"To assess the impact of presence of Septic Tank on Groundwater and spread of Water Borne Diseases and to identify means to solve the problems created by the Waste Water in Balrampur District in Uttar Pradesh"

A

Report on

Research and Development Project of Ministry of Water Resources and Jamia Millia Islamia University New Delhi

By

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CHAPTER # 1

1. STATEMENT OF THE PROBLEM

Water is a prime natural resource, a basic human need, as precious a material as life. Importance of water is crucial for the development planning as the country has already entered in the 21 century. It is essential to have pure and uncontaminated water for human and animal consumption to attain a healthy society. As in the rural and semi-urban regions of the country most of the water used for above purpose is drawn from the ground so it becomes mandatory for us to keep it clean from any kind of contamination. Also it is estimated that the consumption pattern of water will increase as time proceeds with growing demand of food production so not only the quality but also the quantity of ground water is to be enhanced.

India lives in villages and the mode of life of people residing in villages is different from that of life in modern cities. The facilities provided to them relating to water and sanitation along with many other things are also not sufficient for better life. Earlier people in most part of Uttar Pradesh especially Balrampur district in case traditionally used their agriculture fields for the disposal of night soil. However, now with the advent of modernization and improvement in their living standard these sectors have got the soak pits and septic tanks, which are mostly undesigned. It has lead to plethora of problems. The night soil pollutes ground water when it directly goes into the water table or through their overflow the sewage water is collected in the pond by virtue of which the polluted water of pond further pollutes ground water as recharge. People in these areas have mostly been using hand pumps for drinking water, which has not been changed for a long time. Since the ground water is polluted and hand pumps are installed at shallow level therefore, the chances of ground water contamination leading to the occurrence of many water borne diseases like, Cholera, Typhoid, Methemoglobinaemia i.e. Blue Baby Syndrome, Decentry, Jaundice, etc are high in these areas.

Therefore, it is necessary to make assessment and characterization of Groundwater contamination and its impact on groundwater quality and human health due to the possible spread of water borne diseases in Balrampur district of Uttar Pradesh. Apart from this there is also a need to find out some possible remedial measures and evolving sustainable strategies that can be applied to check the ground water contamination from improper design of Septic Tanks and spread of water borne diseases in the district. Findings of the study can also be used as a guideline in several other parts of India, which are facing similar problems.

CHAPTER # 2

2. AIMS AND OBJECTIVES

1. Detailed characterization of hydro geological framework of the study area through analysis of available information and detailed field inventory.
2. To study the impact of wastewater originating from septic tanks on the quality of ground water.
3. To ascertain the kind of water borne diseases in the locality and its spatial distribution.
4. To Perform Hydro geological and geophysical study to identify potential contamination sites.
5. Assessment of ambient status of contamination and identification of potential sources and pathways of migration of pollutants.
6. Periodic ground water regime monitoring in terms of quality and quantity in selected observation wells and making ground water models to identify the geochemical behavior and migration pathways of contaminants in ground water and its future predictions.
7. To assess the above issues and evolve techniques of effective wastewater treatment and design of septic tanks to improve quality of Ground water.
8. To propose a **Ground water management cum monitoring Programme** for future.

CHAPTER # 3

3.0 PRESENT STATUS

3.1 NATIONAL

As the population is increasing day by day, the demand of fresh water for drinking purposes continue to grow among the people all over the country. Since most of the usable water comes from ground, the septic tanks are cause of concern today mainly due to their improper design as they are causing the spread of many water borne diseases in the developing countries like ours. As far as India is concerned the deadly diseases due to contaminated water are results of poor sanitary condition and they have gobbled thousands of precious human lives.

India is facing the threat of such contaminants since long time and number of researches have been carried out in this regard but the remedies are not looking so far.

3.2 INTERNATIONAL

Apart from India, people in other parts of the world especially developing countries are facing similar types of problems. So a number of studies have been carried out on the groundwater quality and pollution throughout the world by various organizations and scientists till date. The threat of water borne diseases and in particular the effect of nitrate in the groundwater has been studied but exhaustive and an efficient study is the need of the hour. Lack of integrated studies is the main reason and the humans are suffering from various deadly diseases. Ground water management cum monitoring programme for future is need of the hour.

CHAPTER # 4

4.0 BACKGROUND STUDY

The impact of septic tanks on groundwater quality and in turn the health hazards caused to human lives is one of the major problems India is facing in this 21^{st} Century. The Balrampur district has septic tanks and soak pits as the sanitary system. Leachate, an inevitable product from the septic tanks containing volatile organic compounds and other toxic constituents in absence of adequate protection measures poses threat to groundwater systems.

Balrampur district has been engulfed by the symptoms of Nitrate effects. The nitrate content is high enough and hence water is unsuitable for drinking purposes. Nitrate is a potential health threat to infants causing **Methemoglobinaemia.** Chronic consumption may also cause cancer. It also leads to reduced vitality, increased stillbirth and birth weight. There is an increased risk of bladder cancer. Poor sanitary condition may result in outbreak of many other water borne diseases, iodine and iron deficiency cause havoc in the areas of Balrampur district. Cases of Goiter and Hydroceal are also reported in large number.

Ground water is extremely critical to agricultural production but there are vast stretches of land affected by pollution of ground water due to the leachate from the septic tanks in the locality. These septic tanks have been constructed to treat the wastewater derived from human excreta. Ideally the wastewater should be able to decompose and its bacteria to be destroyed in these septic tanks. But these septic tanks are being made randomly and in totally unplanned manner. Firstly their location, which is very critical, is being taken arbitrarily whereas the septic tank should always lie downstream of the flow of water so that no drawing of water is affected by it. Secondly there are too many numbers of septic tanks in a small area. Since normally the villages are agglomerations of houses clustered together with not very well worked out drainage network, there are too many latrines in a small stretch of land. Hence the gradual seepage from numerous septic tanks accumulates to become large in quantity and reaches the ground water aquifers. Also during heavy rains this process is further accelerated whereas most of the recharge of ground water happens during this period and if this, recharging water itself is polluted it will only give impurities to the aquifers. The cleansing property of the soil is also drastically reduced because the concentration of the leachates is much higher than the soil's carrying capacity. Also due to improper construction and design of septic tanks and inadequate quality control by the local administration the positive effects of septic tank are likely to be subdued by the negative ones on ground water. Also the old septic tanks, which need regular cleaning, are often neglected and they are let to overflow. Thanks to the Policy for Rural Sanitation under the Ministry of Rural Development, there are many schemes where subsidies and loans are granted/given to local farmers both through the central and state governments. But what is lacking is post-project monitoring for execution, local level planning and evaluation of design of septic tanks according to local site conditions. So there is an urgency to check on all these issues so as to keep the Ground water pure. Also the availability of ground water is inadequate in the lean months.

CHAPTER # 5

5.0 METHODOLOGY

The methodology adopted for carrying out the project is as explained in the following sub-sections.

5.1 STEPS INVOLVED IN THE METHODOLOGY:

In order to accomplish the work the methodology was splitted into four tasks, covering the entire activities of the project.

A. Selection of areas for detailed scale study
B. Data Collection and Generation
C. Data Interpretation and Analysis
D. Results and Proposals

The subjects that constitute the data collection are:

1. Hydrogeology
2. Geomorphology
3. Land use and land cover
4. Drainage pattern
5. Cropping pattern
6. Soil and Pedo-analytical analysis (Micro studies at broad scale)

7. Disease pattern observed in the last five years (through primary survey of local hospitals, dispensaries and household surveys)
8. Eradication possibilities of water borne diseases and the measures to be followed.

