water table approaches nearer the ground surface, the greater is the risk of contamination. The area around the well should be protected—either uncultivated or simply laid down to pasture. The number of harmful organisms is generally reduced to tolerable levels by percolation of water through 2—3m of fine grained soil.

Bacterial and viral contamination are among the most significant health hazards that must be considered in protecting water quality. Bacteria also affect ground water quality indirectly in beneficial ways. Studies of bacteria and virus in ground water system have suggested that these organisms may travel only short distance in sand aquifers but long distances in short periods of time in more porous and permeable aquifers. The source of pollution of ground water can be traced by chemical and bacteriological methods. The most common chemicals used for tracing pollution are the dyes which may be added as concentrated solutions, to give coloration of water even when diluted several millions times. A strong alkaline solution of Fluoresine is the commonly used dye and should be used with care. Where turbid water is to be investigated, the red dye Rhoda mine B may be employed for the detection of leaks from drains. Either of these liquids may be poured, in some quantity, on the ground surface around the well and pump pipe. If the inside of the well is illuminated, one can observe the indicator slowly trickling into the well. The quicker the advent of the test liquid, the greater is the opportunity for pollution. Common salt and sodium phosphate can also be used as tracers. Several different bacteria have been successfully used as tracers. *Serratiamarcescens* is easily identified by the red color of its colonies when it is cultured. Strains of aerogenes—like bacteria which ferment lactose at 44°C may also be used under certain selected condition as test organisms. Whichever chemical or organism is used, it must first be established that it does not appear naturally in water which is under investigation. When ground water wells are constructed, proper sanitary protection should be provided against surface contamination. A well should be located at a safe distance from all possible source of contamination. Some recommended distance are given in table.1.1 as a guide

Table 1.1: Recommended minimum distance between a ground water well and source of contamination

Contamination source	Recommended source (m)
Building sewer	15
Septic tank	15
Disposal field	30
Seepage pit	30
Cess pool	45

The well site should be prevented from being flooded and should be graded so as to facilitate the rapid drainage of surface water away from the well. The area should be filled if necessary and maintained to prevent the accumulation or retention of surface water within a radius of 15m from the well. For a well on a hill side, adequate intercepting ditches should be constructed on the uphill side of the well in order to keep the runoff at least 15m away in all direction. Pump platforms, pump floors or well covers should be located at least 60cm above the maximum flood level. The annular space around the casing should be filled with neat cement grout. In addition to protecting the supply against surface pollution grouting also serves to provide a protective sheath around the casing against corrosion, to seal off water of unsuitable chemical quality in strata above the desirable water bearing formation and to stabilize soil or rock formation which are of a caving nature. The ratio of water to cement for a suitable cement grout is 22 to 27 liters per 50kg bag of cement, which will keep shrinkage to a minimum. Bentonite (3% by weight of cement) may be added to reduce shrinkage and improve fluidity of the mixture. Bentonite and water should be mixed first and cement added to the clay- water suspension. The water used in mixing the slurry should meet reasonable standards for drinking water. The top of the casing should be extended at least 60cm above the general level of the surrounding surface. Wherever possible, a concrete platform should be constructed around the casing at the ground surface. The top of the casing should then be provided with a sanitary well seal to fill the annular space between the pump column pipe and well casing. The sanitary well seal consists of suitable bushing or packing glands making a

water-tight seal at the top of the casing. If the pump is not installed immediately after the construction of the well, the top of the casing should be securely closed with a metal cap either screwed or tack welded in place. After installing the pump, the well and its appurtenances including casing, pump and pipe systems should be disinfected thoroughly in order to kill any pathogenic organisms that may be present. A solution containing about 100ppm of available chlorine is the simplest and most effective agent for disinfecting the well and its appurtenances. Pump room floors should drain outside. The pump house should be well lighted and ventilated. It is desirable to provide a water sampling tap on the discharge line from the pump which can also be used for releasing ant trapped air in the system.

Abandoned wells should be properly sealed to prevent the ingress of surface waters and the sealing materials include concrete, cement grout, neat cement, clay, sand or a combination of these materials.

1.7 MAIN FACTORS AFFECTING QUALITY OF GROUND WATER

- a. Salt water intrusion
- b. Organic, and inorganic and heat pollution by sewage and industrial wastes
- c. Pollution of good quality aquifers by bad quality aquifers because of faulty construction method

Sea water intrusion can be halted or prevented by maintenance of ground water levels well above sea level. This can be accomplished by reducing ground water extractions, modifying the pumping patterns and also by augmenting the natural replenishment by artificial recharge of local or imported water supplies. Another approach to control sea water intrusion is to form a subsurface dam by constructing a cut-off wall of sheet pile, concrete or puddled clay. An impervious zone, to prevent ground water movement in the aquifer, might also be created by injection of cement grout, emulsified asphalt, bentonite, silica gel, calcium acrylate or suitable plastics. A series of spreading grounds or injection wells, or a combination of both, could be utilized, along the coast as dictated by the geological condition encountered to create a ground water mound or ridge. The fresh water utilized to maintain the ridge augments recharge to the ground water basin which is available for re-use. A pumping trough can be developed by a line of pumping wells, properly spaced along the coast. These wells produce a mixture of saline and fresh water resulting in waste of considerable quantities of fresh water

The pumping costs involved and waste of otherwise usable water are major factors to be considered in evaluating the practicability of protecting a ground water basin by maintaining a pumping trough.

In locations downstream from heavily irrigated areas, the water may be too saline for satisfactory crop production. The removal of salinity is exceedingly expensive. A possible solution is to dilute with waters to lower salt concentration so that the resulting water after mixing is suitable for use.

There is need for understanding pollution as a first step for its evaluation and control. The hydrologic environments that cause pollution include the interdependence of factors such as permeability, adsorption, hydraulic gradient, position of water table and distance from contamination source. Waste disposal and salinity are the two major sources of pollution.

1.7.1 Urban Pollution

- a. Recharge by effluent spreading and injection gypsum, saliness and exchangeable Na on the substrata cause percolating waters of poor quality.
- b. Municipal dumps and sanitary landfills—should be located on relatively impermeable material to retard leachate movement; proper site topography is important to avoid surface drainage contamination; lime stone quarries, sand and gravel pits and poorly drained swampy areas make poor sites.
- c. Road salts—chloride ions from runoff from road deicing salts cause high chlorinity in ground water.
- d. Septic tanks— a potential source of N and P contamination due to effluent discharge by means of tile drains and seepage pits, hence extreme care should be exercised in locating septic tanks.

1.7.2 Industrial Pollution

- a. Industrial waste disposal—solid and liquid effluents.
- b. Petroleum products—brines, crude oil gas may infiltrate and pollute ground water; improved control methods for safe and permanent disposal are necessary.

- c. Metal waste—the seepage of plating waste containing Cd. and hexavalent Cr. pollute ground water; pretreatment facilities should be installed prior to disposal of waste.
- d. Mines—oxidation and leaching of mine drainage produce high Fe and SO₄ concentrations and low pH in ground water.
- e. Oil field brines—highly mineralized contaminants resulting from subsurface disposal of oil field brines, poor casing or cementing in oil wells, abandoned wells not properly plugged and seepage from unlined pits used for brine disposal. Prohibition of brine injection into oil wells which permit upward migration, discontinuance of unlined disposal pits and periodic tracer surveys on all disposal wells are some possible control methods.

1.7.3 Agriculture Pollution

- a. Agricultural wastes—plant residues.
- b. Animal wastes—infiltration of nitrates from manures cause pollution. Liquid manure can be disposed by water spreading irrigation system utilizing the soil and plant cover for treatment, sometimes preceded by the use of aerobic and anaerobic lagoons.
- c. Irrigation return flow—saline waste waters (Ca, SO₄, HCO₃ & Cl ions dominate), Nitrate—Nitrogen dominating due to leaching of percolating irrigation water from feed lots, dairies, and septic tank drain fields in the area, cause pollution.
- d. Fertilizers, pesticides and herbicides—due to soil adsorption and movement to water table.

1.7.4 Pollution from Wells

- a. Disposal wells—wells drilled for the disposal of industrial wastes become clogged, losing their efficiency to absorb waste; drainage wells should be discouraged, the effective alternative being municipal sewerage, surface and sub surface soil adsorption systems, and sedimentation—recirculation systems.
- b. Injection well—for disposal of liquid wastes by deep well injection; salt water, industrial wastes and radioactive wastes are amenable to deep well disposal.
- c. Recharge well—fresh and degraded water with settled sewage injected at various rates.

- d. Poorly constructed and abandoned wells: poor quality water and/or aquifers should be excluded.

1.7.5 Pollution from Salt water and Surface water

- a. Salt water intrusion—due to (i) reduction or reversal of ground water gradients,(ii) damage caused to natural barriers to salt water movement, (iii) accidental or inadvertent disposal of waste saline water.
- b. Surface water contamination—Effluent discharged into a river above the water supply aquifer and concentration of pollutions.
- c. Bacteria and viruses—due to waterborne outbreaks of viral diseases, effluent from subsurface waste water disposal system, recharge of large basins with reclaimed sewage.
- d. Synthetic detergents—chemical and bacteriological contamination due to proximity of sewage disposal units (septic tanks).

1.8 Pollution Evaluation

- a. Pollution travel—(i) Tracers of salt, sodium, fluorescein dye and tritium are used to determine the rate, directions, recharge and discharge, quality and quantity of ground water. (ii)Chemical pollutants are found to travel with moisture fronts; fine materials are effective in filtering bacteria within a meter of leach bed.(iii)the clogging phenomenon is dependent upon microbial activity and food supply in sewage.(iv)straining of pathogens at the soil surface and the sorption of viruses near the surface are the most effective limitations of pathogen travel.
- b. Pollution monitoring—special problem include spatial and temporal quantity variation and constituents (dissolved minerals, bacteria, radioactivity, oxygen content) and minimal surveillance requirements (observation wells versus outflow sampling). Monitoring methods include: temperature probes, liquid scintillation counting or gas counting, CI and EC measurement on samples, water quality indicators and earth resistivity measurements (when a resistivity contrast exists between the contaminated and uncontaminated ground water).

1.9 Pathogen Characteristics

Pathogens are defined as disease-causing organisms, of which human excreta may contain four major types: worm eggs, protozoa, bacteria and viruses. Eggs and protozoa are effectively screened by soil during groundwater flow, so bacteria and viruses, which are much smaller, are the main focus of concern. Individuals excrete around 10⁹ bacteria /gram of feces, the vast majority of which are not pathogenic. An infected individual can excrete up to 10⁶ viruses per gram of feces.

Over 50 percent of the United States population utilizes groundwater as its drinking water source. Approximately 96 percent of the groundwater users live in small rural areas often utilizing small individual wells, where the resources for treatment and monitoring are limited. Consequently, groundwater contamination caused by pathogens or chemicals often remains undetected. This failure to detect groundwater contamination is due to the existence of a large number of wells and high cost of sample analysis. In the state of Illinois alone, there are 3400 public supply wells and about 500,000 private wells. The average cost of an organics scan of the sample in 1981 was approximately 1000 dollars per sample.

1.9.1 Organisms

In 1984, Craun stated that "contaminated water causes almost half of the outbreaks of water-borne diseases each year in the United States" (Craun, 1979, 1984). The organisms most responsible for water borne diseases include: bacteria such as Salmonella and vibrio, viruses such as hepatitis virus and poliovirus, and protozoa such as Cryptosporidium and Giardia (Teutsch, 1991, Brock, 1994). Defective and improperly designed or installed septic tanks, sewage sludge land applications, undetected sewage system leakage, and improperly maintained and enclosed bioremediation sites are the major sources for pathogens in groundwater (Gallagher, 1996, Teutsch, 1991, Abu-Ashour, 1994).

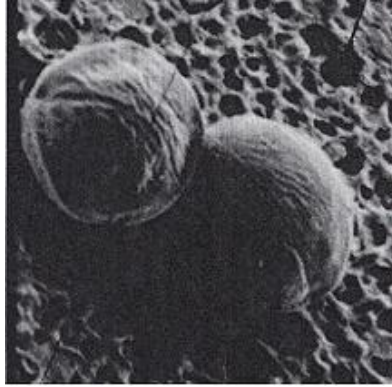


Fig.1.2: An overview of cryptosporidium

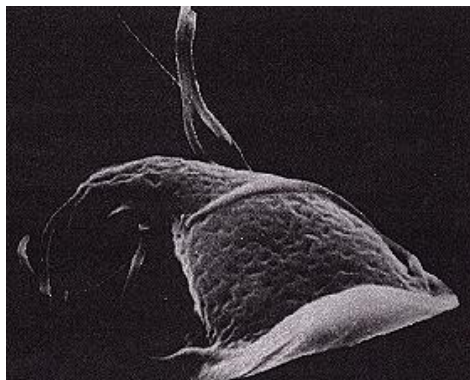


Fig.1.3: An overview of Giardia

1.9.2 Survival and Transport

Two factors determine whether or not the groundwater will become contaminated with pathogens, i.e. survival and transport rate of pathogens within the system. The survival rate is influenced by the environmental conditions, the physical and chemical properties of water and soil in the system, as well as the identity and physiological state of the organisms. The transport of pathogens is affected by the physical and chemical properties of water and soil, hydrology of the system, and microbial characteristics (Teutsch, 1991, Abu-Ashour, 1994).

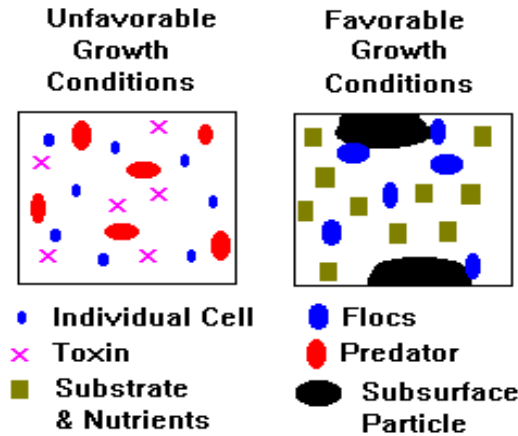


Fig.1.4: Factors Affecting Growth and Survival of Pathogen

The properties and conditions of the surrounding environment control the identity and physiological state of the microorganisms which influences the survival and transport capabilities of the organisms. One important characteristic of the organisms is their ability to compete for substrate and nutrients. In general, an organism will have a shorter survival time in the presence of its predators or in the presence of competing organisms, where the resources (substrate, nutrients) become limited. Flocculation forming organisms will have an increased chance for survival because of the protection and opportunity to share resources within the flock. The ability to survive and transport will be affected by the size of the individual organism or its flock. Transport will be influenced by the size of other members of the population by limiting the pore spaces the organism is able to move through without encountering blockage (Teutsch, 1991, Abu-Ashour, 1994).

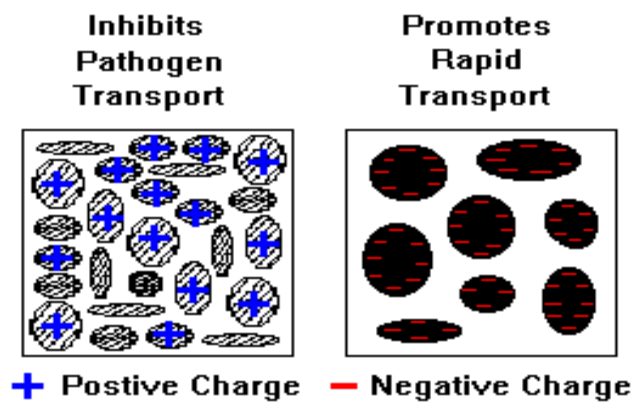


Fig.1.5: Factors Affecting Movement and Sorption of Pathogens

The physical and chemical characteristics of water and soil have a great influence on the survival and transport of the microorganisms, as indicated above. Pathogens generally survive longer in waters and soils where organic matter is readily available; organic matter can provide substrate and nutrients to the organisms. However, toxic organic matter such as antibiotics will decrease the survival rate of organisms. Microorganisms thrive in moisture rich soils, because water is the means of substrate and nutrient transport as well as organism transport. The Ph of the environment is an important variable; ph affects the solubility of compounds and the charge distribution in the system, which affects the adsorption of organisms on to the soil. The advantages of soil adsorption, similar to the flock formation advantages, include protection and nutrient and substrate sharing by the organisms. In addition to ph, adsorption is also affected by the soil type, texture, particle size, distribution and pore size distribution (Teutsch, 1991, Abu-Ashour, 1994). The entire above are related to the surface charges and surface area available for adsorption as illustrated in the figures.

The environmental characteristics that affect the microorganism's survival and transport include: temperature, water content, hydrology of the area and application methods of organisms to the system. Temperature affects the die-off rate of the organisms, especially in viruses. Higher temperature has increased die-off rate of the organisms while lower temperature has lower die-off rates. Temperature also affects the density and viscosity of water altering the water velocity (Teutsch, 1991). An increase in temperature will also cause increased molecular diffusion. The water content and the hydrology affect the water velocities and direction of flow in the ground. The route and ground frequency of organism's introduction to the soil determines the number of organisms in the ground water system (Abu-Ashour, 1994). For example, a onetime contamination from a defective septic tank will result in a lower number of microorganisms in the soil than frequent contamination of soil by the land application of sludge.

1.9.3 Modeling

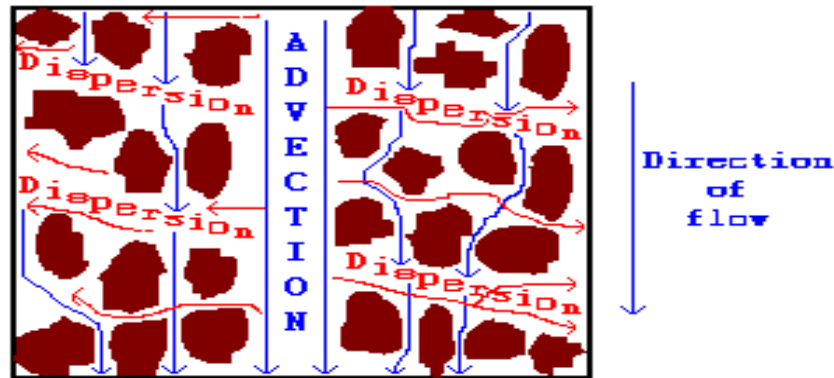


Fig.1.6: Schematic representation of Advection and Dispersion

Many researchers have attempted to predict the transport of microorganisms in groundwater using mathematical models. The models are based on two transport mechanisms: advection and dispersion. Advection is defined as the movement of organisms carried by water in the direction of flow. Dispersion is the movement of organisms carried by water in direction other than that of the flow. Dispersion is defined by the sum of molecular diffusion and mechanical mixing effects in the system. The advection term in the transport equation is controlled by the average linear velocity of the groundwater. Pathogen transport is directly proportional to the groundwater velocity: an increase in velocity will result in greater pathogen transport. Many factors affect the dispersion of pathogens or contaminants in the subsurface. The fig.1.7 below depicts three factors affecting dispersion.

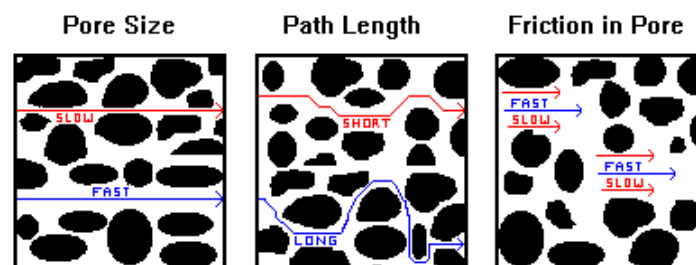


Fig1.7: Factors Affecting Dispersion

The following factors are included in the mass conservation equations used to model the fate of microorganisms in the subsurface. Growth of the organisms is represented using Monod kinetics. Filtration of the organisms, which is related to pore blockage and size of organisms and flocks, is typically represented by a first order function. Adsorption is represented by isotherm models such as the linear, Freundlich, or Langmuir isotherms. High adsorption to the subsurface particles will reduce the transport of pathogens while low adsorption will minimally affect the transport. The adsorption effect is depicted in the fig.1.8 below.