5.2 HYDROGEOGICAL STUDIES AND FENCE DIAGRAM

The study area has been surveyed on two scales i.e. Macro and Micro level. The Macro level scale study is all about broadly the Regional character and micro level study denote selecting certain critical parts of the study area and carrying out a detailed research. Regional data has been collected from already established sources and agencies like Central Ground Water Board, State Ground Water Board, Different District offices etc. But the Detailed data has been collected personally by dedicated research team from the study area and fence diagram prepared.

The Hydro geological studies, which have been done, are (as per inventory given by Central Ground Water Board):

1. Depth to Water level study
2. Water level fluctuation study
3. Ground water movement study
4. Ground water balance study with respect to requirement versus availability by balancing the parameters.
5. Ground water Quality study

5.3 HAND DRILLING AT BLOCK LEVEL AND PROCUREMENT OF DEPTHWISE WATER SAMPLES

Boring at different locations in the study area has been done near septic tanks/soak pits for the collection of Soil and Water Samples. The water levels were taken and depth wise water samples were collected for pre and post monsoon periods in last two years. Altogether 56 stations were fixed for water level and out of that from 28 stations of importance with the view to effect of septic tanks, water samples were collected for and analysis.

5.4 HYDROCHEMICAL ANALYSIS AS PER IS: 10500

For evaluation of chemical quality of ground water, samples were collected from dug wells and hand pumps. Chemical analysis of these samples has been done and maps prepared.

Ground water quality has been examined by using pH/TDS metre, Inova-10 (Digital) instrument and Microbiological analysis has been done with INOVA 10B water testing kit, designed for the examination of bacteriological parameters in drinking water using **membrane filter technique** (MF technique) in highly sophisticated environment. Membrane filter technique is an alternative to Most Probable Number (MPN) procedure and has the key benefit of processing a larger sample of water. It uses as much as 100 ml of the sample in contrast to MPN procedure using Pour Plate technique is limited to sample volume of 2 ml. The following parameters have been evaluated:

5.4.1 Physical Information

1. pH
2. Electrical conductivity

5.4.2 Chemical Composition

1. Hardness
2. Nitrate
3. Chloride
4. Total Dissolved Solids

5.4.3 Bacteriological

1. M.P.N. count for Bacteria
2. Pathogens characters and their relation with diseases.

5.5 SURVEY FOR WATER BORNE DESEASES

To know the presence of water borne diseases and its spread throughout the district Balrampur many hospitals and private dispensaries have been visited. Also face-to-face discussion with people in some parts of district have been made to ascertain the different types of water borne diseases and severity of them in different parts of the study area. Disease data has also been collected from:

a) District Hospital
b) Private Hospital
c) Tehsil Level Hospital
d) Nursing Homes
e) Dispensaries of Individual Doctors
f) Local Clinics
g) Any other sources

(XVI to XVIII) give a detailed study of the total number of patients, different types of tests performed on the patients, type of treatment provided, etc. The -XVIII gives a detailed survey of the types of diseases reported from different blocks. From the statistical record, it is well understood that, the occurrence of water borne diseases in different blocks of Balrampur district is a serious issue, which requires immediate attention.

CHAPTER # 6

6. ANALYSIS AND DISCUSSION

6.1 ENVIRONMENTAL SETUP OF BALRAMPUR DISTRICT

6.1.1 Location

Fig. 6.1, Location of Balrampur within UP

Balrampur district is one of the newly born districts of Uttar Pradesh and has been created after being separated from Gonda district. It marks the part of northern border area of the country and lies in the extremes of latitudes 27° 26' and 27° 50' North and longitudes 82° 11' and 82° 46' East extending from the Sharavasti on the west to that of Siddhartha Nagar in the east and Nepal border running throughout the north. On the east, the Anah river separates it from Nepal for some 35 km while the Siddhartha Nagar district forms the remaining portion of the boundary. To the south of it lies the Gonda district of which it was once a part. Basti marks its southeast boundary. **Fig 6.1** above shows location of Balrampur within UP.

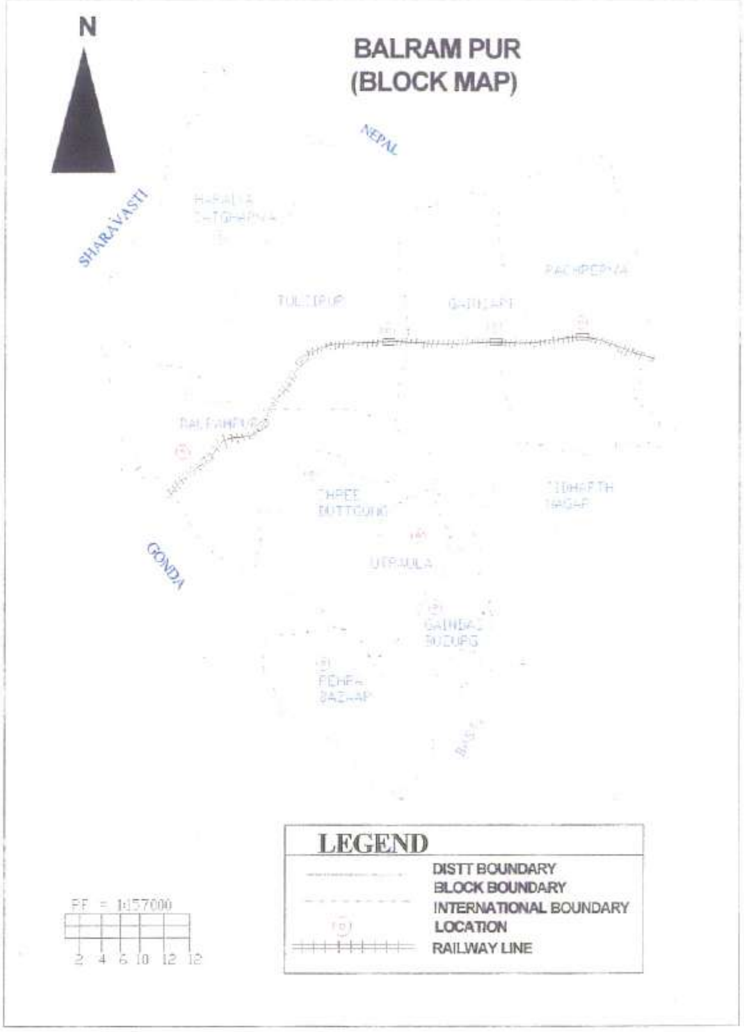


Fig. 6.2, Administrative Setup of Balrampur District

6.1.2 Block level divisions

Balrampur district is having a total area of 3377 sq km and as per Administrative setup the whole district is divided into 9 Blocks **(See Fig.6.2)** having total population of 1,252,269 millions as per census 2001. **Table 6.1** below shows overall setup of Balrampur District. **Table 6.2** below shows the block wise area and population of Balrampur district. The total land area utilized for different purposes is shown in **-I**

Table 6.1, Overall Setup of Balrampur District

S.No	Decsription	Area in Sq.Km	Population*
1	Total Block Area	2904.5	1,252,269
2.	Total Forested Land	205	778
3.	Total Rural	3102.5	1253047
4.	Total Urban	267.5	88242
5.	Total District	3377.0	1341289

**Source: As per Census 2001*

Table 6.2 Block wise Area and Population of Balrampur District

S.No	Block Name	Area in Sq.Km	Population*
1	Haraya Satgrharwa	485.2	162,341
2.	Balrampur	443.5	196,199
3.	Tulsipur	410.0	162,224
4.	Gainsari	462.4	154,144
5.	Pachperwa	383.5	133,724
6.	Shri Gutt Ganj	174.5	108,496
7.	Utraula	157.0	102,127
8.	Gaindas Buzurg	152.3	97,122
9.	Rehra Bazaar	236.1	135,892
	Total	**2904.5**	**1,252,269**

6.1.3 Rainfall and Climate

Balrampur experiences a sub tropical monsoon type of climate, which is characterized by a seasonal rain, produced by the southwest and northeast monsoon. Data on Monthly Rainfall is presented in **Annexures-IIA &IIB.** The direction of wind is generally from NW to SE in the NE monsoon season and from SE to NW in the SW monsoon season. The SW monsoon season from mid June to October is influenced by the humid winds of the oceanic origin and its main characteristics are cloudy weather, Temperature fluctuations, heavy rainfall high relative humidity Wind Velocity and Dust Storm etc. These all affect the soil characteristics, water availability and its quality as well. Data on climatic condition of Balrampur is presented in **-III.**

6.1.4 Physiography and drainage

Physiographic observations show that the Balrampur is a plain sloping gradually from North to South or South to East, and its elevation in general is 105 metres above the mean sea level. However the level of the surface is interrupted by several ditches, jhils, canals, rivers and number of hilly areas. On the basis of drainage and structural variations the district of Balrampur as a whole can be divided into the following physical divisions. **(See Fig.6.3)**

1. **Terai**
2. **Khaddar**
3. **Central Upland**

Figure 6.3 below shows the **physical division of Balrampur district** based on these three classifications.

Terai: In the north of Balrampur is the moist tract of terai and extending southward from the forest at the foothills to the Rapti and the villages immediately under the influence of the river on its south bank. It covers greater part of the district covering the areas of Haraiya

Satgharwa, Tulsipur, Gainsari and Pachperwa etc blocks. As in all sub mountaineer tract, it lies low; water is very near the surface; and floods are frequent. In the north the innumerable torrents bring down boulders and debris from the hills and their broad beds are covered with shingle and sand; but further south swamps are frequent and the soil is a heavy clay admirably suited for the growth of the fine paddy.

Uparhar: The Terai gives place to the Uparhar or Central Upland which extends from the line of Rapti to a broken sandy ridge, known as Uparhar edge, running north west to south east a few Kilometers north of the Terhi river in Gonda district. In Balrampur it covers the areas of

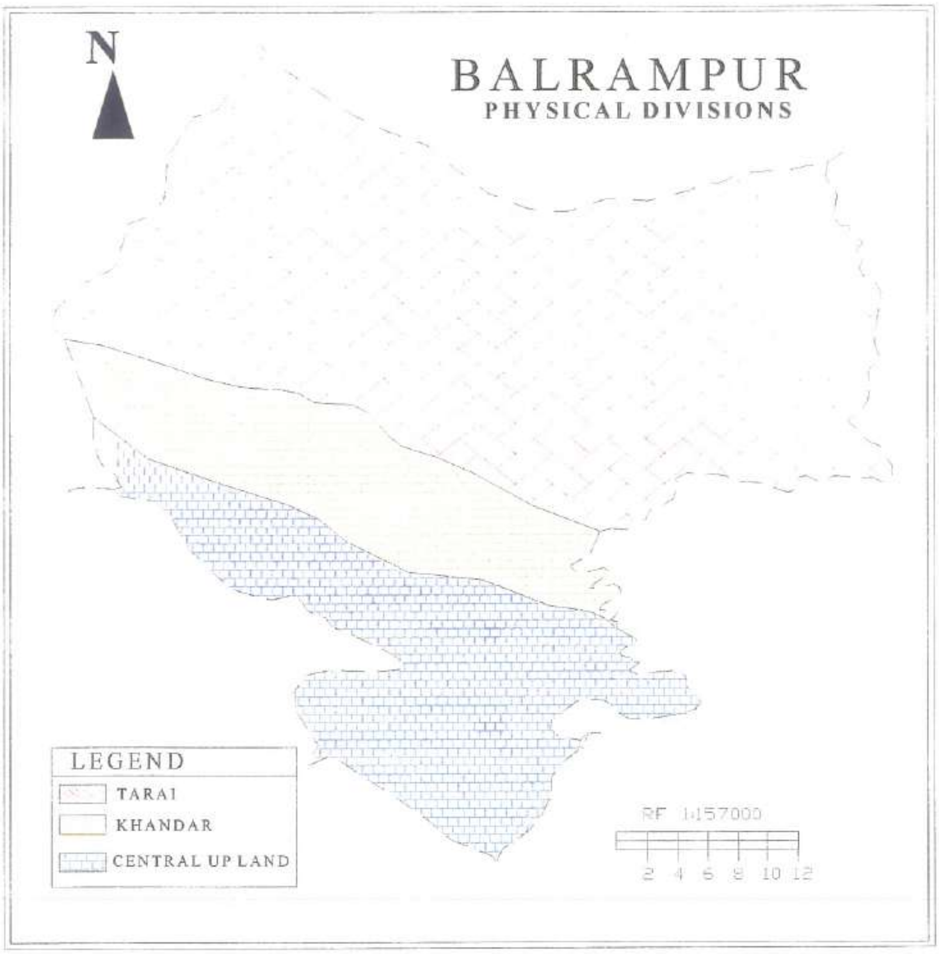


Fig. 6.3, Physical Divisions of Balrampur

Rehra bazaar block along with very little portions of Balrampur, Sriduttgunj, Utraula and Gaindas Buzurg blocks.

Khaddar: This land is present on either side of the Rapti river and forms the middle part of the district covering mostly the parts of Balrampur, Sridutt gunj, Utraula and Gaindas Buzurg blocks.

Levels: The Slope of the district is from Northwest to Southeast and is not very marked. In the extreme north it is about 200 meter above the sea level and from this point it drops to 107 metres at Tulsipur and 108 meters at Balrampur .The central plateau is slightly higher than this in the northwest, the level at Kauria station being 112 m but towards the southeast it drops steadily.

6.1.5 Geology and Soil

The selected area forms a humid part of the northern most fringe of the Indo-gangetic plain, which lies between the recently built lofty Himalayan chain and the stable block of the southern peninsula. The plain has been formed by the detritus and alluvium brought by the Himalayan rivers in the north and peninsular rivers in the south. The geology of the district exposes nothing but the ordinary Gangetic alluvium with an exception of boulders and debris brought down by the hill torrents in the north. The mineral products of the district are very insignificant and practically confined to Kankar, Reh and Brick earth.

The district Balrampur is a part of the Rapti Alluvial plains and is underlain by Quaternary alluvium comprising mainly sands of various grades with clay and Kankar and at places boulders and pebbles. The Bhabhar tract (piedmont zone) extends over very limited area in the northwest in the northern part of spring line. The tract comprises boulders, cobbles, and pebbles of sandstone quartzite, shale, siliceous limestone and sands of various grades mixed with clay. The Bhabhar sediments have been derived out from the Siwalik Hills in the northwest by turbulent streams and nallas.

In the southern part of the spring line, the Terai belt gradually developed typically, having shallow water level. In the Terai belt, clay beds are dominating and conversely due to non-availability of the sufficient sand beds the aquifers are not producing flowing artesian conditions.

It is suggested that the plain were a fore deep in the way of advancing Himalayan high crust waves, which were checked, by the inflexible been deposited by the detritus of the rivers rising from the Himalayas for along time of the geological history that gave it the recent solid landmasses of peninsula. It was of a cynical nature, which had continuously shape.

The major fact, which emerges from the above discussions, is that the region was a depression, which began to form in the upper Eocene. Since then the trough has been gradually filled up by the sediments to form the level plain with gentle slope towards the sea.

Sub-Surface Geology:

To describe the sub surface geology of Balrampur district a fence diagram and cross sections were prepared on section line viz. W-E, W'-E', and N-S. The Section line W-E runs in the northern part of the river

Rapti and is based on the lithological logs of four deep tubes-wells constructed by C.G.W.B. This section is shown in **fig. 6.4 (a)(Aquifer Section W-E)** below, it indicates the predominance of clay with kankar with three-tier aquifer system between the depth range of 10-30 m, 120-140 m, and south of Rapti river and is based on and 210-220 m. The clay is sticky and yellowish in color. The aquifer material ranges from fine sand to gravel and the thickness ranges from 5.00 to 25.00 m.