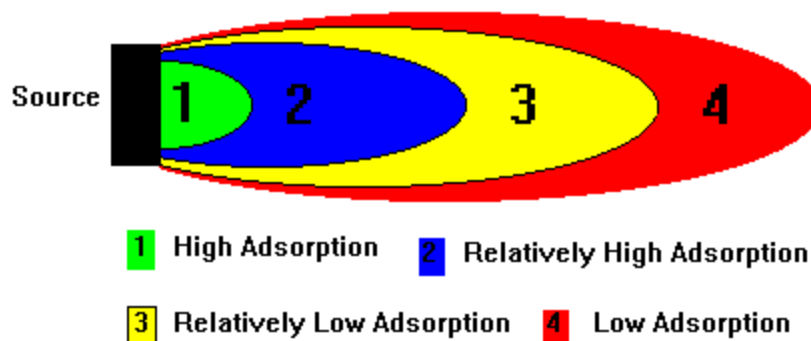


Fig.1.8: Adsorption Effects on Pathogen Transport

The typical assumptions in these models include (Abu-Ashour, 1994):

- 1 homogeneous and isotropic soil
- 2 steady flow
- 3 Darcy's Law
- 4 flow in one dimension
- 5 thermodynamic equilibrium between sorbed and aqueous states exists

There are many problems with the above approach. The models assume that organisms have as a dissolved contaminant, while their behavior is closer to a colloidal model. They do not include changes in porosity and permeability due the presence of organisms. Most of the studies lack of accurate fundamental hydraulic parameters needed in the mathematical

models. In addition, studies rely on dye traces, which do not provide accurate representation of organism flow (Harvey, 1995, Fontes, 1991).

1.10 GROUNDWATER POLLUTION FROM ON-SITE SANITATION

The risks of aquifer pollution are substantially affected by groundwater hydrology. Aquifers (water-bearing layers of soil) lie in the saturated zone below the water table. Soil above the water table is unsaturated with water, and is classified as part of the unsaturated zone.

Pathogens do not travel farther or faster than the water in which they are suspended.

Water flows very slowly in the unsaturated zone, as flow is along a thin and tortuous path along the surface of soil particles. Flow is much more rapid in the saturated zone, as water flows directly through the soil pores. Most on-site sanitation systems depend upon the capacity of the soils in the unsaturated zone to accept and purify effluent. ***The key factor that affects the removal and elimination of bacteria and viruses from groundwater is thus the maximisation of the effluent residence time between the source of contamination and the point of water abstraction. Because of the very low velocities of unsaturated flow, the unsaturated zone is the most important line of defence against faecal pollution of aquifers.***

Commonly used guidelines in many soil conditions keep the bottom of the pit at least 2 m above the water table, and at least 15 m from any well used for drinking purposes. In some areas, however, such criteria cannot be met, or the soil conditions (such as fissured limestone) do not assure groundwater protection when such guidelines are followed. In these cases, the choice of sanitation technology depends upon a number of factors, including the relative risks of alternatives.

1.11 Health Aspects

There are two main health risks commonly associated with water quality degradation from onsite sanitation: fecal-oral disease transmission, and nitrate poisoning. Nitrate standards may be violated from latrine leachate, especially in arid areas where dilution of nitrogen loadings is consequently limited. High nitrates can lead to methaemoglobinaemia, (also known as "blue baby" syndrome.) This condition, in which oxygen cannot be effectively transported or released by the bloodstream, occurs mostly in children under 3 months of age. Methaemoglobinaemia is a rare condition; between 1945 and 1972, only 2000 cases were reported worldwide, most of which were not fatal. This contrasts markedly with diarrhoeal disease (the second main health risk associated with contaminated groundwater), which causes up to 3 million deaths annually.

Methaemoglobinaemia is also much less of a risk where breast-feeding is common, as breastfed children are less likely to ingest high-nitrate water. The epidemiology of faecal-oral disease, water, and sanitation is fraught with conceptual difficulties. Nevertheless, a number of studies summarised by Esrey (1991, 1996) point to (a) the greater impact of improved sanitation upon health relative to improved water supply, and (b) the greater importance of water quantity to health when compared with water quality. Studies by Moe et al. (1991), and Kirchoff et al. (1982) pointed to a lack of significant response to "moderate" contamination, and raise questions about both dose-response relations for fecal contamination and water quality standards.

1.12 Options and Choices

The common reaction with regard to pit latrines "unacceptable" in dense urban areas because of the risks of groundwater contamination needs to be considered more critically. As outlined in Section 5, this response is often based on a number of unstated, untested, and in many cases, improbable assumptions about the causal chain of disease and the choice of sanitation technology. In practice, the choice of technology is more tightly constrained by issues of water supply and sludge removal than by hypothetical balances of risks. Where large quantities of water require disposal, sewerage becomes more attractive and pit latrines are likely to be inadequate; where only small or irregular quantities of water are available, sewerage will prove difficult to support as an option. Data from urban settlements in India are presented which support the hypothesis that it may be cheaper to combine on-site sanitation with public water supplies drawn from outside the contamination zone, than to combine on-site wells with off-site sanitation (i.e. sewerage). In the final analysis, planners should understand that any decision to ban on-site sanitation that leads, as a practical consequence, to a reduction in sanitation coverage and use is, in fact, a step backwards for public health.

CHAPTER 2

LITERATURE REVIEW

2.1 IN INDIA AND ELSEWHERE

In India, many scientists have contributed to the field of Environmental Hydrology. Hora in 1942 published a short note on the pollution of streams and its likely effect on fisheries. Ganapati and Chacko (1951), made an investigation on the river Godavari and examined the effects of paper mill pollution at Rajamundry. Chakraborty et. al. (1959), studied the physico-chemical condition and planktonic population of river Yamuna at Allahabad between 1954 and 1955. Water quality of some of the Indian rivers (Ganga, Kosi, Brahmaputra, Kaveri, Bias, Sutlej and Narmada), were reported by earlier workers based on the studies carried out during 1955 to 1966. The study revealed that the water quality is good as their EC values fall below 350 · mhos/cm, while salinity of those of Chambal, Yamuna, Tapi, Godavari and Krishna ranged from 450 to 1400 · mhos/cm. In south India, waters of Hagari and Tungabhadra rivers were of moderate salinity. Mohan and Sarkar (1961), made preliminary investigations on the pollution of river Yamuna.

In some arid and salt affected areas of Gujarat, waters of some seasonal rivers show that the salt concentration goes up to 700 ppm (Paliwal, 1980). Mohan Rao (1972), studied the characteristics of dairy waste with reference to Indian standards. Arora et al (1973 and 1974), made a survey of sugar mill effluent treatment and disposal in some typical sugar mills of Uttar Pradesh, which is the largest sugarcane producing state in India and reported that effluents are rich in suspended solids, BOD and grease and hence, have great pollution potential. of various industrial effluents with reference to Indian Standards.

Verma and Delela (1975) studied the pollution of Kalinadi by Industrial wastes near Mansurpur. In Western district of Uttar Pradesh (U.P), mainly Sahranpur, Muzaffarnagar, Meerut and Bulandshahar, large number of water resources are used for irrigation, fisheries and recreation. The same water resources are also utilized for the disposal of industrial wastes of more than 20 different industries. Verma et al (1974) studied the characteristics and disposal problems, Verma et al. made a detailed study on the pollution of Hindon river in relation to fish and fisheries and stream Khala by the Sugar factory effluent near Laksar in district Sahranpur.

Agrawal et al (1976), studied the physico-chemical characteristics of the Ganges at Varanasi. Apart from groundwater quality and pollution problems emanating due to activity of man, there are water quality problems due to natural causes in several areas of the country. Fluoride concentrations in groundwater are high in several parts of the country particularly in semi-arid and arid tracts. In parts of Rajasthan, Southern Punjab, Haryana, U.P., Gujarat, cases of mottling of teeth, dental and skeletal fluorosis were reported from many places. In certain exceptional cases like Sagalia in Gujarat, the fluoride concentration has been found to be 19 mg/l (RaghavaRao, 1977).

Bilgrami and Datta Munshi (1979), made limnological survey of the river Ganga in relation to the human activities from Baruni to Farakka. Kudesia in 1980, published a book on water pollution, in which he reviewed his findings on water quality of different rivers in India. Mahatree.al (1980), studied the effect of industrial pollution on the aquatic ecosystem of Kali river. The studies conducted in our countries have shown that ground water pollution from discharge of untreated or inadequately treated industrial effluent has reached alarming proportion in several parts of the country. Various researchers have found in their case studies that groundwater has been severely affected due to industrial pollution in India (Naram, 1981; Krishnaswamy, 1981; Das and Kidwai, 1981; Kachwaha, 1981). Kakkar (1981) has carried out geohydrological investigation in North and South–West Haryana and observed the localized rise in nitrate concentration from 43 mg/l (at Singhani) to 1920 mg/l in natural groundwater. This nitrate pollution is likely to be caused by sewage and agricultural waste because due to absence of any geological source of nitrate in the area and non-uniform distribution of nitrate along the direction of groundwater movement.

Kakkar and Bhatnagar (1981) conducted field studies in Ludhiana (Punjab) and observed that ground water at shallow depths of aquifer near bicycle factories had been polluted by hexavalent chromium and cyanides in concentrations ranging from 3.5 to 12.9 mg/l and 0.05 mg/l to 0.98 mg/l respectively. Other trace elements such as copper, zinc, cadmium, cobalt, molybdenum, strontium, lithium and silver were also detected in ground water in different concentrations (less than the permissible limits) in drinking water. Patil and Patil (1983), published their findings on water quality of Ulhas river with reference to mercury, cadmium and copper. Muralikrishna and Sumalatha (1983) have conducted some preliminary studies on the water quality of ground water of Kakinada town and recommended that any water source must be thoroughly analysed and studied before being used for domestic purposes. Water

quality investigations in various parts of the country, have shown that most industries produce waste products also (gaseous, liquid and solid) as by-products, which can harm the environment, unless treated properly and conform to specified standards laid down by health authorities (Handa, 1977, 1983, 1994; Joshi et al., 1982; Singh, 1986; CGWB, 1991; Moitra, 1991).

National Institute of Hydrology, Roorkee has carried out study to work out groundwater quality variations in Saharanpur District (U.P) for shallow wells which are generally used for agriculture and domestic purposes. The results indicate that the quality of groundwater in the area under study is in general good for irrigation as well as for drinking purposes. However, temporal variations of ground water quality have also been reported (Kumar, et al., 1988). Narayana and Suresh (1989) have studied the chemical quality of ground water of Mangalore City, Karnataka and reported two distinct ground water zones in the city.

Chidambaram (1990) carried out studies on the effect of irrigated agriculture on groundwater quality in north of Madras state. According to him, intensive irrigation in about 20 years had raised the Cl concentration of ground water from pre-irrigation level of 110 – 125 mg/l to 210 – 240 mg/l, during the post irrigation period, an annual increase of about 4 – 5 mg/l. Govardhan (1990) carried out the study on ground water pollution in different mandals of district Nalgonda in Andhra Pradesh.

A very high concentration of nitrate was found in ground water around North Railway City Station in Lucknow. The main source of this nitrate pollution was septic tanks, which are located in the study area (Singh, et al., 1991). Ramaswami and Rajaguru (1991) have conducted study on groundwater quality at Tirupur town in Coimbatore district of Tamil nadu and reported that several parameters exceeded the permissible limits for various uses pointing out to the necessity of proper treatment and disposal of wastes in the area. Ravichandran and Pundarikanthan (1991) have studied ground water quality in Madras with the context of polluted waterways of the city and confirmed the increasing concentration of chloride towards coast due to saline intrusion.

Elango (1992) has studied groundwater quality in coastal regions of South Madras and reported that a few places the water is not suitable even for irrigation purposes. Satyaji Rao et al (1998 and 1999) studied the spatial variation of ground water quality in Kakinada town and also made attempts to relate water quality with ground water level fluctuations. Seth and Singhal (1994)

have carried out studies in order to assess status of ground water quality of upper Hindon Basin, Saharanpur (UP) due to large scale Industrial and agricultural activities. The results indicate that the ground water of the area is marginally affected comparing the chemical results of water as per World Health Organization and Indian Standards norms. In their investigation, the concentration of toxic metals (lead, cadmium and total chromium) was high, however its erratic concentration at few localities were also observed.

The ground water quality studies in the Jammu & Kashmir State are hardly reported. The Central Ground Water Board (CGWB), Jammu is doing fields investigations to measure the condition and trends of ground water quality and quantity in the State. This organization is monitoring depth of water levels four times in a year in open wells during January, May, August and November since 1986 for Jammu, Kathua, Udhampur, Srinagar, Phulwama, Budgam, Kupwada, Anantnag and Baramula Districts in J & K.

The National Institute of Hydrology, Western Himalayan Regional Centre located at Jammu has conducted ground water quality monitoring and evaluation study in Jammu district during 1994 – 95. The study was aimed at (i) to delineate the contaminated zones for drinking and for irrigation purposes, (ii) to monitor seasonal variation in the ground water quality, and (iii) to identify possible sources of pollution. The Centre has extended its water quality monitoring and evaluation program from Jammu district to Kathua district in the Jammu and Kashmir State and study was continued to subsequent years (Jain et al., 1994; Omkar et al., 1998). Ground water quality studies in Western Uttar Pradesh were studied by Jain et al (1996) during Pre-monsoon and Post-monsoon seasons to evaluate the suitability of water for irrigation and domestic purposes. Jain and Sharma (1997) observed significant correlation between conductivity and total dissolved solids, alkalinity hardness, chloride, nitrate, sulphate, sodium and potassium although the quality of ground water varied widely. Pradeep (1998) studied the hydrochemistry of sub-surface water of upper Urmil Basin in Chhatrapur district of Central India. Purandara (1998) studied the Ground quality of Belgaum city and indicated the impact of urbanization on ground water quality. Purandara (1999) reported the ground water quality variation in various parts of Belgaum district. Varadarajan (2000) studied the ground water quality in parts of Belgaum district and reported the fluoride concentration from Saundatti taluk in Belgaum district. Madhurima (2000) carried out surface water quality studies in Ghataprabha river and showed the impact anthropogenic activity on DO variations. Jayashree (2000) studied the impact of sewage on surface and ground water quality in Belgaum city area.

2.2 INFECTIOUS DISEASE TRANSMISSION THROUGH GROUNDWATER

The global incidence of waterborne disease is significant, though it can only be estimated since reliable data are not sufficiently available for direct assessment of disease cases (Prüss-Üstün *et al.*, 2004). The contribution of groundwater to the global incidence of waterborne disease cannot be assessed easily, as there are many competing transmission routes; confounding from socioeconomic and behavioral factors is typically high; definitions of outcome vary; and, exposure-risk relationships are often unclear (Esrey *et al.*, 1991; Payment and Hunter, 2001; Prüss and Havelaar, 2001). Many waterborne disease outbreaks could have been prevented by good understanding and management of groundwater for health. Pathogen contamination has often been associated with simple deficiencies in sanitation but also with inadequate understanding of the processes of attenuation of disease agents in the subsurface

The most comprehensive reports of waterborne disease outbreaks come from two countries, the USA and the United Kingdom, and some indications of the role of groundwater in the infectious diarrhea disease burden can be estimated in these countries (Craun, 1992; Hunter, 1997; Payment and Hunter, 2001; Craun *et al.*, 2003; 2004)

Lee *et al.* (2002) identified that of 39 outbreaks of waterborne disease in the USA between 1999 and 2000, 17 were due to consumption of untreated groundwater, although approximately half of these outbreaks were reported from individual water supplies, which are not operated by a utility and served less than 15 connections or less than 25 persons. A further eight were reported in non-community supplies, which serve facilities such as schools, factories and restaurants.

A detailed analysis of the incidence of waterborne disease in the USA was published in the mid-1980s by Craun (1985), which is still relevant. In his summary of data from the period between 1971 and 1982, Craun reports that untreated or inadequately treated groundwater was responsible for 51 per cent of all waterborne disease outbreaks and 40 per cent of all waterborne illness. A recent analysis of public health data in the USA showed little change to the epidemiology of disease outbreaks (Craun *et al.*, 1997). Between 1971 and 1994, 58 per cent of all waterborne outbreaks were caused by contaminated groundwater systems, although this is in part due to the higher number of water supplies using groundwater than those using surface water.

Craun *et al.* (2003) report that for the period 1991-1998, 68 per cent of the outbreaks in public systems were associated with groundwater, an increase from previous reports (Craun, 1985; Craun *et al.*, 1997). However, this apparent increase is likely to be due in part to the introduction of the USA Surface Water Treatment Rule in 1991, which requires 'conventional filtration' of most surface water supplies. In general it appears that waterborne outbreaks in the USA decreased after 1991, with the introduction of more stringent monitoring and treatment requirements.

2.3 PROTECTING GROUNDWATER FOR HEALTH

Craun *et al.* (2004) provides a detailed discussion of waterborne outbreaks in relation to zoonotic organisms (organisms with an animal as well as human reservoir) between 1971 and 2000 in the USA. They note that 751 outbreaks were reported linked to drinking-water supplies during this period, the majority (648) being linked to community (year-round public service) water supplies. The etiology was either known or suspected in 89 per cent of the outbreaks and zoonotic agents caused 118 outbreaks in community systems representing 38 per cent of outbreaks associated with these systems and 56 per cent of those where etiology was identified. The data show that the majority of illnesses and deaths were caused by zoonotic agents in the reported waterborne outbreaks.

The zoonotic agents of greatest importance were *Giardia*, *Campylobacter*, *Cryptosporidium*, *Salmonella*, and *E. coli* in outbreaks caused by contaminated drinking water. The majority of outbreaks caused by zoonotic bacteria (71 per cent) and *Cryptosporidium* (53 per cent) were reported in groundwater supplies. The use of contaminated, untreated or poorly treated groundwater was responsible for 49 per cent of outbreaks caused by *Campylobacter*, *Salmonella*, *E. coli*, and *Yersinia*. Groundwater that was contaminated, untreated or poorly treated contributed 18 per cent of all outbreaks caused by *Giardia* and *Cryptosporidium*. Kukkula *et al.* (1997) describe an outbreak of waterborne viral gastroenteritis in the Finnish municipality of Noormarkku that affected some 1500-3000 people, i.e. between 25 and 50 per cent of the exposed population. Laboratory investigations confirmed that adenovirus, Norwalk-like virus and group A and C rotaviruses were the principal causative agents. The source of the outbreak was thought to be a groundwater well situated on the embankment of a river polluted by sewage discharges. In 1974 an outbreak of acute gastrointestinal illness at Richmond Heights in Florida, USA was traced to a supply well that was continuously contaminated with sewage from a nearby septic tank (Weissman *et al.*, 1976). The main a etiological agent was

thought to be *Shigellasonnei*. During the outbreak approximately 1200 cases were recorded from a population of 6500. Outbreaks of cryptosporidiosis have also been linked to groundwater sources, despite being usually regarded as a surface water problem. A large outbreak of cryptosporidiosis occurred in 1998 in Brush Creek, Texas, USA from the use of untreated ground water drawn from the Edwards Plateau karst aquifer (Bergmire-Sweat *et al.*, 1999). There were 89 stool-confirmed cases and the estimated number of cases was between 1300 and 1500. This outbreak was associated with the consumption of water drawn from deep wells of over 30 m located more than 400 m from Brush Creek.

In 1997, epidemiological investigations traced an outbreak of cryptosporidiosis in the United Kingdom to water abstracted from a deep chalk borehole. Three hundred and forty five confirmed cases were recorded by the investigation team, who claimed this to be the largest outbreak linked to groundwater to have been reported (Willcocks *et al.*, 1998). This incident has particular significance because the water used in the supply was drawn from a deep borehole and was filtered before distribution. In the outbreak of *E. coli* O157:H7 and *Campylobacter* in Walkerton, Ontario in Canada in 2000, the original source of pathogens appears to have derived from contaminated surface water entering into a surface water body directly linked to an abstraction borehole (Health Canada, 2000). Although the series of events leading to the Groundwater and public health outbreak indicate a failure in subsequent treatment and management of water quality, better protection of groundwater would have reduced the potential for such an outbreak. An outbreak of *E. coli* O157:H7 occurred among attendees at the Washington Country Fair, New York, USA and was shown to be caused by consuming water from a contaminated shallow well that had no chlorination (CDC, 1999). A total of 951 people reported having diarrhoea after attending the fair and stool cultures from 116 people yielded *E. coli* O157:H7. This outbreak resulted in hospitalization of 65 people, 11 children developed haemolytic syndrome and two people died. In developing countries evidence of the role of groundwater in causing disease outbreaks is more limited, although there have been numerous studies into the impact of drinking-water, sanitation and hygiene on diarrhoeal disease. In part the limited data on groundwater related outbreaks reflects the often limited capacity of local health surveillance systems to identify causal factors and because it is common that several factors may be implicated in the spread of disease. However, the limited data on outbreaks specifically linked to groundwater may also reflect that improved ground water sources are generally of relatively good quality. Diarrhoeal disease related directly to drinking-water is most likely to result from consumption of poorly protected or unimproved

groundwater sources, untreated or poorly treated surface water, contamination of distribution systems and recontamination of water during transport. Pokhrel and Viraraghavan (2004) in a review of diarrhoeal disease in Nepal in relation to water and sanitation, cite examples from South Asia where contamination of groundwater supplies has led to outbreaks of disease.

A study of local populations in Kanpur, India recorded an overall incidence rate of waterborne disease of 80.1 per 1000 population (Trivedi *et al.*, 1971). The communities in the study areas took water from shallow groundwater sources, analysis of which revealed that over 70 per cent of the wells were contaminated. Of the cases of water borne disease investigated, the greatest proportion was of gastroenteritis, followed by dysentery.

In addition to outbreaks, there is some evidence of contaminated ground water contributing to background levels of endemic diarrhoeal disease. For example, Nasinyama *et al.* (2000) showed that the use of protected springs in Kampala, Uganda which was in generally in poor condition was associated with higher rates of diarrhea than the use of piped water supplies. Much of this disease burden is thought to occur in developing countries where the use of untreated water from shallow groundwater sources is common in both rural and peri-urban settlements (Pedley and Howard, 1997).

2.5 CHEMICAL HAZARD

The risk to health from chemicals is typically lower than that from pathogens. The health effects of most, but not all, chemical hazards arise after prolonged exposure, and tend to be limited to specific geographical areas or particular water source types. Much remains to be understood about the epidemiology of diseases related to chemical hazards in water and the scale of disease burden remains uncertain. However, some data do exist. Craun *et al.*(2004) reported that 11 per cent of waterborne outbreaks in the USA between 1971 and 2000 were associated with acute effects following ingestion of a chemical. Protecting Groundwater for Health Ensuring that chemicals of health concern do not occur at significant concentrations in groundwater implies understanding sources of pollution, aquifer vulnerability and specific attenuation processes as well as recognizing the importance of natural chemicals of health concern. In groundwater, however, there are two contaminants in particular that represent particular hazards of concern: fluoride and arsenic. Fluoride affects bone development and in excess leads to dental or, in extreme form, skeletal fluorosis. The latter is a painful debilitating disease that causes physical impairment. However, too little fluoride has also been associated with dental caries and other

dental ill-health (WHO, 2004b). Drinking-water is the principal route of exposure to fluoride in most settings, although burning of high fluoride coal is a significant route of exposure in parts of China (Gu *et al.*, 1990). Arsenic causes concern given the widespread occurrence in shallow groundwater in Bangladesh, West Bengal, India and in groundwater in several other countries. The scale of arsenic contamination is most severe in the shallow groundwater of Bangladesh. At present, the total population exposed to elevated arsenic concentrations in drinking-water in Bangladesh remains uncertain, but is thought to be somewhere between 35 and 77 million and has been described as the largest recorded poisoning in history (Smith *et al.*, 2000; BGS and DPHE, 2001). Problems are also noted in countries as diverse as Mexico, Canada, Hungary and Ghana, although the sources of arsenic and control strategies available vary. The true scale of the public health impact of arsenic in groundwater remains uncertain and the epidemiology is not fully understood.

In the case of Bangladesh, the lack of country-wide case-controlled studies makes estimating prevalence of arsenicosis difficult. In a recent evaluation of data collected by the DPHE-Unicef arsenic mitigation programs, Rosenboom *et al.* (2004) found a prevalence rate of arsenicosis (keratosis, melanosis and de-pigmentation) of 0.78 per 1000 population exposed to elevated arsenic (above 50 µg/l) in 15 heavily affected Upazilas (an administrative unit in Bangladesh). These authors note, however, that the data were difficult to interpret and that exposure had been relatively short and therefore these numbers could increase. The lack of a National cancer prevalence study makes estimations outside small cross-section studies problematic.

Increasing numbers of countries in Asia are now identifying arsenic contamination of groundwater (including Cambodia, China, Laos, Myanmar, Nepal, Pakistan and Vietnam). In India, increasing numbers of areas are being identified as arsenic affected beyond West Bengal (School of Environmental Studies, Jadavpur University, 2004). This demonstrates that arsenic is an important contaminant for public health and concerns growing.

Other chemical contaminants of concern in groundwater may also lead to health problems. These include nitrate, uranium and selenium. Of these, nitrate is of concern as it is associated with an acute health effect (methaemoglobinaemia or infantile cyanosis). The scale of the health burden derived from nitrate remains uncertain although it has been suggested to cause significant health problems in some low-income countries where levels in groundwater reach extremely high values (Melianet *et al.*, 1999). Nitrate is also of concern given that it is stable once

in groundwater with reasonably high oxygen content, groundwater and public health 13 where it will not degrade.

Thus it may accumulate to a long-term water resource problem that is expensive and difficult to remediate and whose effect may not be noticed until concentrations become critical.

From the above review, it is noted that the studies on water quality are quite limited in hard rock catchments. In order to develop water quality index, it is necessary to go for basin-wise studies rather than area-wise. The present study is a preliminary attempt in this direction to systematically determine the variation in both surface and ground water quality parameters which are found to vary with various man-made changes and agricultural practices.

CHAPTER 3

STUDY AREA

The Belgaum city is one of the popular places among the 29 districts of Karnataka State. It is at 747.47 m above MSL. The minimum temperature is recorded is 8°C and maximum temperature recorded is up to 42°C. The city is famous for its cool atmosphere. The city is surrounded by Goa state on the west side and Kolhapur district on north side.

The area falls under semi-arid climate with an average annual normal rainfall of 1324 mm due to Western Ghats called as Sahyadri Ghats. Nearly 95% of the annual rainfall is received during the period June to October through Southwest monsoon. The rapid urbanization due to cool atmosphere and decent social atmosphere has given way to many environmental issues. There is a need to study the environmental status of the city. The city area is divided into 3 river catchments namely Bellary nala (53.35%), Markandeya river catchment (31.65%) and Mongetri Nala catchment (14.98%). Belgaum municipality was established in the year 1951 and in 1977 it was given the status of Municipal Corporation. In the later years Kudchi, Kanabargi, Alarwad and Yamunapur were merged with corporation of city of Belgaum. The population of the city is around 10 lakhs including cantonment population.

The Bellary Nala flows through Belgaum city originating from the hills of Belgaum (Yellur and Damne) and flowing eastwards towards the Markandeya river. The Bellary Nala is a part of Deccan plains and lies between longitude 74° 30' E and 74° 40' E and latitude 15° 45' N to 15° 55' N in the Belgaum district of Karnataka. The basin area is of about 108 sq. km (upto gauging site at Hudli). The Nala, which was once, perennial stream carrying fresh water, has now turned into a sewer drain all along its course of 30 km. Since there are no sewage treatment plants and recycling facilities within the city area, the entire sewage is directed to Bellary Nala by Lendi Nala, which is linked through gutters and sewer lines.

The Kakati Industrial area is one of the important industrial areas of Belgaum city. It lies at the longitude 74° 31' 857" E and latitude 15° 55' 591" N. The industrial area is of about 1500 acres of area. The important industries of area are Textile Industry, Motor Vehicles Body Building industries, Wire Industries, Plastic Industries, Chemical Industries etc. This industrial area shows faster development and urbanization due to their geographical location.

The drainage system available in the industrial area is poorly maintained and at many places it is damaged. The effluent that is flowing in the drainage system seeps into the ground and enters

the aquifer. Also Chemical industries in the industrial area, due to improper treatment, have effluent discharged into the pond and in the factory premises which has resulted in pollution of ground water in the industrial area.

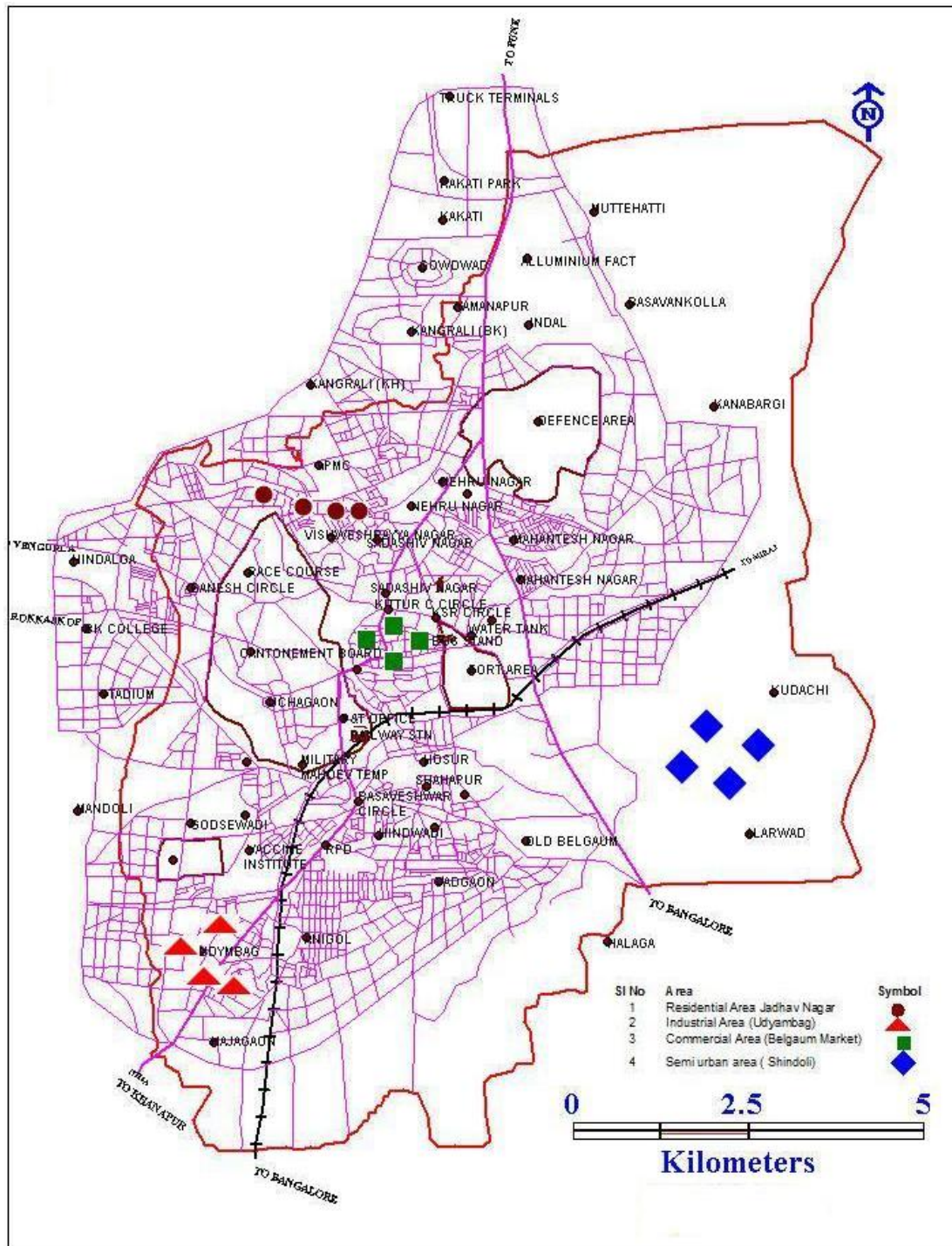


Figure 3.1: Study Area map of Belgaum City & adjoining area.

The city has developed in an unplanned manner. The underground drainage system is not available in most part of the city, wherever it is available it is poorly maintained and at many

places the pipelines are damaged. The sewage water that is flowing in such underground drainage system seeps into the ground and enters the aquifer. Wherever the underground drainage system is not available, the discharges of bathroom and toilets are let out into the open natural drainage system. This flow of sewage waters in natural drainage system is hindered by uneven topography and is stranded at low lying areas like Vadagaon, Khasbhag and Kudchi. Such stored water seeps into soil cover, once the soil cover is saturated, the infiltrated water moves to subsurface water through fissures and joints. The groundwater recovered from such localities yield polluted water.

The city gets its water supply from Rakaskop barrage across Markandeya river located about 25 km west of Belgaum city. The area falls under semi-arid climate with an average annual normal rainfall of 1324 mm. Nearly 95% of the annual rainfall is received during the period June to October through south-west monsoon.

The city is getting water from Hidkal dam also, apart from the ground water resources in the form of open wells, bore wells and tube wells.

Physiographic ally, the area is in a depression with hill range surrounding it , open towards the east. The area consists of fertile agricultural land with seasonal streams joining the Nala.

3.1 GEOLOGY AND SOILS

The Belgaum corporation area is in the form of depression with elevated portions on north, west and south. The eastern part is open. The central and eastern portion is almost silted with black cotton soil due to weathering and erosion, the drainage generally follows easterly direction. The area comprises of black soil, red soil, laterites, weathered Basalt, Basalt and Kaladgis in the N-E portions. Laterite and weathered basalt are the only litho units that are water bearing.

The area comprises of black soil, red soil, laterites, weathered basalt, basalt and Kaladgis (Proterozoic sedimentary in the N-E portions). The laterite and weathered basalt are the only litho units, which are bearing water. The laterites are covered with these soils. Their thickness varies from few meters to 50 meters. They are highly porous and perforated with innumerable, irregular, sinuous and tubular cavities. These cavities vary in diameter from 0.05 to 2.5 cm. At such places, the cavities are filled with buff colored clays. These clays are often stained to yellow and brown because of peseolatry iron solution. The cavities act as conduits and water bearing.

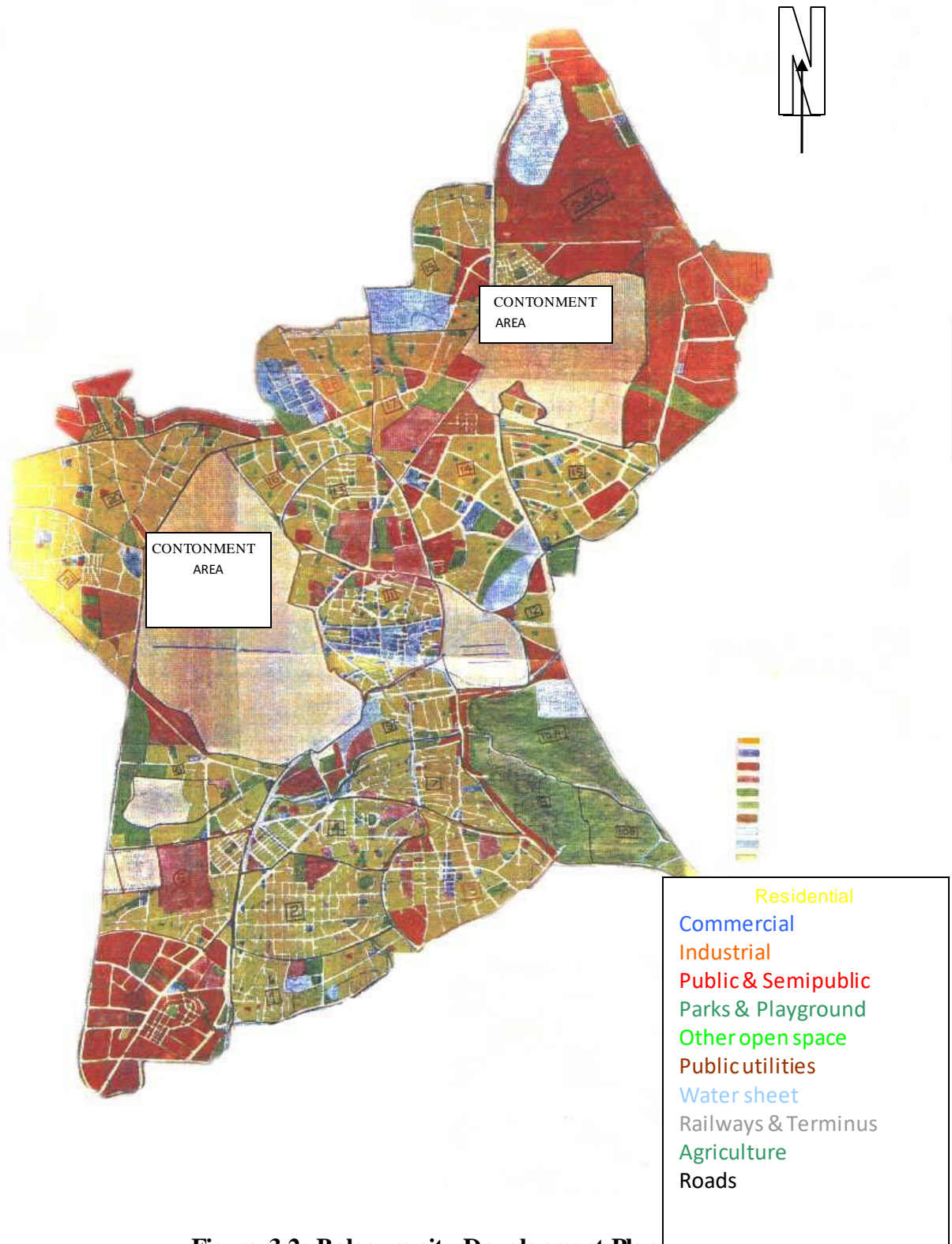


Figure 3.2: Belgaum city Development Plan

CHAPTER 4

METHODOLOGY

4.1 Sampling Techniques and Preservation

Sampling is one of the most important step in collection of representative water samples for ground water quality studies. Moreover, the integrity of the sample must be maintained from the time of collection to the time of analysis. Factors involved in the proper selection of sampling sites depend on the objectives of the study, accessibility, chemical source locations, manpower and facilities available to conduct the study. Furthermore, the hydrologist must be aware of the locations of point and non point sources of chemical and physical constituents, such as industrial complexes, sewage out falls, agricultural wastes etc. The use of a few strategic locations and enough samples to define the results in terms of statistical significance is usually much more reliable than using many stations with only a few samples from each.

The quantity of samples to be collected varies with the extent of laboratory analysis to be performed. A sample volume between two and three liters is normally sufficient for a fairly complete analysis. The total number of samples will depend upon the objectives of the monitoring program. To achieve the objectives of the study, 20 samples were collected from Belgaum city by dip (or grab) sampling method during pre-monsoon (March-April 2014). The samples were collected from both open and bore wells, which are being extensively used for drinking and other domestic purposes. Depth integrated samples were collected by lowering the container in the open wells. The depth of the water in the respective wells was also measured with Hand held Water level indicator. The samples were collected in clean polyethylene containers fitted with screw caps. One container of 500 ml sample was acidified with nitric acid for analysis of metal ions. Some parameters like pH and temperature were measured in the field at the time of sample collection using portable kits and the other chemical parameters were analyzed in the laboratory. Separate samples were collected using standard method for the analysis of micro-organisms. A schematic representation of monitoring and analysis procedure is given in fig.4.1.