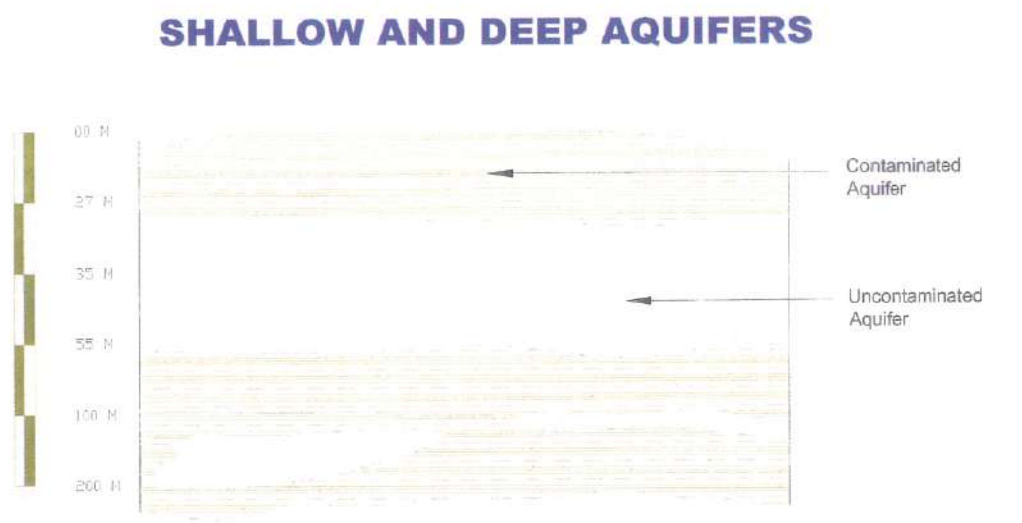


Fig. 6.4a, Aquifer Section (W-E)

The section line W'-E' runs parallel and south of the Rapti river and is based on lithological logs of five state tubewells. The section is shown below as **fig 6.4 b (Aquifer Section W'-E').** The section shows the presence of 15.00 to 25.00 metres thick surface clay underlain by fine to course sand in the depth range of 30.00.to 60.00 metres.

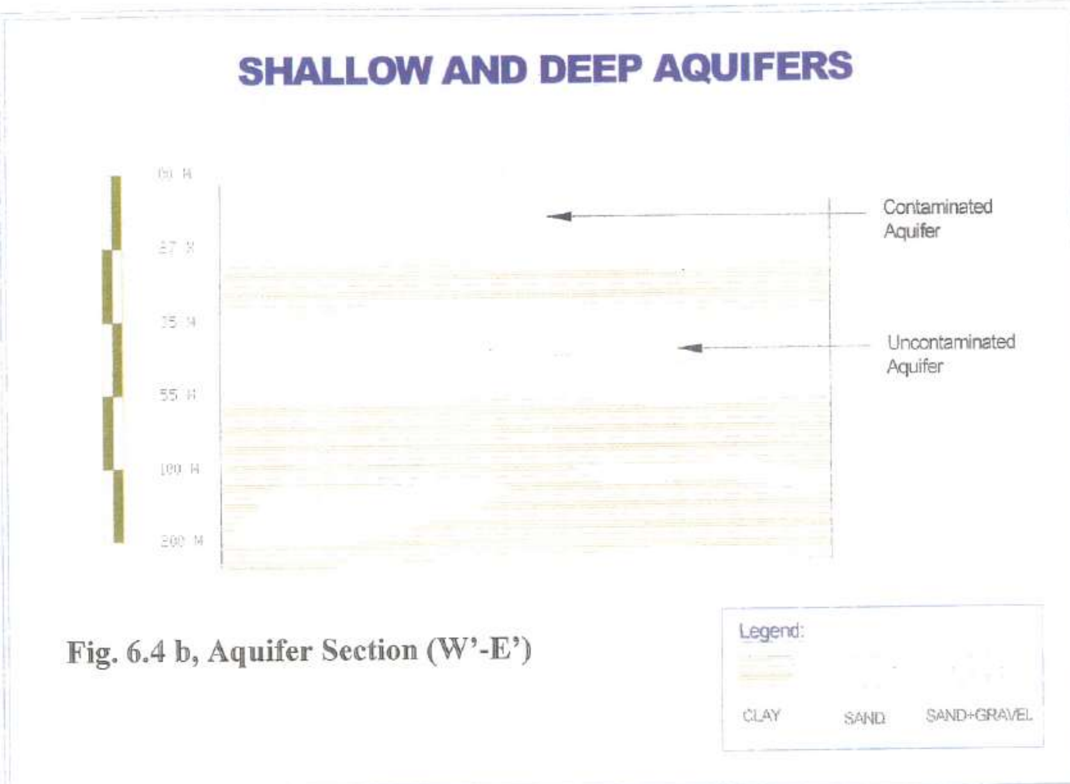
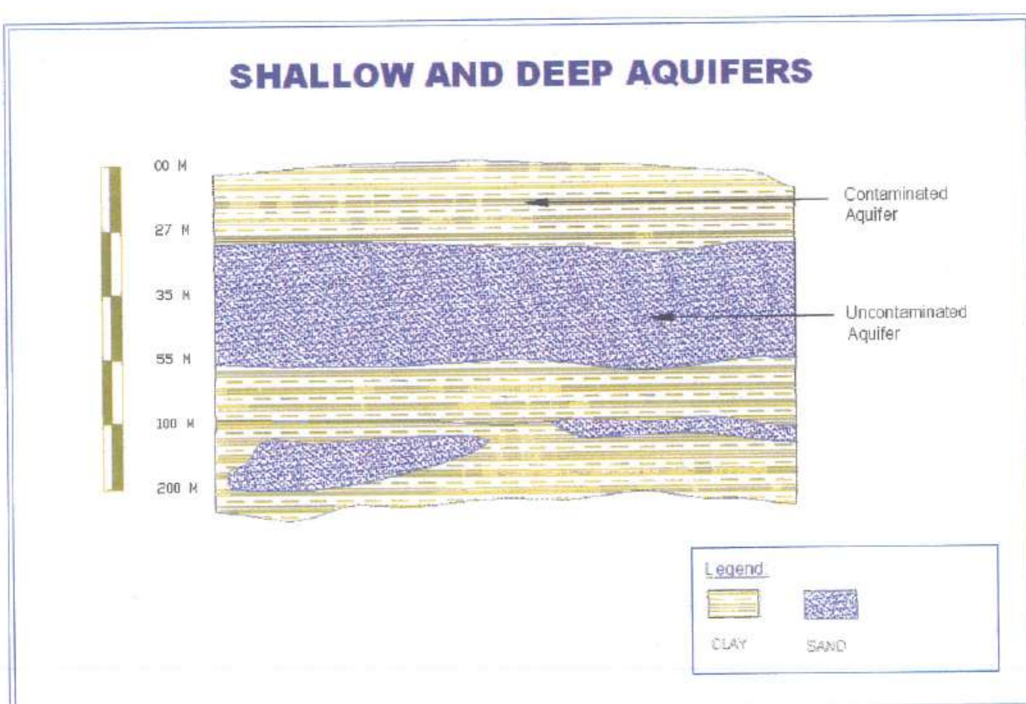


Fig. 6.4 b, Aquifer Section (W'-E')

The section line **N-S fig. 6.4 c** is based on the study of six tube wells



(three constructed by C.G.W.B and three constructed by state government).