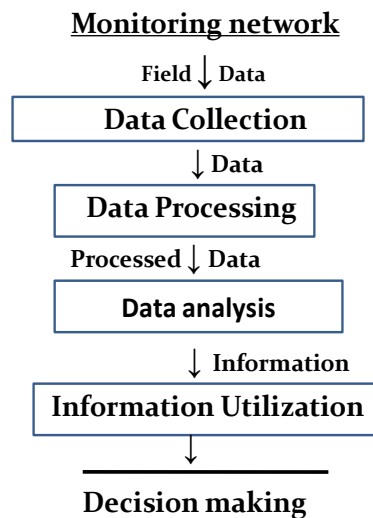


Fig.4.1: Present Monitoring System and the Water Quality Database

4.2 Methods of Analysis

The quality of water depends on a large number of individual hydrological, physical, chemical and biological factors. Some parameters are of special importance and deserve frequent attention and observation, whereas other gives a rough picture of water body and its quality status. During the present study, the chemical properties and the constituents of water analyzed are pH, Specific conductance (EC), Temperature, Total Dissolved Solids, Alkalinity (carbonates and bicarbonates), Hardness and major cations and anions. Chemical parameters of the samples were analyzed in the laboratory by standard methods recommended in the manuals. Some of the parameters like pH and temperature were measured in the field by using portable kits, at the time of sample collection. The list of equipments used and methods of analysis are presented in Table 9.

4.2.1 pH

The pH value of water is a measure of hydrogen ion concentration. The pH value may be determined potentiometrically by a wide variety of pH meters which are battery operated or run by standard-line power. They are equipped with glass and reference electrodes which require standardizing with standard buffer solutions before each measurement.

4.2.2 Temperature

The temperature of the water is measured at the time of sample collection by using mercury thermometers calibrated to 0.1 to 0.5 °C division. Water temperature is also measured by electrical instruments equipped with thermostat-type sensors.

4.2.3 Electrical Conductivity

The electrical conductivity is the measure of capacity of water to carry an electrical current and is directly related to the concentrations of ionized substances in the water. The cell constant of the instrument is determined with the standard KCl solution. The instrument is set at the cell constant, immerse the electrode in the water sample and record the reading.

Table.4.1: Analytical methods and equipment used in the study

Sl.No	Parameters	Methods	Equipments
1.	PH	Electrometric	pH Meter (AQUA LYTIC)
2.	Total Dissolved Solids	Electrometric	Conductivity meter
3.	Conductivity	Electrometric	-do-
4.	Temperature	Thermometric	T 100 N LCD – Thermometer
5.	Calcium	Titration by EDTA	Volumetric glassware
6.	Magnesium	Titration by EDTA	Volumetric glassware
7.	Sodium	Flame emission	Flame Photometer (Model Chemito 1000)
8.	Potassium	Flame emission	Flame Photometer (Model Chemito 1000)
9.	Carbonate	Titration	Volumetric glassware

10.	Bicarbonate	Titration	Volumetric glassware
11.	Chloride	Titration by Silver nitrate	Volumetric glassware
12.	Sulphate	Turbidimetric	
13.	Hardness	Titration by EDTA	Volumetric glassware

4.2.4 Total Dissolved Solids

In water sources, the dissolved solids, which usually predominate, consist mainly of inorganic salts and small amount of organic matter. Take 100 ml of water sample in a borosil beaker and evaporate the whole water to dryness. The residue left in the beaker is then weighed and expressed in mg/l as TDS.

4.2.5 Alkalinity

Total alkalinity is the measure of capacity of water to neutralize a strong acid. The alkalinity in the water is generally imparted by the salts of carbonates, bicarbonates, borates, nitrates and silicates. Take 50 ml of water sample in a conical flask, add 2-3 drops of phenolphthalein indicator. Titrate it against 0.02N H₂SO₄ till the pink color just disappears. Then to same solution, add 2-3 drops of methyl orange indicator, continue the titration with 0.02N H₂SO₄ till the pink color reappears. Calculate phenolphthalein (P) alkalinity and methyl orange (M) alkalinity. Then calculate OH, CO₃ and HCO₃ with the help of table.4.2.

Table.4.2: Phenolphthalein and Methyl Orange Alkalinity

ALKALINITY	OH	CO ₃	HCO ₃
P = 0	0	0	M
P = M/2	0	2P	0
P < M/2	0	2P	M - 2P
P > M/2	2P - M	2(M - P)	0
P = M	M	0	0

4.2.6 Sulphate

Sulphate appears in natural water in a wide range of concentrations. Sulphate ions are precipitated in acetic acid solution with barium chloride so as to form a uniform suspension of barium sulphate crystals. The absorbance of the suspension is measured by a Photoelectric Colorimeter and the sulphate concentration is determined by comparison of the reading with a standard curve.

4.2.7 Chloride

The chloride ions are always present in water in one or more forms like CaCl_2 , MgCl_2 and NaCl etc. It is determined volumetrically by Mohr's method, titrating against standard silver nitrate solution in the presence of potassium chromate indicator. Take 100 ml of water sample in a conical flask, add a pinch of potassium chromate indicator. Titrate against standard silver nitrate solution till the color of the solution changes from yellow to brick red.

4.2.8 Total Hardness

Total hardness can be estimated volumetrically by titrating against EDTA solution. Take 50 ml of water sample in a conical flask, and add 2 to 3 drops of Eriochrome Black T indicator and 2-3 ml of ammonia buffer solution. Titrate with standard EDTA till color changes from wine red to blue.

4.2.9 Calcium

Hardness of water is caused by the presence of bivalent metallic ions with cations and anions of Ca^{++} . It can be determined volumetrically by titration with EDTA. Take 50 ml of water sample in a conical flask. Add 1 ml of 2N NaOH solution and a pinch of murexide indicator, so that the color will be pink. Titrate it with EDTA till colour changes from pink to purple.

4.2.10 Magnesium

Hardness of water is caused by the presence of bivalent metallic ions with cations and anions of Mg^{++} . Magnesium is determined by subtracting the value of calcium from the total hardness value.

4.2.11 Sodium & Potassium

Trace amounts of sodium and potassium can be determined by flame emission photometry at a wavelength of 589 and 766.5 nm respectively. The sample is sprayed into a gas flame and excitation is carried out under carefully controlled and reproducible conditions. The desired spectral line is isolated by the use of interference filters or by a suitable slit arrangement in light-dispersing devices such as prisms or gratings. The intensity of light is measured by a photo tube potentiometer or other appropriate circuit. The standard calibration curve is prepared and concentration of sample is determined from the calibration curve.

4.3 Spread Plate method for microorganisms studies

Microbial growth involves an increase in the number of cells. The growth considered is exponential. In the spread plate method, a volume (usually 0.1 ml or less) of an appropriately diluted culture is spread over the surface of an agar plate using a sterile glass spreader. The plate is then incubated until the colonies appear, and the number of colonies is counted. It is important that the surface of the plate be fairly dry so that the spread liquid soaks in. Volumes greater than 0.1 ml are rarely used in this method because the excess liquid does not soak in and may cause the colonies.

4.3.1 Sample Collection

it is essential that the operator use the proper sampling procedure when collecting water samples to test for coliform bacteria since the quality of the sample determines the accuracy of the test's results. If the operator contaminates the sample in any way, then he will have to perform follow-up tests which are costly and time-consuming. Collecting a good sample consists of choosing a representative sampling location, preparing the faucet, and taking the sample.

The first step in collecting a good sample is to select a representative sampling location with a faucet which can be easily sterilized. In the water treatment plant, the water piped into the lab can be used. In the wastewater treatment plant, the operator should collect a sample of raw wastewater from the first available point in the plant and a sample of treated water just before the effluent is released into the natural waters. Operators may also be called upon to test for coliform bacteria in the distribution system in order to locate cross-connections and leaks which

contaminate the lines. In the distribution system, it is important the operator take samples from various representative spigots over the entire system.

A sample bottle should have already been sterilized. If the sample is going to be sent off for testing, then the lab will send a sterilized bottle. Otherwise, the bottle can be sterilized in an autoclave, adding sodium thiosulfate to neutralize any chlorine in the sample. In either case, the stopper should be left on the bottle until the bottle is ready to use. The bottle should not be rinsed with chlorinated water before use since this can kill coliform bacteria and make the

Test results inaccurate. With the tap running, the operator is ready to take the sample. Holding the bottle in one hand, he uses the other hand to pull back any foil or paper covering the stopper. Then he removes the stopper from the bottle, taking care not to touch the inside or top of the sample bottle. To prevent contamination to the stopper, the operator should continue to hold the stopper in his hand while taking the sample and should use the paper covering to shield the top from falling dust particles. Next, the operator holds the sample bottle under the faucet, allowing the water to flow directly into the bottle. Water should fill the bottle to the neck, leaving about 5 to 10% of the bottle empty. While filling the bottle, take care that water does not splash onto the lip of the bottle any more than is necessary.

As soon as the bottle is filled to the neck, the operator removes the bottle from underneath the faucet and replaces the top. He presses the paper back down around the neck of the bottle. If the sample is to be tested at the plant, the operator should begin the test as soon as possible, waiting no longer than six hours and refrigerating the sample if it must be stored for more than one hour.

4.3.2 HPC method

The heterotrophic plate count (HPC), formerly known as the standard plate count, is a procedure for estimating the number of live heterotrophic bacteria (requiring organic compounds of carbon and nitrogen for nourishment) in water. This test can provide useful information about water quality and supporting data on the significance of coliform test results. High concentrations of the general bacterial population may hinder the recovery of coliforms. Heterotrophs are those microorganisms that use organic compounds for most or all of their

carbon requirements. Most bacteria, including many of the bacteria associated with drinking water systems, are heterotrophs. Heterotrophic Plate Count (HPC) is a microbial method that uses colony formation on culture media to approximate the levels of heterotrophic flora. HPC does not, however, give an indication of the types of organisms present or their sources. It should also be noted that the results obtained using an HPC test are not an accurate assessment of total heterotrophic concentrations but, instead, are indications of culturable organisms present. For example, it has been shown that only approximately 1% of the total bacteria found using direct microscopy are enumerated using HPC procedures. Possible explanations for this difference include the presence of some bacteria in a viable but non-culturable state and the fact that HPC media do not provide the complex nutritional requirements necessary for the growth of all heterotrophs.

Unlike other indicators, such as *E. coli* or total coliforms, low concentrations of HPC organisms will still be present after drinking water treatment. In general, water utilities can achieve heterotrophic bacteria concentrations of 10 colony-forming units (cfu./mL) or less in finished water. Within a distribution system, increases in the density of HPC bacteria are usually the result of bacterial regrowth. The density reached can be influenced by the bacterial quality of the finished water entering the system, temperature, residence time, presence or absence of a disinfectant residual, construction materials, surface-to-volume ratio, flow conditions, the availability of nutrients for growth and in chlorinated systems, the chlorine/ammonia ratio and the activity of nitrifying bacteria. Three different methods for performing the heterotrophic plate count, using three different types of media, will be described. The three methods are the spread plate; pour plate and membrane filtration methods.

4.3.4 Diluting Cell Suspensions before Plating

With both the spread plate and pour plate methods, it is important that the *number* of colonies developing on the plates not be too large. On crowded plates some cells may not form colonies, and some colonies may fuse, leading to erroneous measurements. It is also essential that the number of colonies not be too small, or the statistical significance of the calculated count will be low.

4.4 Drastic Methodology

A numerical ranking system has been devised in order to assess the ground water pollution potential in hydrogeologic settings using the DRASTIC model (Aller et al, 1987). DRASTIC is derived from the seven factors

D=Depth to water table in meters

R=Net recharge in meters

A=Aquifer media

S=Soil media

T=Topography (Slope 0%)

I=Impact of Vadose zone

C=Hydraulic conductivity

It contains three significant parts viz. weights, ranges and ratings.

4.4.1 Weights (w):

Each of the DRASTIC parameters has been assigned a weight rating from 1 to 5 to describe relative importance in the pollution process as compared to other parameters.

4.4.2 Ranges:

Each DRASTIC factor has been divided into either ranges or significant media types, which have an impact on pollution potential.

4.4.3 Ratings (r):

The ratings vary from 1 to 10 for each range in DRASTIC factor. The factors DRST and C have been assigned a typical value or to just adjust the value based on more specific knowledge.

Once the entire factors have been assigned a rate, each rate is multiplied by the assigned weight and the resultant numbers are summed up to get what is called DRASTIC index (table 14) or

pollution potential. This model is formulated as an equation using a linear combination methodology.

$$D.I. = Dr Dw + Rr Rw + Ar Aw + Sr Sw + Tr Tw + Ir Iw + Cr Cw = \text{pollution potential}$$

Where r= rating of the site, w=weight of the parameter.

The index value computed by the model is considered as a relative indication of pollution potential. Higher scores indicate greater vulnerability. The index must be however be interpreted within a specific hydro-geologic setting in a composite description of all the major geologic and hydrologic factors, which affect and control ground water movement into, through and out of an area.

Use of the index without reference to its hydro geologic setting may lead to erroneous interpretation of results.

The design and information of DRASTIC was predicted on several assumptions;

- i. The data required by the model are available
- ii. The variables included in the model are critically related to groundwater vulnerability and,
- iii. The ratings, weightings and mathematical relationships between variables are adequately set forth in the DRASTIC procedure. Further , the model is to be used only for a region (site specific studies).s

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Groundwater Quality

The ground water quality parameters were analysed in the laboratory and statistical analysis were carried out using the SYSTAT computer program (Table.5.1). It is found that there is a wide variation between the various parameters which is clearly demonstrated by standard deviation. It is observed that in some of the wells, Electrical conductivity, TDS, bicarbonates, total alkalinity, chlorides, total hardness, calcium and sodium exceeds far above the permissible limits. The count taken for the microorganisms showed a significant concentration rendering the water unusable for drinking purposes.

Table.5.1: Descriptive Statistics of Observed Ground water Quality Parameters

Parameters	max	min	std dev
pH	7.34	4.1	2.291026
EC	3445	60	1199.124
TDS	2360	40	738.8355
HCO ₃	900	22	213.2289
Tot Alk	900	22	214.1692
Chlorides	2268	18	554.2101
Sulphate	67	11	16.05397
TH	776	12	261.7293
Ca	490	4.2	116.9147
Mg	84	0.98	26.59368
Na	187	9	64.76589
K	24	2	6.493361
E.Coli	300	12	65.16816

5.1.1 Temperature

The temperature of water is one of the most important characteristics, which determine the trends and tendencies of changes in its quality. The shifting of various dynamic equilibrium of parameters such as concentration of carbonates, sulphides and degree of alkalinity or electrical conductivity is affected by temperature changes. In the present study temperature of the samples varies from 25.6°C to 27.6°C.

5.1.2 pH Value

The pH is a master variable controlling chemical systems. It is a measure of hydrogen ion concentration of the water sample. It may be noted that the pH of natural water is 7, acidic water is less than 7 and alkaline water is more than 7.

The pH value varies from 4.1 to 7.34. The minimum was observed Near Narthaki Talkies and Kapileshwari Temple open well. The maximum was noticed at Jyothiriling Galli and Kanbargi open well. In general, water is of acidic nature while in other places it is mostly neutral. In the outskirts of the city, the pH ranges between 5.9 and 7.28.

5.1.3 Electrical Conductivity

Water that has high specific conductance induces corrosion of iron and steel. Conductivity is the measure of capacity or solution to conduct electrical current. It is the reciprocal of the resistance, in ohms. The conductivity value is used as a criterion for expressing the total concentration of soluble salts in water.

Electrical Conductivity varies between 60 mmhos/cm and 3445 mmhos/cm. Minimum is observed at Mangalwar Peth, Tilakwadi and maximum is observed in Kanbargi (near main road bus stop). There is a marked variation in the Electrical conductivity in the rural area. It is found that the electrical conductivity of the rural areas is higher in the villages close to Bellary nala whereas it is considerably less in wells away from the nala.

5.1.4 Total Dissolved Solids

The bulk of the total dissolved solids include bicarbonates, sulphates, chlorides, calcium, magnesium, sodium and silica. The total dissolved solids content of ground may range from 20 mg/l in the areas of high rainfall to over 100,000 mg/l in some desert brines.

Total dissolved solids also show a good correlation with the concentration of electrical conductivity. Higher concentration of TDS is seen towards the Kanbargi (near main road bus stop). In the case of residential area, higher TDS was observed in the northeastern part of Belgaum i.e. in Annapurneshwari Nagar, Vadagoan. The TDS content varies from 40 mg/l to 2360 mg/l. The maximum TDS is noted in the wells in the irrigated lands.

5.1.5 Total Alkalinity

The primary source of carbonate and bicarbonate ion in ground water is the dissolved carbon dioxide in rain, which as it enters the soil, dissolves more carbon dioxide. Water charged with carbon dioxide dissolves carbonate minerals, as it passes through soil and rocks, to give bicarbonates.

Total alkalinity represents the combined concentration of both carbonates and bicarbonates. This is found to be minimum (22 mg/l) at Mangalwarpeth, Tilakwadi and maximum (900 mg/l) at Adarsh Vidyalay Road, Hindwadi. Wide variations in the alkalinity values were observed in areas outside the city.

5.1.6 Chloride

The chloride content of groundwater may be due to the presence of the soluble chlorides from rocks, saline intrusion, connate and juvenile water. In the zone of actual circulation the chloride concentration is normally relatively small. The Chloride concentration is harmless upto 1500 mg/l but produces a salty taste at 250 mg/l to 500 mg/l.

Chloride concentration varies from 18 mg/l to 2268 mg/l. in the city area. The minimum is observed at Hanuman Nagar, Hindwadi area and maximum at Kanbargi (near main bus stop). The main reason for such a high value of chloride in Kanbargi is because of the continuous use of Bellary nala water for irrigation during the non-monsoon season. It is also observed that the chloride concentration is increasing towards the southeastern side. It is important to note the declination of chloride concentration away from Bellary nala.

5.1.7 Fluoride (F)

Fluoride derived from fluorite and the minerals apatite and mica, is generally present in only low concentration in ground water. Volcanic and fumarolic gases can contain fluoride, and in some areas may be the source of fluoride in ground water. The concentration of fluoride in

drinking water must be in the range of 0.1– 3.85 mg/l. The median range of fluoride is 0.8 mg/l. Very high content fluorides could be due to the agricultural activities as wells geogenic reasons.

5.1.8 Nitrates (NO₃)

Nitrate represents the highest oxidized form of nitrogen. The most nitrates in natural water come from organic sources or from industrial and agricultural fertilizers. Nitric oxides produced in atmosphere by lightning discharges are added in the form of nitrate to water.

Normal water contains only 0.1 to 10 mg/l of nitrate. Nitrate compounds are highly soluble and encourage the growth of primitive plants.

Nitrogen is very minor constituents of rocks, but is a major constituent of the atmosphere. The average nitrogen content in rainwater is reported to 0.02 ppm (Riffenburg, 1926). Groundwater when not polluted contains less than 5 ppm of nitrates but polluted water contains up to 100 ppm or even more. The concentration of nitrate in the present study varies between 0.29 ppm to 29.2. It is well within the permissible limit. This clearly indicates that the ground water is getting polluted in and around Belgaum city due to manmade reasons.

5.1.9 Sulphate (SO₄)

The Sulphate content of atmospheric precipitation is only about 2 mg/l, but a wide range in sulphate content in ground water is made possible through reduction by precipitation, solution and concentration, as the water traverses through rocks. It is reported that in arid and semi-arid regions higher concentration of sulphates due to the accumulation of soluble salts in soil and shallow aquifer. Rainwater has quite high concentration of sulphate particularly in the areas of high atmospheric pollution.

The sulphate content in the present study area varies from 11 mg/l to 67 mg/l. Very low sulphate is found in a well near Old P.B. Road (well close to Manikbag automobiles and adjoining areas). Maximum sulphate concentration of 67 mg/l was found in Kanbargi(near main road bus stop). This indicates that no such atmospheric pollution exists in the city. But many places show the sulphate concentration below the detectable limit.

5.1.9 Calcium (Ca) and Magnesium (Mg)

Calcium occurs in calcareous rocks such as limestone, dolomite, gypsum and basic igneous rocks. Because of its wide spread occurrence in rocks and soils and its ready solubility, makes

the presence of calcium in nearly all waters. The desirable limit of calcium for drinking water is 75 mg/l. The range of Ca in the study area varies between 32 – 240 mg/l. Median is 64 mg/l.

Calcium as such has no hazardous effects on human health. Concentrations up to 1800 mg/l have been found not to impair any physiological reaction in man. The importance of Calcium concentration lies in the fact that it's disadvantageous in household and industrial uses. High concentration of calcium is not desirable in washing, laundering and bathing owing to its suppression of formation of lather with soap.

In ground water, the calcium content generally exceeds the magnesium content, in accordance with their relative abundance in rocks but contrary to the relative solubility's of their salts. As in the case of calcium carbonates, magnesium carbonate is more soluble in water containing sodium salts.

The recommended desirable limits of magnesium for drinking water standard (WHO) are 30 mg/l. Magnesium concentration ranges between 5 mg/l and 102 mg/l.

The distribution of alkaline earth metals like Calcium and Magnesium are found to be high in irrigated lands. Highest concentrations of Ca (490 mg/l) were noted in a well near main road bus stop, Kanbargi and 235 mg/l is observed in Gayathri nagar. Both these locations are close to the Bellary Nala. It is observed that the concentration decreases towards the western part of the study area. In the outskirts of the city, the concentration of calcium is comparatively lower than the city area. Similar trend is seen in the case of distribution of Magnesium. Maximum concentration is noticed at Main Road Bus Stop, Kanbargi (58.56 mg/l) and minimum of 0.98 mg/l is observed at Jeonibhavi, Kanbargi. In general, both calcium and magnesium are comparatively lower in the western part of the Belgaum city.

5.1.10 Total Hardness (TH)

Hardness is an important criterion for determining the usability of water for domestic, drinking and many industrial supplies.

Hardness has no known adverse effects on health, however some evidence has been given to indicate its role in heart disease. The hard water is also not suitable for domestic use in washing, cleaning and laundering. The highest desirable value for drinking water standard is 300 mg/l.

Hardness is one of the common problems particularly in Belgaum and surrounding areas. It is primarily the amount of calcium and magnesium, and to a lesser extent, iron in the water. Hardness is measured by adding the concentrations of calcium, magnesium and converting the value to an equivalent concentration of calcium carbonate (CaCO_3) in mg/l. of water. Based on literature and present investigations, hardness can be classified as:

Hardness Category Equivalent Concentration of CaCO_3

Soft < 60 mg/l

Medium hard 60 mg/l to < 120 mg/l

Hard 120 mg/l to < 180 mg/l

Very hard 180 mg/l or greater

In the study area, total hardness varies between 12 mg/l and 776 mg/l. Minimum was observed at Jeoni bhavi, Kanbargi and maximum at Annapurneshwari nagar, Vadagoan. In the extension and rural areas the hardness showed a wide variation, ranging between 26 mg/l and 760 mg/l. The minimum hardness was observed at Mangalwarpeth, Tilakwadi and maximum at Indal Road Kanbargi. Hardness of the water is also high in villages like Shindholi, Hirebagewadi etc. However, it is seen that, there is a gradual decline in hardness away from Bellary nala catchment towards Markandeya river catchment.

The optimum range of hardness in drinking water is from 80 mg/l to 100 mg/l. Water with hardness greater than 200 mg/l was considered objectionable in many parts of the world and water with hardness greater than 500 mg/l was normally considered unacceptable for domestic purposes. From the present results, it is clear that in all residential areas (including villages), hardness is below the prescribed limits.

5.1.11 Sodium and Potassium

Alkali elements such as sodium and potassium also play a significant role in vital processes of plants. Potassium plays a major role in synthesis and respiration processes and, even more importantly, regulates the hydration of tissues. Sodium, on the other hand, influences the physicochemical properties of plasma and water supply. The uptake of these elements is strictly dependent on the relationship between their contents in soil.

Sodium concentration ranges from 9 mg/l to 187 mg/l. Minimum concentration is found in Jeoni Bhavi, Kanbargi and the maximum is noticed at Main Road Bus Stop, Kanbargi. In the extension and rural areas the variation of sodium was between 11 mg/l and 149 mg/l. The

minimum is observed at Mangalwarpeth, Tilakwadi and maximum at Annapurneshwari Nagar, Vadagoan. Similar to the distribution of other ions, sodium also found to be higher in the irrigated lands. Further, the concentration showed an increasing nature towards north-eastern part of the city. In general, the distribution of sodium showed an increase in the rural areas as compared to the city area. Similar trend is seen in the case of potassium. Highest concentration is reported from Main Road Bus Stop, Kanbargi.

5.1.12 Iron

Iron is one of the major constituents of rocks. Usually iron in groundwater, in the form of ferric hydroxide is less than 0.3 ppm. Present observation does not highlight much concentrations of iron in majority of the locations both in irrigated and non irrigated areas. However, at Halga, Kamkarhatti and Santibastwad iron concentration observed is 0.2 mg/l. The contour maps of iron in irrigated and residential area.

5.2 Temporal Variations of Major Cations and Anions

An attempt was made to understand the variations of major cations and anions over a period from 1996 to 2009, in residential and industrial areas of Belgaum city. Fig 5.1 & Fig 5.2 represent the variation of various parameters of cations and anions from the selected wells present in the residential and industrial areas. In the industrial area (Kakati and Udyambag) both anions and cations showed considerable increase from year 1996 to 2014 (data considered are 1996, 2003, 2009 and 2014). However, these variations could be attributed to various reasons such as unplanned disposal of wastes in the industrial area and change in ground water level conditions. In the residential area, significant variations were not observed from year to year Table.5.2 gives the physico-chemical characteristics of various parameters at Hindwadi and Udyambag.

Table 5.2 : temporal variation of Physico-chemical characteristics of groundwater for selected wells

Year 1996													
Location	pH	TDS	EC	Ca	Mg	Na	K	HCO ₃	SO ₄	Cl	NO ₃	F	Fe
Industrial area	7.05	50	0.118	19.3	0.88	3	0	25	24	7	3.9	0.35	0.563
Residential area	7.13	330	0.27	47	8	11	2	152	10	20	2.7	0.27	0.625

Year 2003													
Industrial area	6.5	400	0.263	41.7	11.7	12	0	124	25.25	32.7	3.04	0.15	0.26
Residential area	6.6	300	0.357	37.4	13.2	11	2	146.4	8.5	82.4	6.4	0.16	0.55
Year 2009													
Industrial area	6.7	204	0.34	80	44	10	0	243	27	96	11.1	1.8	0.35
Residential area	6.6	198	0.33	68	28	16	3	183	27	80	3.7	1.25	0.88

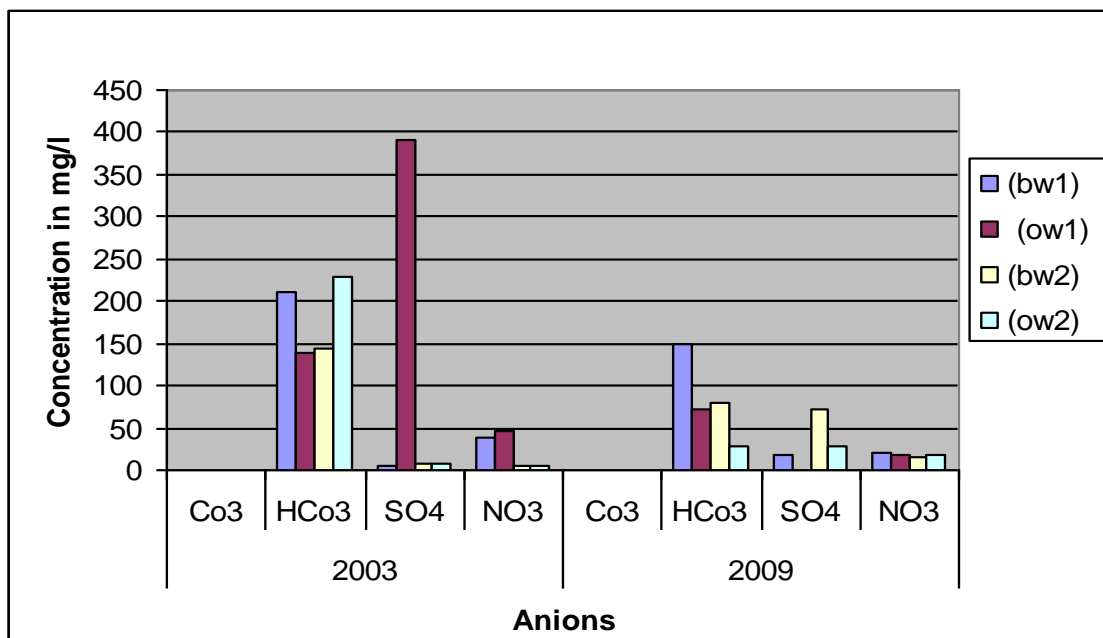


Figure 5.1: Temporal variation of major anions in the outskirts of the city.

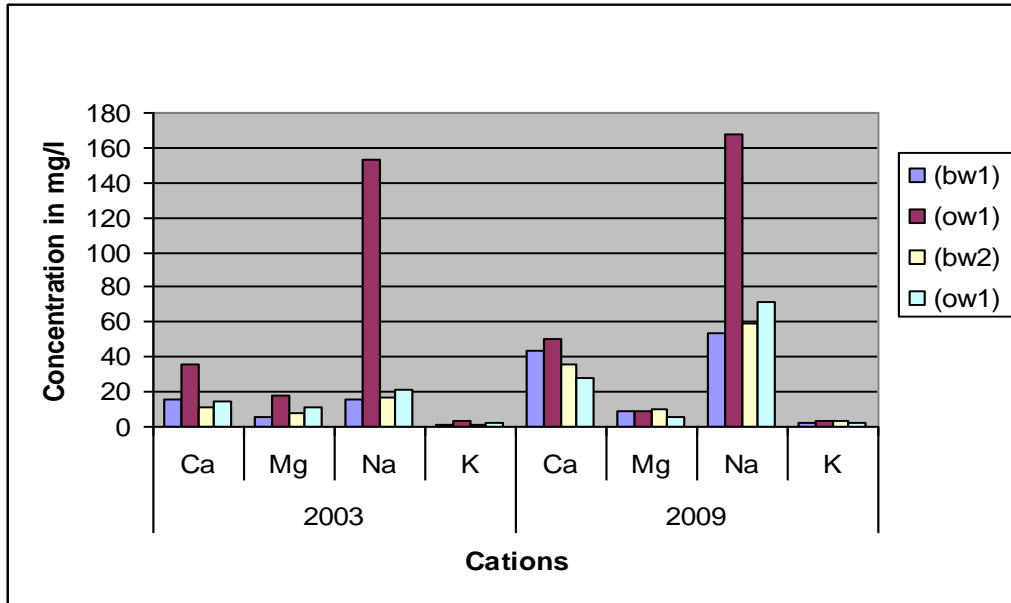


Figure 5.2: Temporal variation of major cations at the outskirts of the city

5.3 Hydrochemical Ratios in the Study Area

5.3.1 Spatial Distribution of Sulphate/Chloride Ratio

In order to assess the impact of anthropogenic disturbance on water quality, sulphate /chloride ratio was determined. The variations in sulphate to chloride ratio could be related to change in land use type (level of urbanization) and cropping pattern. Higher chloride concentration was observed in residential areas. It is surmised that the increase in sulphate/chloride ratio in urban area is due to the human activity and industrialization whereas; in the rural areas it could be due to the impact of agriculture practice. It is also expected that higher sulphate could also be due to higher recharge from the agriculture lands.

Ratios of Mg/Cl , Cl/HCO_3 and Mg/Ca were calculated for each well during the study period. In majority of the wells, Mg/Cl ratio was more than 1(one) which clearly indicates the mixing of ground water with sewage or waste water. Cl/HCO_3 varies from 0.417(Jyotirling galli , Kanbargi) to 20.25 (Kanbargi, Main bus stop) in bore-wells. An exorbitantly high value of Cl/HCO_3 observed in a well at Kanbargi could be due to the dumping of wastes which resulted in very high values of chloride concentration. In general, results shows that the wells in the city and adjoining areas are not maintained in a hygienic conditions which resulted in contamination of ground water. Fig.5.3 shows the variation of $Cl/(Cl+HCO_3)$ with the TDS. It is noticed that there is a linear relationship between TDS and the ratio of Chloride/Chloride+ HCO_3 , Cl/HCO_3 is minimum at Jyothirling galli, Kanbargi (0.147) Cl/HCO_3 is maximum Near Narthaki,

Talkies, Kapileshwari temple (20.25)Mg / Cl is minimum at Old PB Road Khasbhag (0.011) Mg / Cl is maximum at Mangalwarpeth, Tilakwadi (0.78) Mg / Ca is minimum at Indal Road, Kanbargi (0.052)Mg / Cais maximum at Kanbergi Bus stop (0.84).

Table 5.3: Ratios of Mg/Cl, Cl/HCO₃ and Mg/ Ca at different sampling stations.

Sampling Stations	Cl/ HCO₃	Mg / Cl	Mg / Ca
Yellur U/S	3.76	0.034	0.46
Yellur D/S	4.3	0.046	0.83
Annad nagar, Vadagaon	0.43	0.33	0.57
KLE Hospital, Yellur Road	1.11	0.11	0.16
Annapurneshwari nagar, Vadagaon	2.66	0.069	0.44
Manickbag	1.78	0.1135	0.5
Patil galli	1.28	0.1192	0.4
Old PB Road Khasbhag	2.14	0.011	0.15
Gayathri nagar	0.417	0.33	0.5
Near Narthaki, Talkies, Kapileshwari temple	20.25	0.026	0.12
Indal Road, Kanbargi	0.83	0.037	0.052
Jyothirling galli, Indal road, Kanbargi	0.575	0.22	0.64
Kanbergi Bus stop	0.76	0.53	0.84
Jeoni bhavi	0.58	0.32	0.067
Jyothirling galli, Kanbargi	0.147	0.033	0.068
Adarsh Vidyalay, Hindwadi	0.59	0.241	0.4
Hanuman nagar, Hindwadi	0.28	0.38	0.57
Mangalwarpeth, Tilakwadi	1.136	0.78	0.464
. Somwarpeth, Tilakwadi	0.59	0.51	0.62
Somawarpeth, Tilakwadi	0.47	0.376	0.38

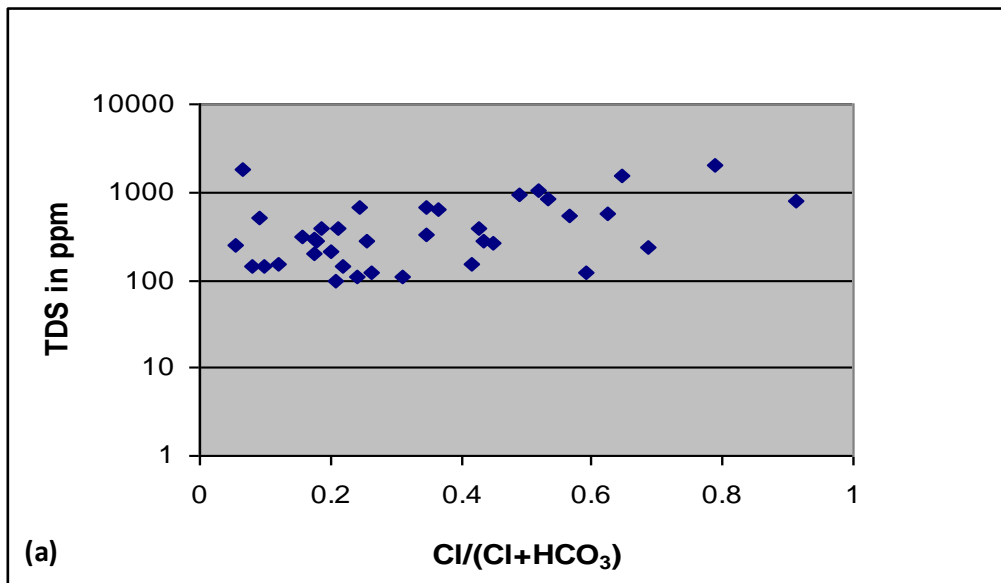


Figure 5.3 : Plot between $\text{Cl}/(\text{Cl}+\text{HCO}_3)$ and TDS

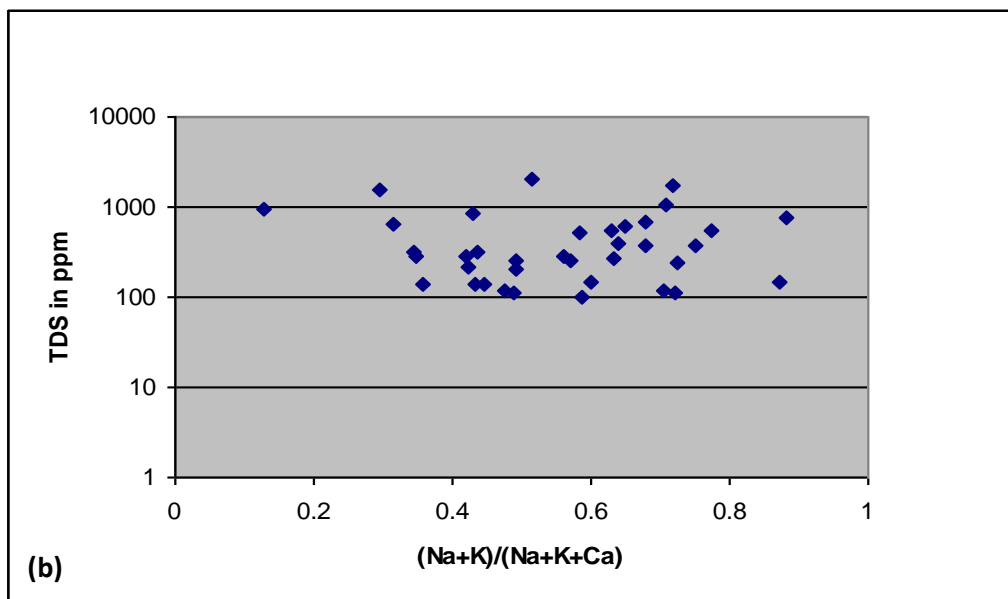


Figure 5.4 : Plot between $\text{(Na+K)}/(\text{Na} + \text{K} + \text{Ca})$ and TDS

Mg/Ca ratio is used for diagnostic characteristics of geochemical environment of the ground water. The low values (0.052) indicate a recharge area (Rao, 1996-97). The range of Mg/Ca values in the study area vary between 0.052 (Manikbag) and 0.84 (Old P B Road). From the Mg/Ca ratio, it is noticed that the recharge in the study area is quite good and needs only maintenance of the wells for the purpose of safe drinking water. In the above figure 5.4 a ratio between the sum of alkali metals with the Alkali and alkaline earth metal is plotted. From the

figure it is evident that the concentration of calcium is independent of the alkali metals and attributed to the source rocks.

5.4 Diagrammatic Representation of Geochemical data

Geochemical studies often involve synthesis and interpretation of a mass of analytical data. The objective of interpretation may be to aid in the classification of waters of different geochemical characteristics for utilitarian purposes, solving problems of saline water intrusion, or ascertaining various factors on which the chemical characteristics of waters depend. The examination of tabular statements of geochemical data of a large number of samples is not only a tedious and irksome process, but also fails to bring geochemical aspects. Piper's diagram has been extensively used to understand problems about the geochemical evolution of groundwater.

I. Piper's Diagram

The diagram consists of three distinct fields - two triangular fields and a diamond shaped field. In the triangular fields plotted separately, are the percentage eqm values of cations, Ca and Mg (alkaline earths) and Na (alkali), and anions, HCO_3 (weak acid) and SO_4 and Cl (strong acid). The overall characteristics of the water are represented in the diamond-shaped field by projecting the position of the plots in the triangular fields. Minor alkalis like potassium and strong acids like iodide, fluoride and nitrate are clubbed with the major ones.