Study of the sections indicates that in the northern part and central part of the district clay and clay with kankar pre-dominates over sand and gravel and vice versa in southern part. The total thickness of granular zones ranges from 60-90 m and precisely intercalations of the clays in this sand horizon reduces the effective thickness to about 40-80 m. Lithological logs of tube wells used to prepare the fence diagram are appended in **Annexure-IV.**

Balrampur district comprises the alluvial deposits sediments to from the level plain with gentle slope of clay silt and sand with occasional beds of gravel calcareous nodules and peaty organic matter up to the depth of 8-15 meters below the ground level, geologically these deposits may be classified into two divisions – The bhangar or the older alluvium and the newer alluvium commonly known as khaddar but locally called as kachhar. The bhangar corresponds to the deposits of Pleistocene age. The water level occurs below the clay and silt formations are composed of medium to coarse-grained sand. It is important to note that in some part of the area the water table is much exposed to surface just at the depth of one or two meters.

The soil is the superficial surface covering the earth crust. There is least doubt that soil plays an important role in determining the quality of underground water of any particular locality. Therefore, it becomes necessary to discuss the different type of soils in this area, in order to have a clear understanding of the hydrogeology of the area.

The soil of the Balrampur is alluvial and consists largely of sandy or clayey loam, but its actual composition changes considerably even within the short distances and varies from pure sand to clay. Deposits of concrete limestone mixed with clay known as Kankar; sometimes occur near the surface. This forms a hardness, which impedes the free decomposition of roots and where present the vegetation is of open strutted xerophytes character.

Types of Soils in Balrampur district:

1) Clayey Dhankar or Matiyar
2) Clayey Kachhar or Rapti Khaddar
3) Loamy Bhangar
4) Clayey Loam

Fig.6.5 shows the **soil composition of Balrampur District**. Considering Balrampur only the northern larger half of the district beyond the Rapti River is included in the Tarai region whereas the remaining half (southern) is graded in the Central upland (Uparhar). Besides this, there is narrow strip of khaddar along the Rapti River.

From the comparative point of view the northern tract is inferior to the southern tract. The substratum is made up entirely of kankar a formation composed of nodules of impure calcium carbonate and other compounds, which are found everywhere at few meters below the surface in some localities.

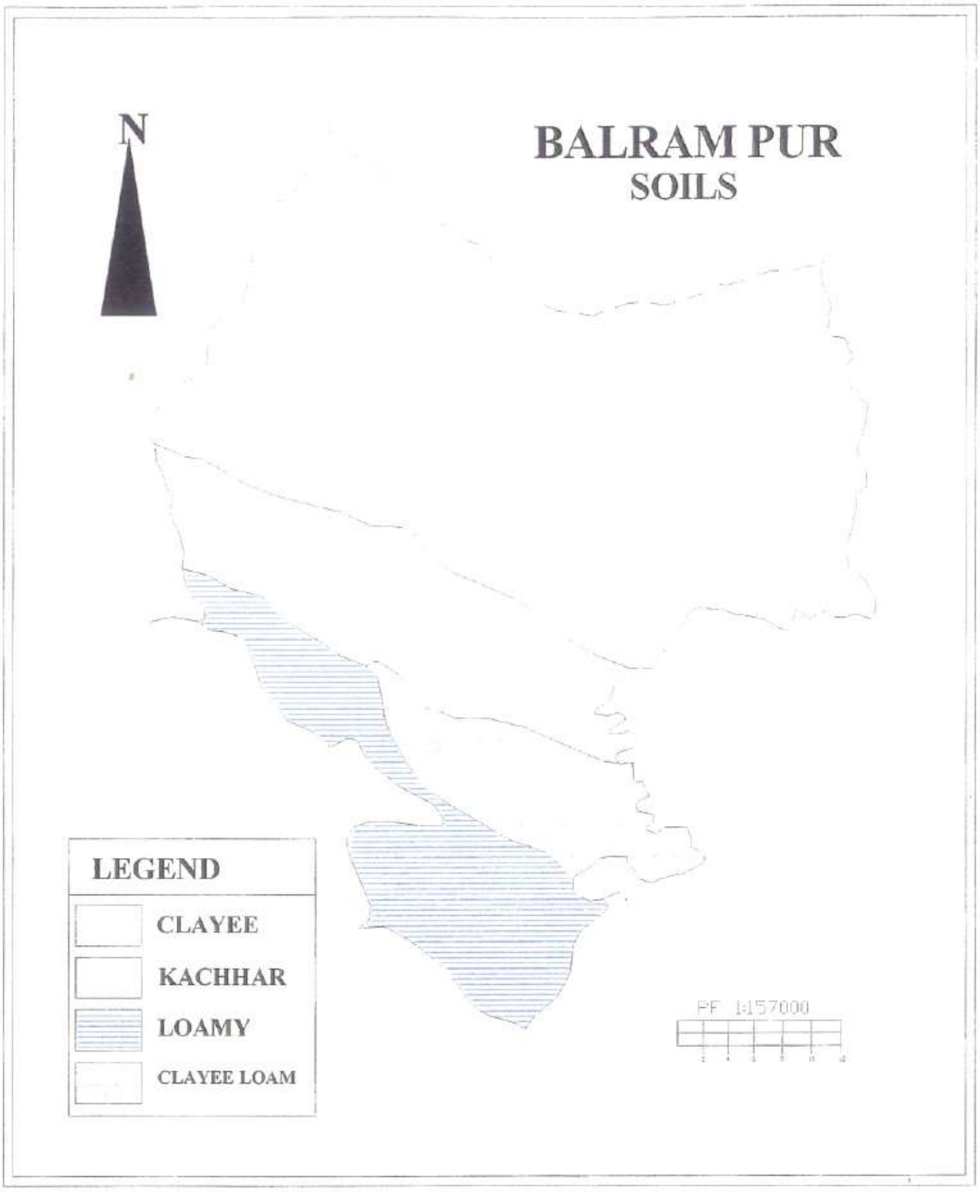


Fig. 6.5, Soil Map of Balrampur District

From the survey of the various types of soils in district, it is evident that the defective drainage is only due to heavy clay impregnated with kankar pans at the depth of 0.75 meter to one meter another feature is the comparative absence of user land from all parts of the district.

The different characteristics of these two major types of soil in Balrampur are represented below in **Table-2.**

Table:6.3, Characteristics of Soil Types In Balrampur

S.No.	Characteristics	Northern lowland Tarai Region	Central Upland Uparhar Region
1.	**Color**	Grey To dark Grey	Yellow to reddish brown
2.	**Concretions**	More kankar	Less kankar
3.	**Texture**	Clay to loamy clay	Loamy to sandy loam
4.	**pH**	6.5-7.5	7-8
5.	**Drainage**	Very poor	Excessive

6.1.6 River system and water resources

All the rivers of the district flow from northwest to southeast and belong to two main systems that of Rapti in the north and the Ghagra in the south. Numerous tributaries feed each river, as they only serve to carry off the surface water during the rainy season of the year. **Fig. 6.6** shows the **drainage map of Balrampur District**.