Different types of groundwater can be distinguished by the position of their plotting occupy in certain areas of the diamond shaped field.

Area 1 - alkaline earths exceed alkalies

Area 2 - alkalies exceed alkaline earths

Area 3 - weak acids exceed strong acid

Area 4 - strong acids exceed weak acids

Area 5 - carbonate hardness exceeds 50 %, i.e. chemical properties of the water are

Dominated by alkaline earths and weak acids.

Area 6 - non-carbonate hardness exceeds 50%

Area 7 - non-carbonate alkali exceeds 50%, i.e. chemical properties are dominated by alkalies and strong acids-ocean water and many brines plot near the right-hand vortex of the subarea.

Area 8 - carbonate alkali exceeds 50% - here plot the waters which are inordinately soft in proportion to their content of dissolved solids.

Area 9 - no one cation-anion pair exceeds 50%.

Piper's diagram has been widely used to study similarities and differences in the composition of waters and to classify them into certain chemical types. The water types demonstrated by the piper diagram, as described by Karanth (1987) show the essential chemical character of different constituents in percentage reacting values, expressed in milligrams equivalent.

Based on Piper's diagram, (Fig.5.5), the Belgaum city water can be classified basically under four major categories. However, the samples mainly exhibit a type dominated by chloride type or Cl-SO₄-HCO₃ type representing strong acids exceed weak acids which represent non-carbonate alkali exceed 50%. In the case of cations, it is noticed that the water is dominated by calcium concentration in majority of the samples.

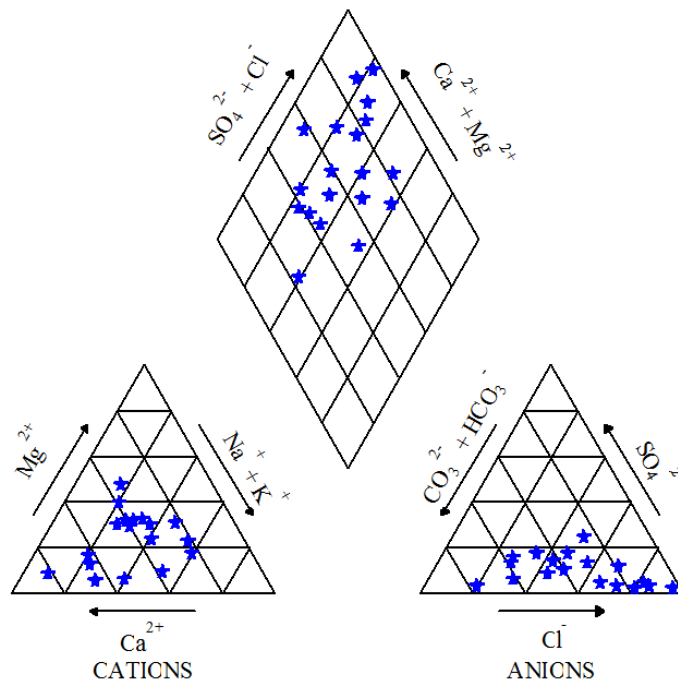


Fig.5.5: pipers Diagram of different sampling stations

II.Chadha's Diagram

The Chadha's diagram shown in Fig.5.6 is a somewhat modified version of the Piper diagram. In the Piper diagram the milliequivalent percentages of the major cations and anions are plotted in each triangle and the type of water is determined on the basis of position of the data in the respective cationic and anionic triangular fields. The plotting from triangular fields is extended further into the central diamond field, which provides the overall character of the water.

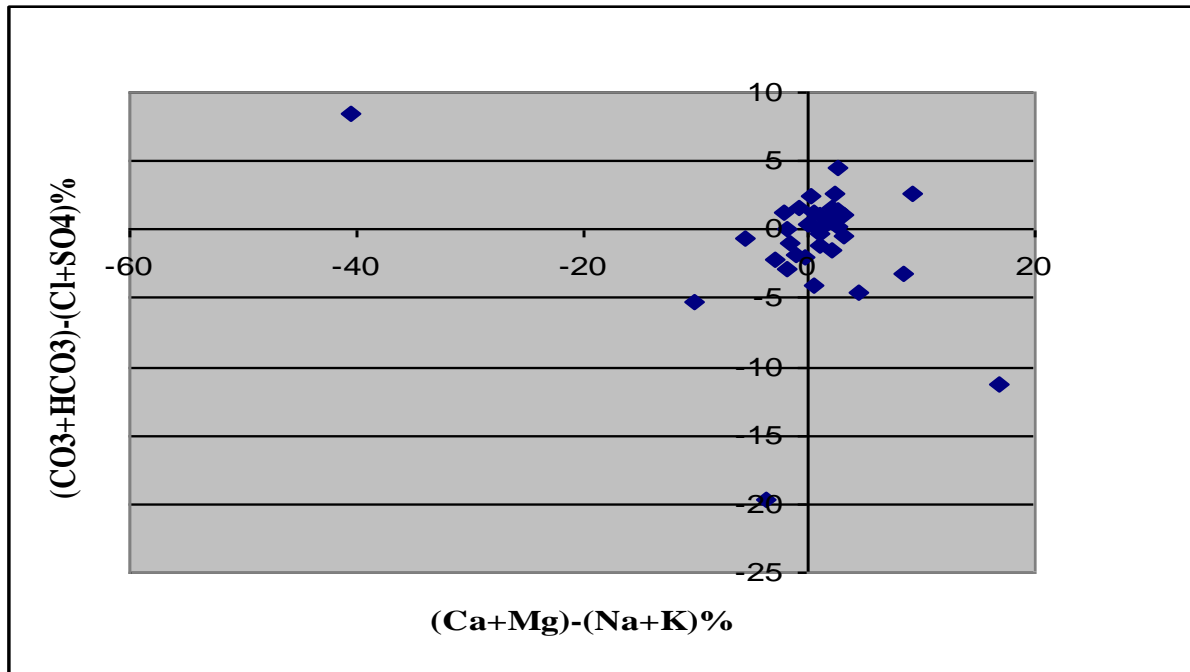


Fig.5.6: Chadha's diagram showing geochemical classification

In contrast, in the Chadha's diagram, the difference in milliequivalent percentage between alkaline earths (calcium + magnesium) and alkali metals (sodium + potassium) expressed as percentage reacting values is plotted along the x -axis and the difference in milliequivalent percentage between weak acidic anions (carbonate + bicarbonate) and strong acidic anions (chloride + sulphate) is plotted along the y -axis. The resulting field of the study is a square or rectangle depending upon the size of the scales chosen for x - and y - co-ordinates. The milliequivalent percentage differences between alkaline earths and alkali metals and between weak acidic anions and strong acidic anions would plot in one of the four possible sub fields of the proposed diagram.

The square or rectangle field describes the overall character of the water. The proposed diagram has all the advantages of the diamond-shaped field of the Piper diagram and can be used to study various hydro-chemical processes, such as base cation exchange, cement pollution, mixing of natural waters, sulphate reduction, saline water (end product water) and other related hydro-chemical problems. In order to define the primary character of water, the rectangular field is divided into eight sub field, each of which represents a water type as follows:

1. Alkaline earths exceed alkali metals.
2. Alkali metals exceed alkaline earths.

3. Weak acidic anions exceed strong acidic anions.
4. Strong acidic anions exceed weak acidic anions.
5. Alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions respectively. Such water has temporary hardness. The position of data points in the proposed diagram represent Ca^{2+} - Mg^{2+} - HCO_3^- type, Ca^{2+} - Mg^{2+} -dominant HCO_3^- type, or HCO_3^- -dominant Ca^{2+} - Mg^{2+} -type waters.
6. Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water has permanent hardness and does not deposit residual sodium carbonate in irrigation use. The position of data points in the proposed diagram represent Ca^{2+} - Mg^{2+} Cl type, Ca^{2+} - Mg^{2+} -dominant Cl type or Cl dominant, Ca^{2+} - Mg^{2+} -type waters.
7. Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. Such water generally creates salinity problems both in irrigation and drinking uses. The position of data points in the proposed diagram represent Na^+ -Cl -type, Na_2SO_4 -type Na^+ -dominant Cl - type, or Cl -dominant Na^+ -type waters.
8. Alkali metals exceed alkaline earths and weak acidic anions exceed strong acidic anions. Such water deposit residual sodium carbonate in irrigation use and cause foaming problems. The positions of data points in the proposed diagram represent Na^+ - HCO_3^- -type, Na^+ -dominant HCO_3^- -type, or HCO_3^- -dominant Na^+ -type waters.

According to Chadha's diagram, the groundwater of Belgaum city fall under categories 2, 3, 4, 5, 6, and 7. It is also noted that all the sample data points are clustered around the central point. The category 2 indicates that the alkali metals exceed alkaline earths. Group 3 shows the weak acidic anions exceeding strong acidic anions. In the group 5 only one sample is seen. This is characterized by alkaline earths and weak acidic anions exceeding both alkali metals and strong acidic anions, respectively. Such water has temporary hardness. Group 6 is represented by Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water has permanent hardness and does not deposit residual sodium carbonate in irrigation use. Group 7 indicates the presence of alkali metals exceeding alkaline earths and strong acidic anions exceeding weak acidic anions. Such water sample generally creates salinity problems both in irrigation and drinking waters.

5.5 Sodium Adsorption Ratio

Sodium concentration is an important criterion in irrigation-water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by Sodium Adsorption Ratio (SAR). The SAR is calculated using the formula:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

In order to classify the ground water based on SAR values following standards were considered in the study area.

- **1 to 5.00 is LOW**
- **5.00 to 10.00 is MODERATE**
- **10.00 to 20.00 is HIGH**
- **> 20, VERY HIGH**

Table.5.4 shows the Sodium Adsorption ratio observed for Belgaum city. The SAR ratio varies from 2.4 to 21.25. The minimum was noticed at KLE Hospital, Yellur Road (2.4) and maximum at Jyothirling galli, Indal road, Kanbargi (21.25).

Table.5.4: The Sodium Adsorption Ratio Observed For Belgaum City

Sl. No.	Sampling Stations	SAR	Category
1	Yellur U/S	4.05	Low
2	Yellur D/S	2.55	Low
3	Annad nagar, Vadagaon	4.18	Low
4	KLE Hospital, Yellur Road	2.4	Low
5	Annapurneshwari nagar, Vadagaon	13.07	High
6	Manickbag	16.39	High
7	Patil galli	4.68	Low
8	Old PB Road Khasbhag	4.58	Low
9	Gayathri nagar	11.29	High
10	Near Narthaki, Talkies, Kapileshwari temple	16.56	High
11	Indal Road, Kanbargi	3.39	Low
12	Jyothirling galli, Indal road, Kanbargi	21.25	Very High
13	Kanbergi Bus stop	18.86	High
14	Jeoni bhavi	2.41	Low
15	Jyothirling galli, Kanbargi	8.21	Moderate
16	Adarsh Vidyalay, Hindwadi	6.52	Moderate
17	Hanuman nagar, Hindwadi	4.57	Low
18	Mangalwarpeth, Tilakwadi	6.28	Moderate
19	Somwarpeth, Tilakwadi	3.74	Low
20	Somawarpeth, Tilakwadi	5.96	Moderate

5.6 Pearson Correlation Coefficient

Table.5.5 shows the Pearson correlation coefficient observed between the major cations and anions. From the table it is evident that alkalinity shows moderately high correlation with Ca

(0.702) and TH (0.704). A moderate correlation is noticed with EC, pH and TDS. The chloride content shows a very high positive correlation with EC ($r= 0.913$), Na ($r=0.893$) and TDS ($r=0.881$). Moderate to high correlation was found with Mg ($r= 0.661$) and TH ($r=0.778$). Potassium ions did not show significant correlation with any of the major anions and cations. Magnesium shows positive correlation with Na ($r= 0.56$), TDS ($r=0.645$) and TH ($r= 0.774$). Sodium ions shows high positive correlation with TDS ($r= 0.889$) and TH ($r=0.685$).

Table 5.5: Pearson Correlation Coefficient between the Ground water quality parameters of Belgaum city

	ALK	Ca	Cl	EC	K	Mg	Na	pH	TDS	TH
ALK	1.000									
Ca	0.702	1.000								
Cl	0.341	0.693	1.000							
EC	0.571	0.866	0.913	1.000						
K	-0.068	0.265	0.316	0.314	1.000					
Mg	0.465	0.495	0.661	0.650	0.131	1.000				
Na	0.333	0.623	0.893	0.878	0.400	0.560	1.000			
PH	0.536	0.440	0.302	0.455	0.016	0.253	0.220	1.000		
TDS	0.566	0.881	0.918	0.990	0.321	0.645	0.889	0.386	1.000	
TH	0.704	0.933	0.778	0.900	0.247	0.774	0.685	0.425	0.908	1.000

5.7 Factor Analysis

Factor analysis was carried out for the ground water quality data of Belgaum city. From the analysis, it is found that there are three major groups. The first group comprises of EC, TDS, SO₄, Na, Mg, TH, Cl, K and Ca. Second group includes alkalinity/bicarbonates. The third group is the microorganisms. The eigen values varied between 7.888 and 1.101 and percentage of variance ranges from 9.082 to 59.326.

Table 5.6: Factor loadings of Ground water quality parameters

SL.NO.	PARAMETERS	FACTOR 1	FACTOR 2	FACTOR 3
1	TDS	0.979	0.110	-0.026
2	EC	0.952	0.141	0.010
3	SO4	0.939	0.159	0.127
4	Na	0.936	0.180	0.100
5	Mg	0.914	0.106	0.038
6	TH	0.892	0.111	-0.183
7	Cl	0.857	-0.055	-0.270
8	K	0.844	0.146	0.321
9	Ca	0.801	-0.031	-0.293
10	ALK	0.246	0.960	-0.041
11	HCO3	0.240	0.958	-0.033
12	pH	0.497	-0.604	0.350
13	ECOLI	-0.079	-0.130	0.856
Eigen values		7.888	2.263	1.101
% of variance		59.326	18.156	9.082
Cumulative % of variance		59.326	77.482	86.564

5.8 DRASTIC INDICES

With the detailed field and laboratory investigation, ratings were allotted for different parameters. Based on the weights and ratings, indices were developed for each location. The range of DRASTIC indices varies between 140 and 204 (Table 5.7). The maximum is observed at Manikbag (204) in old PB road and minimum at Mangalwarpath, Tilkawadi (140). The observed water quality parameters also support the estimate made by using drastic indices. Old PB road is dominated by automobile industries and in most of the open wells in and around PB road exhibit water quality problems. This necessitates the attention from the local authorities to take up water conservation (both quantity and quality) measures to improve the situation.

Sampl. Station	Depth to WL		Recharge		Aquifer media		Soil media		Topograp		Impact of vodose		Hy. Conduct.		Drastic index	category
	W	R	W	R	W	R	W	R	W	R	W	R	W	R		
Yellur U/S	5	9	4	3	3	7	5	6	3	7	4	9	2	1	167	High
Yellur	5	9	4	9	3	7	5	7	3	2	4	5	2	6	175	High
Anand	5	7	4	5	3	5	5	6	3	3	4	7	2	3	143	Mod
KLE Yr	5	9	4	6	3	8	5	7	3	6	4	8	2	6	190	High
.Annap	5	7	4	6	3	8	5	8	3	8	4	8	2	7	193	High
Manick	5	10	4	9	3	8	5	8	3	2	4	8	2	8	204	Very high
Patil	5	8	4	9	3	8	5	8	3	2	4	8	2	8	202	V. High
Old PB	5	8	4	9	3	8	5	7	3	7	4	8	2	7	202	Very high
.Gayath	5	6	4	8	3	7	5	8	3	7	4	7	2	6	184	High
Narthak	5	7	4	8	3	8	5	8	3	8	4	8	2	7	201	Very high

Kanbar	5	7	4	6	3	7	5	6	3	7	4	6	2	5	165	High
Jyothirli	5	7	4	7	3	7	5	6	3	9	4	8	2	6	185	High
.Kan. Bus top	5	7	4	7	3	6	5	6	3	8	4	7	2	4	171	High
.Jeoni	5	9	4	7	3	8	5	7	3	8	4	7	2	5	194	High
Jyothirli ng galli,	5	8	4	6	3	6	5	6	3	5	4	5	2	6	159	High
Adarsh	5	7	4	7	3	6	5	6	3	6	4	6	2	5	163	High
Hanum	5	7	4	6	3	6	5	5	3	7	4	5	2	6	155	H
Manga	5	6	4	5	3	5	5	5	3	6	4	6	2	4	140	Moderate
Som.pet	5	8	4	7	3	6	5	5	3	5	4	6	2	5	160	High
Somp	5	6	4	5	3	4	5	7	3	8	4	5	2	3	142	Moderate

5.9 MICRO ORGANISMS

There is a great diversity of pathogenic bacterial groups and species potentially harmful to human health, of which representatives are frequently detected in groundwater and even drinking water. The majority's natural habitat is the gastrointestinal tract of humans and animals which they leave unintentionally via the excretion of faeces. Most known pathogenic bacteria belong to the family *Enterobacteriaceae*. Members of the *Enterobacteriaceae* are not necessarily pathogenic. Many representatives are widely distributed in soils and aquatic environments (Stevens *et al.* 2003). The most prominent members of the *Enterobacteriaceae* are the coliforms including a heterogeneous mix of different genera and species which vary considerably in terms of their pathogenic properties and virulence. Members of the coliform group, including the total coliform bacteria, the thermo-tolerant coliform bacteria, *Escherichia coli* and faecal streptococci are to date the most important indicators of faecal contamination (Gleeson 1997; Ashbolt *et al.* 2001; Leclerc *et al.* 2001). A common characteristic of this group is the growth at 37°C. Thermotolerant coliforms, including *E. coli*, are even able to grow up to 44°C (WHO 2006). Among the pathogenic representatives of the *Enterobacteriaceae* are several *E. coli* strains responsible for severe infections, namely enteropathogenic *E. coli* (EPEC), enterotoxic *E. coli* (ETEC) and enterohaemorrhagic *E. coli* (EHEC) (Nataro and Kaper 1998). The *Enterococcus* group, a subgroup of the faecal streptococci is known to be, within the coliforms, most resistant to environmental conditions and changes and carry resistances to several antibiotics (McFeters *et al.* 1974; Hartke *et al.* 1998; Sapkota *et al.* 2007). One member of this group, *E. faecalis*, tolerates high temperatures (up to 45°C), high pH values (9.6), and high salt concentrations (up to 6.5% sodium chloride) and is therefore also a valuable bacterial indicator for determining the extent of faecal contamination of water (Foulquie Moreno *et al.* 2006; Farnleitner *et al.* 2010). Further typical bacterial pathogens distributed by the faecal-oral route and occasionally found in groundwater include species of *Salmonella* and *Shigella*, and, emerging mainly in developing countries, species of *Vibrio* with *Vibrio chol.*