- **RAPTI SYSTEM**

Rapti- The Rapti rises in the mountains of Nepal and after traversing the Sharavasti district enters the Balrampur on its western border near Mathura village. It flows in a very tortuous course through Balrampur block as far as the Utraula boundary and reaches the Siddhartha Nagar district at the material ghat. At that point it bends southwards and form the district boundary as far as it junction with the Suwawan river in the south east of Utraula. The banks are usually high but river is continuously changing its course. It only over flow its banks

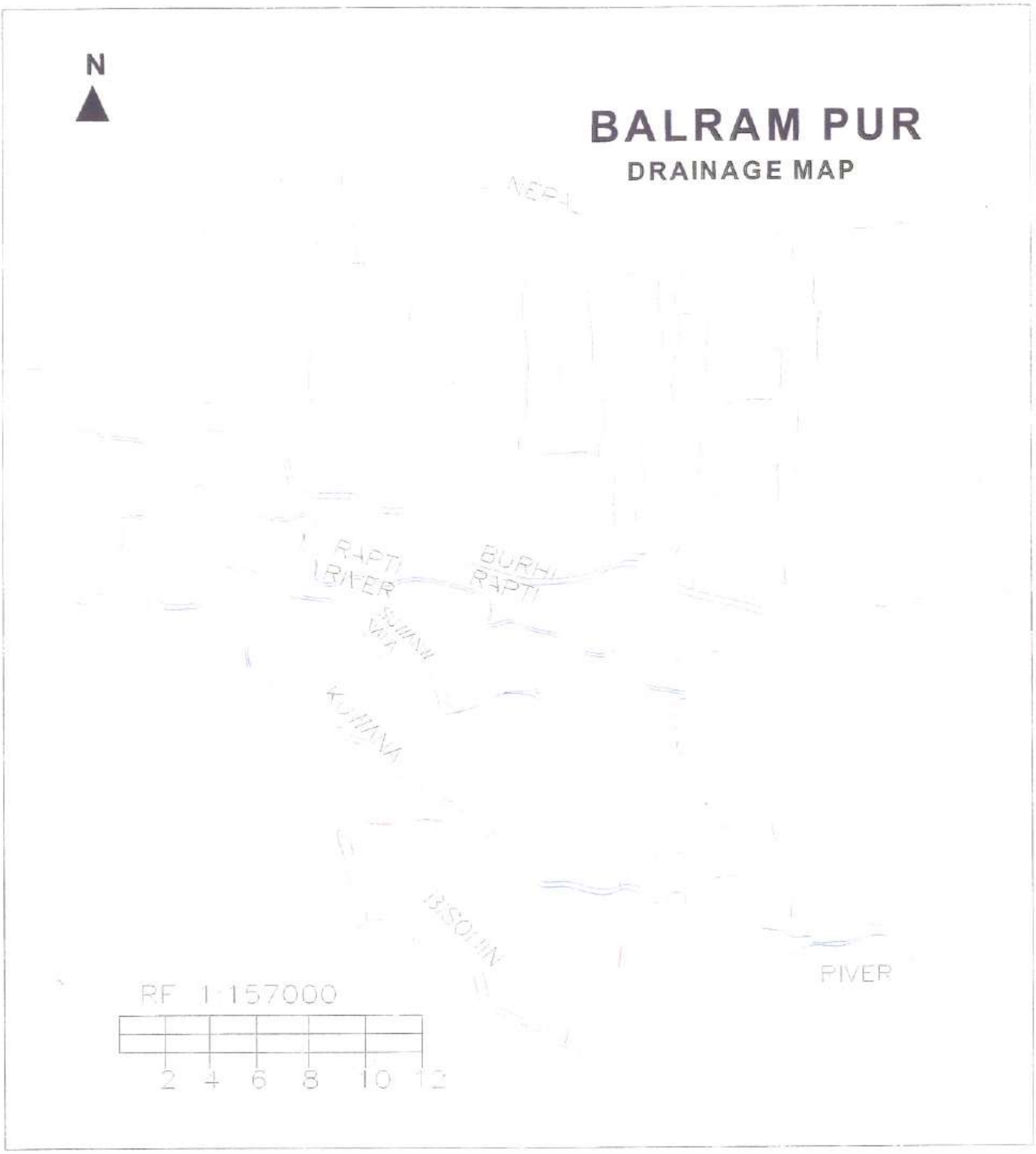


Fig. 6.6, Drainage Map of Balrampur District

in very wet seasons but then instead of covering the submerged land with sand, it usually leaves behind a deposit of rich loam.

Burhi Rapti-On either side of the Rapti, but especially on north, the country is cut up by innumerable deserted channels of the river. Many of these contain water for a part of the year only but the only one which can be considered as a definite stream is that known as the Burhi Rapti which emerges near Mathura and flows across the district in direction roughly parallel to that of the Rapti as far as the Siddhartha Nagar border. Then instead of turning south it maintains an easterly coast and for considerable distance separates the Tulsipur from Siddhartha Nagar. Arrah Nala first joins chharihwa Nala that then joins the Burhi Rapti and at this junction with chharihwa nala Burhi Rapti leaves the district. This river intercepts the water of all the tributary streams which bring down the drainage from the hills to the north and consequently attains at times large proportions. In wet years it over flows and practically forms one stream with Rapti, almost whole of the intervening country being under water.

Hill Torrents: The tributaries of Burhi Rapti are exceedingly numerous and many of them are known by different names in different portions of their course. They all bear a general resemblance to one another, being hill torrents of the usual description with broad boulder strewn beds. In the dry season they either disappear or else carry down an insignificant amount of water, but in the rains they are subjected to sudden freshets and are rapidly transformed into rushing rivers, which do much damage to the land in their neighbourhood and frequently cover the fields with a deposit of barren sand. In the north of Tulsipur their number is great and every little nala has its name. Then as they unite with one another their number decreases, but a great many continue an independent course southwards as far as the Burhi Rapti.

The more important of there from west to east are the kharjar, karwi, kakrawa, katha, Bhambhar, Banrua, and Arrah.

Suwawan: To the south of the Rapti is the Suwawan, flowing along the extreme southern edge of the terai. It rises near the western border and passes close to the town of Balrampur, then flowing through the north of the Utraula and eventually joining the Rapti at Rasulabad on the Siddhartha Nagar border. The Suwawan is a sluggish stream with an exceedingly tortuous course. For a short distance to the east of Balrampur its course resembles rather a succession of jhils than a river. Further east the channel is deeper and more clearly marked, and before it joins the Rapti it becomes a river of considerable proportions.

- **GHAGRA SYSTEM**

The other rivers and streams of the district belong to the Ghagra systems and flows through the Uparhar and Tarhar.

Kuwana: Tenus nala rises in Sharavasti district and after a course of about 13 kilometer it is known as Kuwana River. After flowing about 4 km further as Kuwana river it enters Balrampur district. It then flows along the northern border and as far as the Utraula boundary. The river is fed by two small streams-Jadha Nala and Pindariya nala-flowing down from the Uparhar in the north of Gonda, besides Singha in Sadullah Nagar; and an insignificant water course which has no distinctive name flowing through the central portion of Utraula. The Kuwana is a sluggish stream and rarely changes its course.

Bisuhi: South of the Kuwana is the Bisuhi, a small stream of a similar character. It rises near village Ghuchwapur in Gonda. It flows for some distance nearly due east, and then after having traversed the whole of the north of Gonda, takes a southerly course and enters the Balrampur district where it separates Sadullah Nagar from Mankapur and Burhapara from Babhanipur. It leaves the district just before its junction with Kuwana. It seldom causes any inundation.

- **LAKES**

The district contains several lakes many of which are of considerable size and form a valuable source of water supply. The character of these jhils varies according to the locality. In the Terai they are generally formed by the action of the rivers in changing theirs beds. Their shape is that of horse-shoe, and on the convex side the bank is usually high and sandy. Such jhils were merely bends of a stream, which have become silted up at either side. In the Uparhar and elsewhere they generally consist of shallow depressions in the surface, in which the drainage water collects, while the larger groups of jhils sometimes represent ill-defined lines of drainage, which only develops into streams in years of heavy rainfall. In Terai there are innumerable swamps along the both sides of the Rapti and throughout the low-lying rice tract.

6.2 HYDROGEOLOGICAL STUDY

Hydrogeological surveys have been carried out to check the various hydrogeological parameters of the area and quantitative as well as qualitative analysis of groundwater present in the area.

6.2.1 Mode of occurrence of groundwater

Systematic well inventory of dug wells, shallow wells and deep tube wells has been carried out and relevant data were collected to study the general groundwater condition, behavior of the water table and its occurrence and the movement in the area. In all the **28 key wells** were fixed to monitor the seasonal water lavel fluctuation in the area and water samples were collected. The **location of key wells** is shown in **Fig.6.7** below.

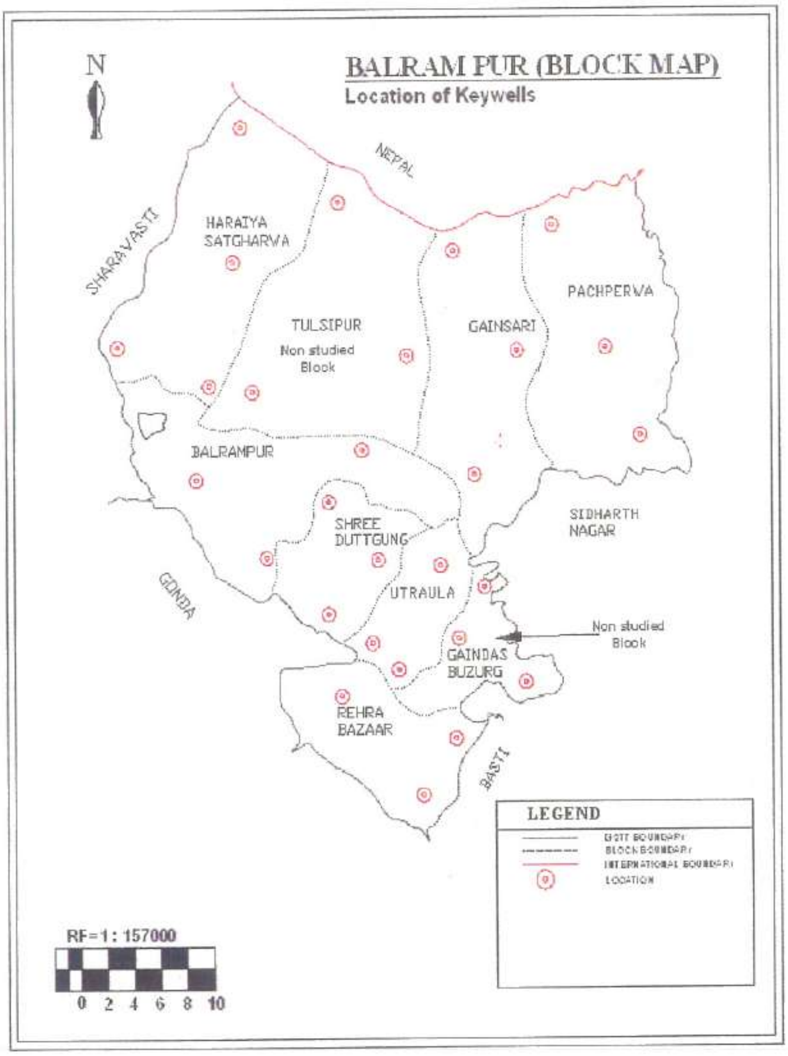


Fig. 6.7, Location of Key Wells

Ground water in the area occurs both under confined and water table condition. It occurs in the zones of saturation within the granular zones encountered below the land surface. The principle source of replenishment to the groundwater body is precipitation.

South of the river Rapti the formation are sandy and suitable for construction of shallow and deep tube wells.

6.2.2 Delineation of aquifers

The disposition of aquifer system has extensively been described under para 6.1. The northern belt ranging from 25 to 75 km. in width (bordering to Nepal) is characterized by thick clay, clay with kankar and a few thin sandy horizons, as evident by a number of exploratory tube wells drilled by Central Ground Water Board. **Fig 6.8** illustrates the **fence diagram**, showing the **vertical profile of rocks**. The area lying south of the river Rapti is suitable for the construction of shallow and deep tube wells. The aquifer material is comprised of fine to medium to course sand with gravel. Construction of deep tube wells is preferable in the northern part of the area.

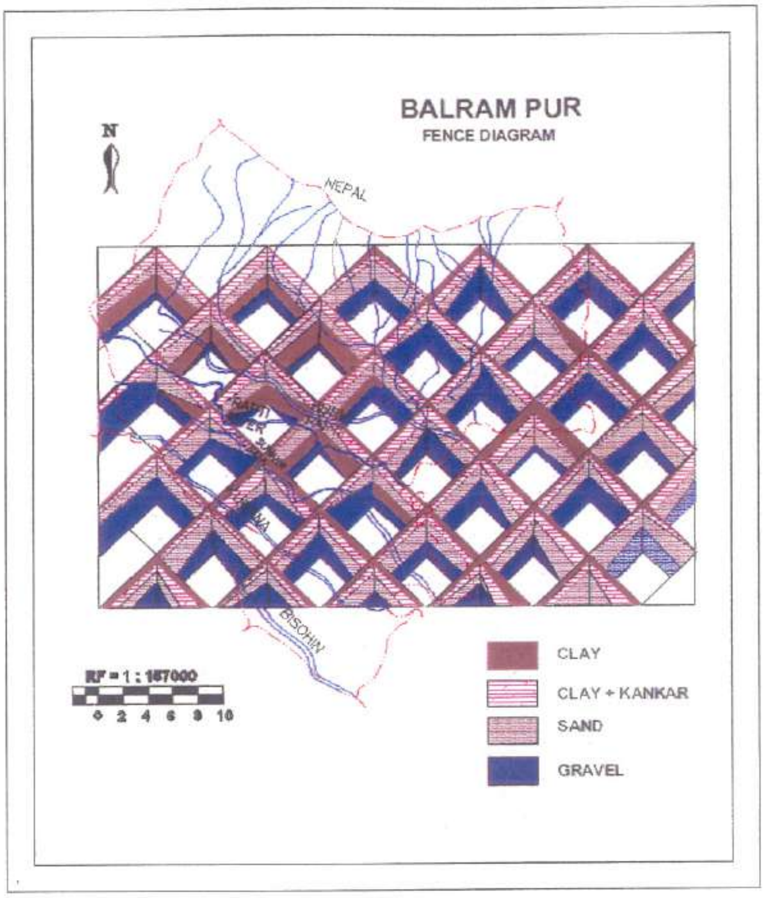


Fig. 6.8, Fence Diagram of Balrampur District

Dug Well Zones and Shallow Aquifers:

Ground water occurs under water table condition in upper aquifers. It is tapped mostly by open wells and Shallow tube wells. During the course of investigation the water level measurements in the key wells were taken in Pre and Post Monsoon seasons in 2005. The data collected was utilized in preparing the **depth to water level map, fig. 6.9.**

As is evident from the map the area can be divided into four zones representing the following depth ranges

I. Zone-I 0.00- to 2.00 m.

II. Zone-II 2.00 to 4.00 m.

III. Zone-III 4.00 to 6.00 m.

IV. Zone-IV 6.00 to 8.00 meters.

The depth of water level ranges from 1.52 m to 10.47 mbgl during pre monsoon and 1.25 to 5.29 mbgl in post monsoon period.