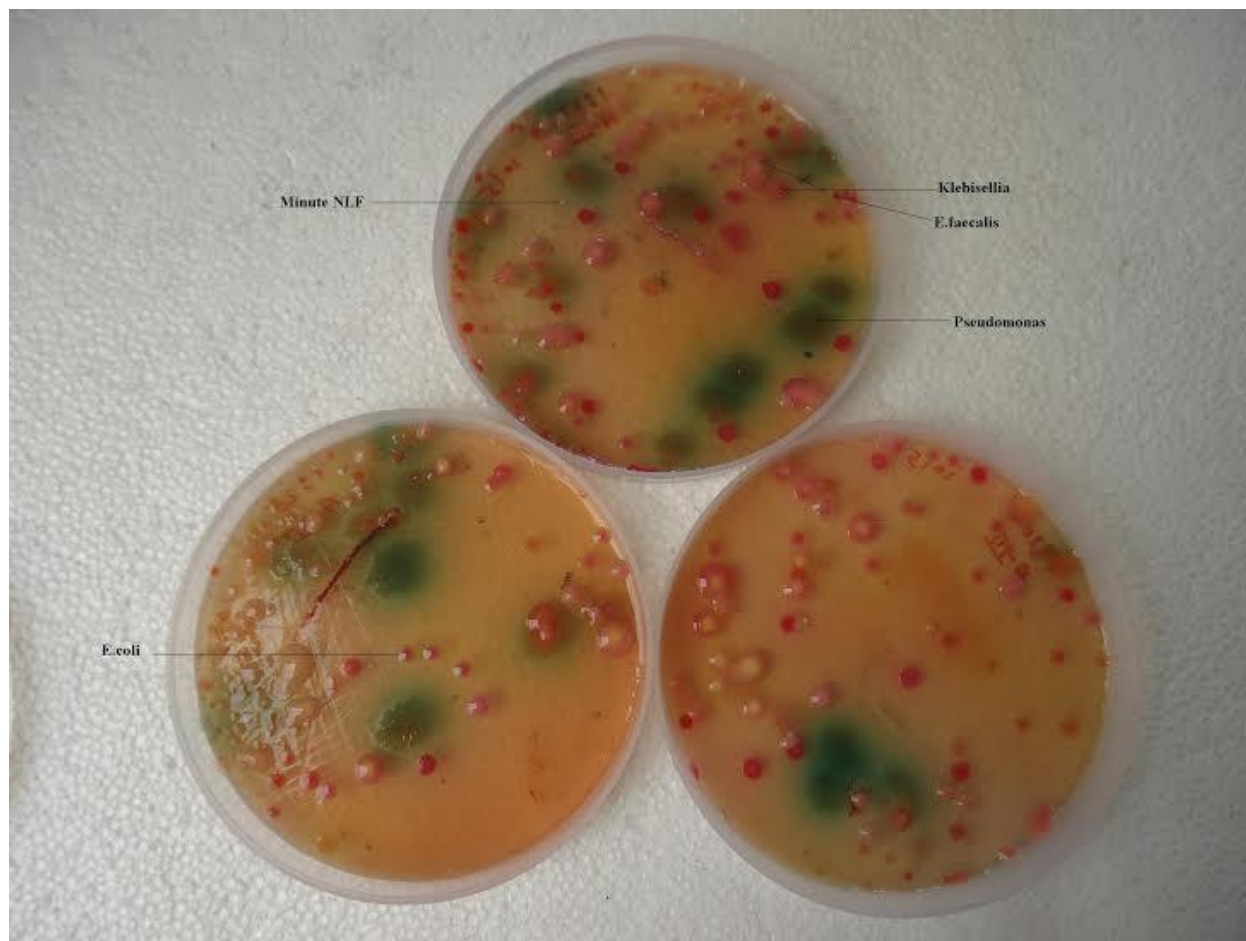


Fig.5.7: Different types of Microorganisms

The typical bacterial pathogens distributed by the faecal-oral route and occasionally found in groundwater include species of *Salmonella* and *Shigella*, and, emerging mainly in developing countries, species of *Vibrio* with *Vibrio cholerae* being the most prominent Representative. The genus *Salmonella* and *Shigella* are also members of the *Enterobacteriaceae*, however, they are not considered as coliforms. In the present investigation carried out in parts of Belgaum city, the highest number of micro-organisms are observed in an open well near KLE hospital, Yellur road (> 500) and near Narthaki talkies (near Kapileshwari temple). In the residential area, maximum microorganisms are observed at Manikbag (>300), Hindwadi, Adarsh Vidyalay road (> 300) and Patil galli (> 200). Groundwater in Kanabargi, Tilakwadi and Yellur area are also contaminated by micro-organisms. Table.5.8 shows the counts of micro-organisms in the ground water of Belgaum city.

Table 5.8: Micro organism counts in Ground water of Belgaum city

Date	Sl.No.	Names of Sampling Stations	Neat	1:25	1:50	0.1111
18-05-2014	1	Yellur U/S	>30	>5	>2	>5
18-05-2014	2	Yellur D/S	>20	>10	>3	>5
18-05-2014	3	Annad nagar, Vadagaon	>500	>300	>300	>300
18-05-2014	4	KLE Hospital, Yellur Road	>10	>3	NG	NG
18-05-2014	5	Annapurneshwari nagar, Vadagaon	>100	>50	>25	>10
21-05-2014	6	Manickbag	130	50	20	10
21-05-2014	7	Patil galli	105	70	38	15
21-05-2014	8	Old PB Road Khasbhag	84	62	49	30
21-05-2014	9	Gayathri nagar	120	90	60	16
21-05-2014	10	Near Narthaki, Talkies, Kapileshwari temple	125	80	30	22
23-05-2014	11	Indal Road, Kanbargi	>300	200	120	100
23-05-2014	12	.Jyothirling galli, Indal road, Kanbargi	200	100	87	45
23-05-2014	13	Kanbergi Bus stop	47	10	30	90
23-05-2014	14	.Jeoni bhavi	25	3	20	63
23-05-2014	15	Jyothirling galli, Kanbargi	>500	>300	>200	>100
26-05-2014	16	Adarsh Vidyalay, Hindwadi	>300	>200	>200	>50
26-05-2014	17	Hanuman nagar, Hindwadi	1	5	NG	NG
26-05-2014	18	Mangalwarpeth, Tilakwadi	18	1	NG	NG
26-05-2014	19	Somwarpeth, Tilakwadi	55	24	12	3
26-05-2014	20	Somawarpeth, Tilakwadi	>100	>50	43	48

5.10 Health effects of microbes in ground water

5.10.1 National Sanitation Foundation Water Quality Index (NSFWQI)

A usual water quality index method was developed by paying great rigor in selecting parameters, developing a common scale and assigning weights. The attempt was supported by the National Sanitation Foundation (NSF) and therefore as NSFWQI in order to calculate WQI of various water bodies critically polluted. The proposed method for comparing the water quality of various water sources is based upon nine water quality parameters such as temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates and total

solids¹. The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Q_i is obtained. The mathematical expression for NSF WQI is given by

$$WQI = \sum_{i=1}^n Q_i W_i$$

Where,

Q_i = sub-index for i^{th} water quality parameter;

W_i = weight associated with i^{th} water quality parameter;

n = number of water quality parameters.

For this NSF WQI method, the ratings of water quality have been defined by using following Table.5.9

Table 5.9: Water Quality Rating as per different Water Quality

Index methods

National Sanitation Foundation Water Quality Index (NSFWQI)	
WQI Value	Rating of Water Quality
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality
Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)	
95-100	Excellent water quality
80-94	Good water quality
60-79	Fair water quality
45-59	Marginal water quality
0-44	Poor water quality
Oregon Water Quality Index (OWQI)	
90-100	Excellent water quality
85-89	Good water quality
80-84	Fair water quality
60-79	Poor water quality
0-59	Very poor water quality

Table 5.10: NSF Index for Different sampling stations of Belgaum City

Sl. No.	Sampling Stations	NSF Index	Category
1	Yellur U/S	66	Very high
2	Yellur D/S	66	Very high
3	Annad nagar, Vadagaon	59	Moderate
4	KLE Hospital, Yellur Road	70	Very high
5	Annapurneshwari nagar, Vadagaon	65	high
6	Manickbag	65	high
7	Patil galli	64	High
8	Old PB RoadKhasbhag	63	High
9	Gayathri nagar	64	High
10	Near Narthaki, Talkies, Kapileshwari temple	57	Moderate
11	Indal Road, Kanbargi	58	Moderate
12	Jyothirling galli, Indal road, Kanbargi	57	Moderate
13	Kanbargi Bus stop	58	Moderate
14	Jeoni bhavi	57	Moderate
15	Jyothirling galli, Kanbargi	56	Moderate
16	Adarsh Vidyalay, Hindwadi	58	Moderate
17	Hanuman nagar, Hindwadi	65	high
18	Mangalwarpeth, Tilakwadi	65	high
19	. Somwarpeth, Tilakwadi	67	Very high
20	Somawarpeth, Tilakwadi	62	High

Note :- NSF Index Category

< 55 = low

56 - 60 = moderate

61 - 65 = high

66 – 70 = very high

It is observed that the NSF index ranges from 56 to 70. In Jyothirling galli, Kanbargi NSF Index is 56 which is the minimum and in KLE Hospital, Yellur Road NSF Index is 70 which is the maximum. Further from table 5.9 Water Quality rating as per different water quality index methods it is observed that the medium water quality ranges from 51-70.hence the water quality of Belgaum city is medium water quality.

In all ground waters there are some bacteria, and in general they carry out beneficial processes, some bacteria or other microorganisms cause disease in humans. Naturally some microorganisms have learned to live on or in the human body. Many of these microorganisms do no harm, and are even beneficial because they compete with other microorganisms that might cause disease if they could become established in or on our bodies. A few microorganisms (called pathogens) can cause disease in humans. Some of this disease - causing microorganism are closely associated with humans and other warm-blooded animals. These pathogens are transmitted from one organism to another by direct contact, or by contamination of food or water. Many of the pathogens which cause gastrointestinal disease are in this category. Several human gastrointestinal pathogens produce toxins which act on the small intestine, causing secretion of fluid which results in diarrhea. Cells of the pathogen are shed in the feces, and if these cells contaminate food or water which is then consumed by another person, the disease spreads. Other pathogens are "opportunists" : they may not be closely associated with humans or other mammals and they rarely cause disease in healthy adults. Instead, these may be common bacteria or fungi which exist in soil or water, but may cause disease in persons already weakened by a pre-existing disease.

The fecal indicator bacteria (*Escherichia coli*, fecal coliforms, fecal streptococci) are typically used to measure the sanitary quality of water for recreational, industrial, agricultural and water supply purposes. The fecal indicator bacteria are natural inhabitants of the gastrointestinal tracts of humans and other warm-blooded animals. These bacteria in general cause no harm. They are released into the environment with feces, and are then exposed to a variety of environmental conditions that eventually cause their death. In general, it is believed that the fecal indicator cannot grow in natural environments, since they are adapted to live in the gastrointestinal tract. Studies have shown that fecal indicator bacteria survive from a few hours up to several days in surface water, but may survive for days or months in lake sediments, where they may be protected from

sunlight and predators. In ground water, temperature, competition with bacteria found naturally in the water, predation by protozoa and other small organisms, and entrapment in pore spaces may all contribute to their demise. We assume that pathogens similar to the fecal indicator bacteria die at the same rate as fecal indicator bacteria. Therefore, if we find relatively high numbers of fecal indicator bacteria in an environment, we assume that there is an increased likelihood of pathogens being present as well. Unfortunately, some pathogenic bacteria, viruses and protozoans may have special survival mechanisms, such as cyst formation in *Cryptosporidium*, or attachment of viruses to particles, so that waters free of fecal indicator bacteria may still harbor these microorganisms. This is even true of water which has undergone treatment for drinking water purposes.

There is no clear way to associate risk of disease with the bacteriological quality of ground water and measured by the presence of fecal indicator bacteria. First, there is no direct association between the presence of fecal indicator bacteria and the presence of specific pathogens. Second, individuals are not equally susceptible to pathogens. Whether or not a pathogen is successful in causing disease is related to the health of the exposed individual and the state of his or her immune system, as well as to the number of pathogen cells required to make the person ill. Some pathogens can cause disease when only a few cells are present. In other cases, many cells are required to make a person ill. Children, elderly persons and persons with pre-existing illnesses are more susceptible to many pathogens than are healthy young or middle-aged adults. Third, it would be difficult to monitor for every possible pathogen. Each type of pathogen requires a specific test and many of these tests are time-consuming or expensive. Monitoring for each type of known pathogen would be prohibitively expensive. Finally, new pathogens are still being discovered. It was only about 5 years ago that a specific bacterium was identified as a cause of stomach ulcers in humans. In addition, "old" bacteria are acquiring new "tricks" in that they are becoming resistant to antibiotics and are re-emerging as serious pathogens. The issue of emerging infectious disease, and a call for the strengthening of our public health knowledge base and infrastructure was made by the Centers for Disease Control (CDC) in 1994.

Table 5.11: Pathogens and the diseases caused by the individual organisms

PATHOGEN	MAJOR DISEASES	SOURCES
Bacteria		
Escherichia coli	Gastroenteritis, haemolytic ureamic syndrome (enterotoxigenic E. coli)	Human faeces
Salmonella spp.	Enterocolitis, endocarditis, meningitis, pericarditis, reactive arthritis, pneumonia	Human and animal faeces
Shigella spp.	Gastroenteritis, dysentery, reactive arthritis	Human faeces
Campylobacter jejuni	Gastroenteritis, Guillain-Barre syndrome	Human and animal faeces
Yersinia spp.	Diarrhea, reactive arthritis	Human and animal faeces
Vibrio spp.	Cholera	Human faeces and freshwater zooplankton
Pseudomonas aeruginosa	Pneumonia (Legionnaires' disease)	Soil and water
Mycobacterium spp.	Pulmonary disease, skin and soft tissue disease	Soil and water
Viruses		
Poliovirus	Poliomyelitis	Human faeces
Coxsackievirus	Fever, pharyngitis, rash, respiratory disease, diarrhea, haemorrhagic conjunctivitis, myocarditis, pericarditis, aseptic meningitis, encephalitis, reactive insulin-dependent diabetes	Human faeces
Echovirus	respiratory disease, aseptic meningitis, rash, fever	Human faeces
Enteroviruses 68-71	Polio-like illness, aseptic meningitis, hand, foot and mouth (E71), Epidemic Conjunctivitis (E70)	Human faeces
Hepatitis A	Fever, nausea, jaundice, liver failure	Human faeces
Hepatitis E	Fever, nausea, jaundice.	Human faeces
Norovirus (Norwalk virus)	Gastroenteritis	Human faeces
Calicivirus	Gastroenteritis	Human faeces
Astrovirus	Gastroenteritis	Human faeces

Sapovirus	Gastroenteritis	Human faeces
Orthoreovirus	Gastroenteritis and upper respiratory disease	Human faeces
Rotavirus A and C	Gastroenteritis	Human faeces
Coronavirus	Gastroenteritis	Human faeces
Adenovirus	respiratory disease, Gastroenteritis	Human faeces
Protozoa		
Cryptosporidium parvum	Cryptosporidiosis (Gastroenteritis)	Water, human and other mammal faeces
Giardia lamblia	Giardiasis (chronic gastroenteritis)	Water and animal faeces
Entamoeba histolytica	Dysentery	human and animal faeces
Acanthamoeba spp.	Encephalitis, keratitis	Human faeces
Naegleria fowleri	meningoencephalitis	Warm water
Toxoplasma gondii	(congenital) toxoplasmosis (encephalitis)	Human and animal faeces

5.11 Groundwater Impact Analysis using VLEACH Model

5.11.1 Model Conceptualization

In the model, one-dimensional finite difference scheme was employed for solving the vadose zone transport equation, and a mass balance principle was used for the mixing calculation in the saturated aquifer underneath the soil columns. Ravi and Johnson (1993) developed one dimensional transport program called VLEACH, which handles only vertical migration of pollutant in a homogeneous soil column. VLEACH calculates the equilibrium distribution of contaminant mass between the liquid, gas, and sorbed phases. Transport processes are then simulated. Liquid advective transport is calculated based on values defined by the user for infiltration and soil water content. The contaminant in the vapor phase migrates into or out of adjacent cells based on the calculated concentration gradients that exist between adjacent cells. After the mass is exchanged between the cells, the total mass in each cell is recalculated and re-equilibrated between the different phases. These steps are conducted for each time step, and each polygon is simulated independently. At the end of the model simulation, the results from each polygon are compiled to determine an overall area weighted ground water impact for the entire modeled area.

5.11.2 Analysis of VLEACH Results

To understand the soil heterogeneity effect in the column the homogeneous soil columns were simulated. Note that, for homogeneous soil, uniform soil property was used. Two types of soil are found in majority of the study area in Kerala. Two major physiographic units were considered for the study, the upland areas dominated by Sandy and sandy clay loams and lowland areas and coastal areas dominated silty sands and clayey soils. Accordingly attempt was made to simulate the impact of water quality parameters on groundwater under different recharge conditions both in upland and lowland regions of Kerala. The results of VLEACH contain mass balance and ground water impact information. In particular the calculated mass in the vadose zone. The mass is calculated in g/sq.ft. The components of the changes in mass are described as advection from the atmosphere, advection from water table, diffusion from atmosphere, diffusion from water table, total inflow at boundaries, and mass discrepancy. A positive value in the mass change indicates mass loss from the system. The final results are presented in Figure 2a & 2b, which provides the summary on ground water impact data. The total ground water impact is defined in terms of total mass and cumulative mass.

Table 5.12: Movement of Pollutant in Ground water in areas of Clay Loam soil

years	Ground water recharge (ft/yr)		
	0.2	0.6	1.00
5	241.8209	1787.63	5241.21
10	314.2763	2456.463	6448.145
15	384.9423	3026.814	7418.713
20	452.746	3509.391	8196.334
25	516.9351	3914.946	8817.291
30	577.0192	4253.758	9311.647
35	632.7178	4535.331	9704.13
40	683.9172	4768.242	10014.95
45	730.6314	4960.093	10260.51
50	772.971	5117.522	10445.110

5.13: Concentration of Pollutants through the Soil media (Clay loam soil)

Depth (ft)	Ground recharge (ft/yr)		
	0.2	0.6	1
0.5	186.3027	197.5347	199.9512
1.5	170.5658	191.73	196.4478
2.5	156.1939	186.0919	192.9992
35	143.0863	180.6163	189.6043
4.5	131.1472	175.299	186.2625
5.5	118.287	168.5238	181.4388
6.5	107.8488	163.3158	178.0828
7.5	98.34046	158.2556	174.7779
8.5	89.64982	153.3396	171.5232
9.5	81.82875	148.5643	168.3179
10.5	73.09426	142.6362	163.9344
11.5	66.16922	137.9755	160.7319
12.5	59.86832	133.4461	157.5773
13.5	54.14192	129.0451	154.4698
14.5	48.94339	124.7693	151.4087
15.5	44.229	120.6157	148.3933
16.5	39.95792	116.5811	145.4231
17.5	36.09212	112.6627	142.4974
18.5	32.59625	108.8574	139.6155
19.5	29.43756	105.1625	136.7767
20.5	26.3859	101.4137	133.827
21.5	23.75618	97.9112	131.0608
22.5	21.38153	94.5108	128.3359
23.5	19.23862	91.2096	125.6518
24.5	17.30602	88.005	123.0038
25.5	15.56404	84.8945	120.403
26.5	13.99461	81.8755	117.8373

Table 5.14: Movement of Pollutant in Ground water in areas of Sandy Clay Loam soil

years	0.2 feet	0.6 feet	1 feet
5	903.6344	143.8677	4089.531
10	894.1543	175.6194	5325.148
15	885.3027	213.4953	6320.773
20	876.7071	257.6425	7116.259
25	868.1873	308.2158	7747.178
30	859.6904	365.3729	8244.399
35	851.246	429.2656	8633.849
40	842.9275	500.0304	8937.44
45	834.8269	577.7783	9172.961
50	827.038	662.5851	9354.894

Table 5.15: Concentration of Pollutants in Soils (Clay loam soil)

Depth (ft)	Ground water recharge (ft/yr)		
	0.2 feet	0.6 feet	1 feet
0.5	133.1573	540.6046	141.8115
1.5	123.1844	521.0774	139.7124
2.5	113.9738	498.1587	137.6421
3.5	105.4795	475.1135	135.6
4.5	97.6569	452.1716	133.5858
5.5	90.4632	429.5294	131.5989
6.5	83.8569	407.352	129.6389
7.5	77.7983	385.7747	127.7057
8.5	72.2493	364.9069	125.7978
9.5	67.1735	344.8337	123.9158
10.5	62.5364	325.6186	122.0588
11.5	58.3053	307.306	120.2266
12.5	54.4489	289.9244	118.4186
13.5	50.938	273.487	116.6348
14.5	47.7451	259.9958	114.8738
15.5	44.8442	243.4418	113.1362
16.5	42.2111	229.8079	111.4211
17.5	39.8231	217.07	109.7283
18.5	37.6591	205.1986	108.0574
19.5	35.6995	194.1597	106.4078
20.5	33.1072	180.8166	104.2382
21.5	31.1432	169.8964	102.5646
22.5	29.322	159.6354	100.9104
23.5	27.6349	150.0135	99.2754
24.5	26.0734	141.0126	97.6592
25.5	24.6294	132.609	96.0617

26.5	23.2951	124.7778	94.4824
27.5	22.0632	117.4925	92.9213
28.5	20.9267	110.7274	91.3778
29.5	19.8788	104.4535	89.852
30.5	18.2587	96.1638	87.9104
31.5	17.0807	89.6435	86.366
32.5	15.9652	83.4863	84.8378
33.5	14.9105	77.6843	83.3252
34.5	13.9152	72.2281	81.8284
35.5	12.9779	67.1069	80.347
36.5	12.0967	62.3089	78.8808
37.5	11.2697	57.8213	77.4294
38.5	10.4947	53.6307	75.9937
39.5	9.7659	49.7231	74.5722
40.5	9.01	45.7743	73.1112
41.5	8.3414	42.2464	71.7121
42.5	7.7144	38.9527	70.327
43.5	7.1272	35.881	68.9559
44.5	6.5777	33.0195	67.5985
45.5	6.064	30.3559	67.2547

The application of VLEACH model and the sensitivity analysis carried out in the study area, indicated that the organic carbon partition coefficient (K_{oc}), infiltration velocity (q), and fraction organic carbon (f_{oc}) have the greatest impact on both soil contaminant concentration and ground water loading. Bulk density (ρ_b) and porosity have significant effect only on the soil contaminant levels. The other parameters are found to have no significant impact on either soil contaminant level or groundwater loading. The application VLEACH shows that the higher recharge in the study area may result in speedy distribution of contaminants to the ground water. This is well demonstrated in the coastal areas where high rainfall accompanied by higher recharge rates were estimated and found that this is major cause of contaminant transport in coastal areas. Further, the density of population is very high all along the coastal belts, sewage and water drained through the soak pits (toilet) passes directly into the water table and results in water contamination. A detailed study is required to understand the phenomenon more systematically.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Ground water has traditionally been considered to be the water source least susceptible to contamination by indicator bacteria or human pathogens. This is certainly true of ground water from deep, confined aquifers. However, in the present investigation, it is noticed that the microbiological quality of ground water is contaminated with microorganisms which is attributed to the dumping of solid wastes and discharge of liquid wastes in unplanned manner. The microorganisms enters the ground water system due to its connection with a contaminated surface environment, such as seepage from a waste lagoon or a contaminated surface water, or a subsurface source of contamination such as a septic tank, a broken or leaking sewer line, or an old or improperly designed land-fill.

One of the major causes of ground water pollution in Belgaum city could be due to the ongoing urbanization and uncontrolled abstraction of water. The land use changes are quite marked in extension areas of the city, particularly on the western and northern zones. In these areas lots of agriculture lands have been converted to habitation lands. Further, agriculture deep ploughing, the uses of heavy machinery, application of excessive fertilizers and pesticides, drainage and irrigation have all lead to water quality problems.

Another important problem associated with ground water quality issues of Belgaum city is due to the long term usage of ground water for irrigation. The excessive irrigation in some parts of the city, results in building up of salts in the soil by capillary rise from water table. If there is not enough leaching, a process of secondary salinization and associated sodification takes place, leading to the soil and ground water salinization. As water moves beneath the root zone but above shallow permeable layers a local ground water system is formed. Salts in the soil are dissolved and salt is deposited on the surface. The primary cause appears to be farming practices in general and cropping pattern in particular. Further, due to high intensity rainfalls in the city, erosion of dumped wastes and soils takes place rate seems to be very high and these sediments

acts a carrier of polluting chemicals, such as pesticides and plant nutrients. Based on the present investigations and data analysis, it is noted that the major cause of water pollution in Belgaum city is due to the man made disturbances. Bacteriological pollution is mainly due to the mixing of sewage water with the shallow aquifers. Geomorphologic and soil characteristics play significant role in transporting solutes to ground water and surface water bodies. This is clearly demonstrated through VLEACH model application. Further, the widely distributed iron contamination is geogenic in origin which can be controlled by proper techniques. Apart from this, following activities are also contributing to water pollution.

- Contamination of groundwater supplies by unsewered sanitation.
- The bacteriological contamination of shallow wells in all types of geological formation.
- The increase of chloride in many wells is a clear indication of mixing of sewage water with ground water
- It is observed that the inner part of the city is getting contaminated due to the thrust of population and commercial complexes.
- A temporal change in the chemical composition of the ground water is noticed at certain locations from the point of recharge to the point of discharge.

DRASTIC index developed for the study area delineated nine critical zones as pollution potential zones. These areas lie mostly in the innermost part of the city and commercial complex where population density is quite high. Further, there are no power sewer lines and dumping sites in this area. Therefore, the DRASTIC parameters show a clear indication of these points. However, it is suggested that the modification of DRASTIC parameters by incorporating other factors such as land use, land cover, chemical applications, well density, irrigation type and intensity will enhance the accuracy of the results.

At the outset, based on the analysis of the data collected, followed by field investigation and discussion held with various scientists working in this area indicated that groundwater is getting contaminated, especially, due to waste disposals without any precautions. This observation shows that it is necessary to go for sewage

treatment plans so that the pollution due to use of this water by farmers and mixing of sewage with ground water can be minimized.

6.2 Recommendations

1. Stringent action should be taken for the management of solid wastes
2. Reconstruction and lining of sewer lines may be taken up on priority basis
3. Restructuring of waste management plan with provision for organic farming by conversion of waste in to organic manures
4. Organising awareness programs in each ward and also in city outskirts to bring knowledge on waste management.
5. Scientific based management plan with technological innovations
6. Regular monitoring of groundwater and surface quality in various parts of the city to understand the impact of waste management on water quality aspects.
7. Sewage treatment plants should be installed at various parts of the city where it is discharged to the Bellary nala.

REFERENCES

APHA (1992).Standard method for examination of Water and Wastewater. American Public Health Assosiation,Washington DC.

Brown, L. C., and Barnwell, T. O., Jr. (1987).The Enhanced Stream Water Quality Models QUAL2E-UNCAS Documentation and Users Manual.U.S.EPA/600/3-87/007.

Churchill, M.A., Elmore, H. L., and Buckingham, R.A. (1962).The prediction of re-aeration rates. *International Journal of Air and Water Pollution*, 6, 467-504.

Ghosh, N.C., and Mcbean, E.A.,(1998). Water Quality Modeling of the Kali river, India. *International Journal of Water, Air and Soil Pollution*, 102, 91-103.

O' Connor, D. J., and Dobbins, W. E. (1958).Mechanism of reaeration in natural streams.*Transactions ASCE*, 123,641-684.

Langbein, W. B., and Darum, W. H. (1967).The aeration capacity of streams, U.S. Geological Survey, Washington, D.C., Cric. 542.

Owens, M., Edwards, R. W., and Gibbs, J. W. (1964). Some reaeration studies in streams. *International Journal of Air and Water Pollution*, 8, 469-486.

Purandara, B. K., and Choubey, V. K. (1996).Hydrological Land Use Study of Ghataprabha catchment using IRS-1A data.*Asian-Pacific Remote Sensing and GIS Journal*.

Pawar, M.G.(2000). Evaluation of surface water quality parameters and water quality modeling using QUAL2E model.M.Tech Dissertation, Visvesvaraya Technological University, Belgaum, Karnataka, Indi

1. Agarwal, D. K. et. al.,(1976). "Physico-Chemical Characters of the Ganges at Varanasi", *Indian Journal of Environmental Health*, Vol. 18; 201-206.
2. APHA, 1985. *Standard Methods for the Estimation of Water and Waste Water*, American Public Health Association, New York.
3. Arora, H. C. and S. N. Chattopadhyay,(1974). "A Study on the Effluent Disposal of Super Phosphate Fertilizer Factory", *Indian Journal of Environmental Health*, 16, 140-150.
4. Arora, H. C. et. al.,(1973). "A Short Term Study on the Eutrophication of Gomti River in Lucknow Region", *Proc. Symposium Environmental Pollution*, CIPHERI, Nagpur, 44 – 58.
5. Bilgrami, K. S. and J. S. DuttaMunshi,(1979). "Limnological Survey and Impact of Human Activities on the River Ganges (Barauni to Farakka)", *Technical Report Submitted to D. S. T.* p. 91.

6. Chakraborty, R. D. et. al., (1967).“A Quantitative Study of Plankton and the Physico-Chemical Conditions of the River Yamuna at Allahabad in 1954 – 55”, Indian of Fisheries, 6(1): 186 – 208.
7. Chidambaram, P. T.(1990). “Impact of Irrigation Agriculture on Ground Water Quality”, M.Sc. Thesis, Anna University, Madras.
8. Central Ground Water Board, (1991).“Ground Water Resources and Developmental Potentials of Chengai Anna (Chingleput) District, Tamil Nadu”, CGWB, Southern Region, Hyderabad.
9. Das, D. K. and A. L. Kidwai,(1981). “Quality of Ground Water in Parts of Upper Catchment of Betwa River Basin in central India”, Proc. Int. Symp. On quality of Ground Water, Noordwijkerhout, the Netherlands.
10. Elengo, L. S., Ramachandran and Choudhry, Y. S. N., Ground water quality in Coastal Regions of South Madras, Indian. J. Environ. Hlth., 31, 228-236.
11. Ganapati, S. V. and P. I. Chacko,(1951). “An Investigation on the River Godavari and Effects of Paper mill Pollution at Rajahmundry”, Proc. Pacific Fish Comm. 2:70.
12. Govardhan, V., (1990). Ground water Pollution Hazards to Human Life - A case study of Nalgonda district, Indian J. Environ. Prot., 10, 54-61.
13. Handa, B. K.,(1994). “Ground Water Contamination in India”, Key Paper, Regional Workshop on Env. Aspects of Ground Water Development, Oct. 17-19, Kurukshetra India.
14. Handa, B. K., (1983). Methods of collection and preservation of water samples. Technical Manual No.6. Central Chemical Lab.CGWB. 1-44.
15. Handa, B. K., (1977). Water quality Criteria for agricultural, Municipal etc. Purposes. Technical Manual No. 4., 1-175.
16. Hem, J. D., (1985). Study and interpretation of the chemical characteristics of Natural water, 3rd edition, US Geological Survey Water Supply. Paper no. 2254, Washington, D. C., 263 p.
17. Hora, S. L.,(1942). “A Short Note on the Pollution of Streams in India and its likely Effect on Fisheries”, ICAR Report Fish Comm.
18. Jain, C. K., K. K. S. Bhatia and T. Vijay,(1997).“Ground Water Quality in a Coastal Region of Andra Pradesh”, Indian Journal of Env. Health., Vol. 39, No. 3, pp. 182-192.

19. Jain, C. K., Omkar, and M. K. Sharma, (1994). Ground water quality monitoring and Evaluation in district Jammu (J & K), CS (AR) 196, NIH, Roorkee.
20. Jain, C. K., Sudhirkumar and K. K. S. Bhatia, (1996). Ground water Quality in Western Uttar Pradesh, Indian J. Environ. Hlth., Vol. 38, No.2, 105-112.
21. Jain, C. K., and M. K. Sharma., (1997). Relationship among Water Quality Parameters of Ground water of Jammu District, Poll Res. 16(4): 241-246.
22. Jayashree, K., (2000). 'Impact of Sewage on Water Quality – a case study'. M. Tech Dissertation submitted to VTU, Belgaum.
23. Joshi, M. C. et. al.,(1982). "Water Pollution Due to Tailings and Copper Complex", Khetrinagar, Jhunjunu District, Rajasthan, Indian Journal of Env. Health, Vol. 24 (4), pp.292-297.
24. Kachwaha, M. S.,(1981). "Ground Water Quality in Rajasthan and Managing Water Supplies", Proc. Intl. Symp. of Quality of Ground Water, Noordwijkerhout, The Netherlands, pp.1053-1056.
25. Kakkar, Y. P., (1981). "Nitrate Pollution of Ground Water in Southern and South Eastern Haryana, India", Proc. Intl. Symp. Held in the Netherlands, march 23-27, pp. 125-129.
26. Kakkar, Y. P. and N. C. Bhatnagar,(1981). "Ground Water Pollution due to Industrial Effluent in Ludhiana, India", Proc. Intl. Symp. Held in the Netherlands, March 23-27, pp.265-272.
27. Karanth, K. R., (1987). Ground water Assessment, Development and Management. Tata McGraw-Hill Publishing Company Limited, New Delhi.
28. Krishnaswamy, R. and G. Haridas, (1981). "Ground Water Pollution by Tanneries in Tamil Nadu, India", Proc. Intl. Symp. on Quality of Ground Water, Noordwijkerhout, The Netherlands.
29. Kudesia, V. P.,(1980). "Water pollution", PragatiPrakashan, Meerut, India.
30. Madhurima, G. P., (2000). Evaluation of Water Quality Parameters and Dissolved Oxygen Modelling for Ghataprabha Sub-basin", M.Tech. thesis, V.T.U., Belgaum.
31. Mahatre, G. N. et. al.,(1980). "Effect of Industrial pollution on the Kalu River Ecosystem", Environmental Pollution Series A23: 67-78, 1980.
32. Mohan, C. and H. L. Sarkar.,(1961). "Preliminary Studies on the Pollution of the River Jamuna", Bulletin CIPHERI 1:76-82.

33. Mohan Rao, G. J., (1972).“Dairy Waste Characteristics With Reference to ISI Standards”, Indian Journal of Env. Health, 14, 218-224.
34. Moitra, J. R.,(1991). “Study of Liquid and Solid Wastes from some Metallurgical and Engineering Industries”, Ph.D. Thesis, Ravishankar University, M.P., 1991.
35. Muralikrishna, K. V. S. G., and Sumalatha, V., 1983. Ground water quality in Kakinada. Proc. of the All India Seminar on Ground water management in Coastal areas, 5-6th June, Vishakhapatnam.
36. Naram, K. R.,(1981). “Ground Water Pollution in Warangal Town, A. P., India”, Proc. Intl. Symp. on Quality of Ground Water, Noordwijkerhout, The Netherlands.
37. Narayana, A. C., and Suresh, G. C., Chemical quality of Groundwater of Managalore City, Karnataka, India J. Environ. Hlth., 31, 228-236.
38. Omkar, Shiv PrakashRai, Vijay Kumar, C. K. Jain,(1998).“Ground Water Quality Monitoring and Evaluation in Jammu and Kathua Districts, J and K, 1997-98”, national Institute of Hydrology, Roorkee, Report No. CS(AR) 21/97-98.
39. Paliwal, K. V., (1980).“Pollution of Surface and Ground Water – Water Pollution and Management Edited by C. K. Varshney, pp. 36-60.
40. Patel, L. B., Verma,V. K., G. S. Toor and P. K. Sharma,(2000). “Hydrochemistry of Ground Waters of Southern Punjab, India in Relation to their Suitability for Irrigation”, Ecol. Env. And Cons. 6 (2): pp. 179-183.
41. Patil, M. R. and A. R. Patil, (1983).“Water Quality of Ulhas River With Respect to Copper, Cadmium and, Mercury”, Pollution Research , 2(1): 24-27.
42. Pionkee, H. B., Sharma, M. L., and Hirschberg, K. J. B., (1990). Impact of Irrigated Horticulture on nitrate concentrations in Ground Water’. Agriculture, Ecosystems and Environment, Vol. 32, pp. 119-132.
43. Pradeep, K. Jain.,(1998). “Hydrochemical Studies of Sub-surface Water in Upper Urmil River Basin, District Chhatarpur, Central India”, Ecol. Env. And Cons. 4 (4): pp. 259-269.
44. Prasad, R. K.,(1995). “Ground Water Development Problems and Prospects”, Yojana, January 26.
45. Purandara, B. K., (1998). Ground water Quality studies in Belgaum City. Technical Report, NIH, Roorkee.
46. Purandara, B. K., (1999). Ground water Quality studies in Belgaum district. Technical Report, NIH, Roorkee.

47. RaghavaRao, K. V., (1977).“Incidence of Flouride in Ground Water”, Proc. Symp. on Fluorosis, Hyderabad”, Oct. 1974, Ind. Acad. Geosci.
48. Ramaswami, V., and Rajaguru, P.,(1991). Ground water quality of Tirupur, Indian J. Environ. Hlth., 33, 187-191.
49. Ravichandran, S., and Pundarikanthan, N. V.,(1991). Studies on Ground water Quality of Madras, Indian J. Environ. Hlth., 33,481-487.
50. SatyajiRao, Y. R., T. Vijaya and D. Mohan Rangan, (1999).“Spatial Evaluation of Ground Water Levels and its quality in Kakinada Town, A. P.”, National Institute of Hydrology, Roorkee, report No. CS(AR) 14/98-99.
51. SatyajiRao, Y. R., T. Vijaya and D. M. Rangan,(1998) “Seasonal Changes in Ground Water Hydrochemistry of Kakinada Town, A.P. During year 1997”, National Institute of hydrology, Roorkee, report No. CS(AR) 22/97-98.
52. Seth, A. K. and D. C. Singhal, (1994).“Status of Ground Water Quality in Upper Hindon Basin, Saharanpur Area, U.P., Regional Workshop on Env. Aspects of Grounda Water Develpoment, Oct. 17-19, Kurukshetra, India.
53. Singh, G., (1986).“Impact of Coal mining on Water Quality”, National Seminar on Env. Pollution Monitoring and Control, Centarl Scientific Inst. Org., Chandigarh, pp.457-463.
54. Singh, B. K. et. al.,(1991).“Ground Water Pollution.: A Case Study around North Eastern Railway City Station, Lucknow, U.P., Bhu-jal News, 6 (2), pp. 46-49.
55. Sudhir Kumar, C. K. Jain and K. K. S. Bhatia,(1988). “Ground Water Quality Variations in Saharanpur District (U.P.), National Institute of Hydrology, Roorkee, report No. TR-50.
56. Sinha, B. P. C., S. K. Sharma and O. P. Pal, (1996). Ground water Pollution Studies in India. INCOH Secretariat, NIH, Roorkee.
57. Streeter, H. W., and Phelps, E. B., (1925). A study of pollution and natural purification of the Ohio river, Pub. Hlth. Bull., U.S. Public Hlth. Service, Washinton, D. C.
58. Varadrajana, N.,(2000). “Ground water Quality Evaluation and Modelling – A case study”, M.E. thesis submitted to Karnataka University, Dharwar.
59. Verma, S. R. and G. R. Shukla, (1969). “Polution in perennial Stream Khala by the Sugar Factory Effluent NearLaksar (District Saharanpur), U. P., India”, Indian Journal of Env. Health, 11, 145-162.

60. Verma, S. R. and R. C. Delela.,(1975). "Studies on the Pollution of the Kalinadi by Industrial Wastes Near Mansurpur: Part I and Part II", *ActaHydrochim. Et. Hydrobial.* 3(3), 239-274.
61. Verma, S.R., et.al., (1974). "Studies on the Characteristics and Disposal Problems of the Industrial Effluents with Reference to ISI Standards: Part I", *Indian Journal of Env. Health*, 16, 289-299.
62. Verma, S. R. et. al.,(1980). "Studies on the Pollution of Hindon River in Realation to Fish and Fisheries", *Limnologica (Berlin)*, 12, 33-75, 1980.
63. Vijayaram, K., (1989). Pollution studies of Ground water in Sembattu, Tiruchirapalli, *Indian J. Environ. Prot.*, 9, 721-724.
64. Wilcox, L. V., (1995). Classification and use of Irrigation water, U. S> dept. of Agr. circular 969.
65. Worsley, R.R. Leg(1939). The Hydrogen Ion of Egyptian, *Sott. Min. Agric. Bull.* No. 83.