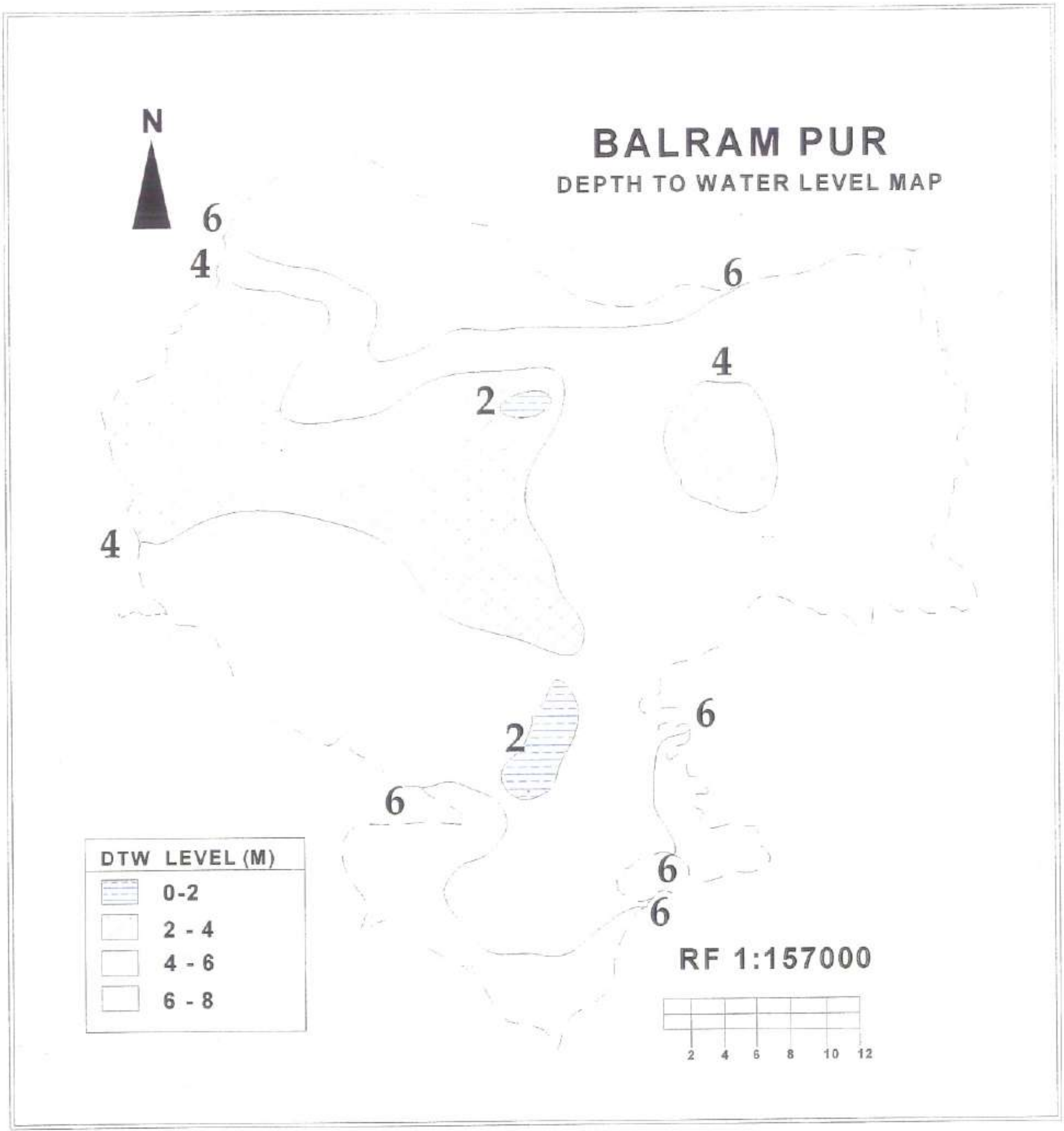


Fig. 6.9, Depth to Water Level/Water Table Contour Map

A perusal of the **Fig. 6.9 (water table contour map)** shows that in about 65% of the area the depth to water level varies in the range of 3.00 and 5.00 mbgl. In northern part of the district, bordering Nepal, the depth to water level varies in the range of 5.00 to 10.00 mbgl and along the river the depth to water level varies between 3.00 to 5.00 mbgl, except at some places along river where water level is noticed between 2.00 to 3.00 mbgl. In southern part of the district, the water level ranges between 3.00 and 5.00 mbgl except two key wells Rehra Bazaar where water level measured between 1.00 to 2.00 & 2.00 to 3.00 mbgl.

Deeper Aquifers:

In the northern part of the district groundwater exploration has been done by Central Ground Water Board, down to the maximum depth of 586.00 mbgl. The aquifer material comprises gravel, Kankar, and sands of various grades in varying proportions. The bed rock was not encountered down to the maximum depth of 586.00 m. Thickness of aquifer tapped in the exploratory tube well ranges from 30-140.00 meters. The Piezometric heads ranges from 4.6 to 10.8 mbgl and discharge of the tube well ranges from 20-3235 lpm, for draw-down ranging from 5.9-18.00 meters. Different aquifer parameters such as transmissivity and storativity have been evaluated, transmissivity ranges between 55- 1631 m^2/d where as the storativity ranges from 0.000019 to 0.0017.

6.2.3 Movement of groundwater:

Water level data of key wells collected during the pre monsoon season were analyzed and altitude of the water table was plotted with reference to the mean sea level was worked out. The reduced levels of the water tables were plotted to prepare the **water table contour map fig. 6.9.**

The elevation of the water table ranges from 149.53 m the northwest corner at Bankatwa NHS, Block Haraiya Satgharwa to 92.52 mamsl at Sadullah Nagar, Block Rehra Bazaar in the southern part of the area. There is a fall of water level elevation from north to south of 57.01 m.

A review of the **water table contour map** also shows that the general direction of the groundwater movement is from north to south in the northern part of Rapti and from northwest to southeast, excepting some localized variations, in the southern part of Rapti area.

In Balrampur district the river Rapti in general is recharged from the groundwater hence it is effluent in the nature. River Kuwana also receives water from ground so it is also effluent in the nature. The steepness of the water table contours in the northern part of the Rapti River indicates low permeability of the aquifer indicating that the sediments are finer and the hydraulic gradient is 6.5 m/km. In the southern part of the Rapti the formations are highly permeable. The gradient calculates for southern part of Rapti is 0.15 m/km.

6.2.4 Water Level Fluctuations:

Long term:

Long-term water level records in the area from 17 permanent hydrograph monitoring stations from 1974 onward have been plotted and calculated on computer by CGWB. It is found that Utraula and Sonpur Hydrograph exhibit no major change in water level trend, where as Jarwa, Haraiya bazaar hydrograph stations show rising trend and the rest of the hydrograph station show decline trend.

Seasonal:

The water level fluctuation between the pre-monsoon and post monsoon periods for the year 1998-99, as obtained from the key wells established in the area, has been worked out by CGWB.

The range of water level fluctuation and the average water level fluctuation of all the 9 blocks of Balrampur district are given in the following **Table-6.4.**

Table: 6.4, Range of Seasonal Water Level Fluctuations and Average Fluctuation

Blocks	Range of Water Level Fluctuation (m)		Average Fluctuation (m)
	From at Place	To at Place	
HARAYA SATGHARWA	0.68 Bankatwa	2.31 Harriya	1.495
BALRAMPUR	-0.58 Jua	2.17 Baraipur	1.238
TULSIPUR	-0.31 Tulsipur	2.54 Narainpur	1.131
GAINSARI	0.32 Bhojpur	5.36 Jarwa	1.816
PACHPERWA	-0.34 Pachperwa	1.69 Ram Nagar	0.940

SHRI DUTT GANJ	0.93 Pachautha	2.30 Sridutt gang	1.828
UTRAULA	1.31 Pipra ekdanga	2.4 Bajar Mudwa	1.985
GAINDAS BUZURG	1.55 Pindia Khurd	2.32 Itai Rampur	1.835
REHRA BAZAR	-1.37 Intwa	1.97 Sadullah Nagar	0.775

6.2.5 Assessment of ground water potential and ground water recharge

The main source of groundwater recharge in the area is direct infiltration from rainfall. There is practically negligible recharge from rivers as most of them are found to be effluent. Recharge from other surface bodies and canals is computed and found to be meager. Efforts have been made to compute the ground water recharge on the block wise basis as per the ground water estimation committees (GEC 1984) norms and figures thus computed are given in **Annexure-V**. Brief descriptions on important aspects are as under:

Monsoon Recharge (Water Table Fluctuation Method):

The monsoon recharge was arrived at by multiplying the net area suitable for ground water recharge, the water level fluctuation as observed in **2005-06**, and the specific yield assumed to be in between 10% to 18.1%. The values of monsoon recharge are given in blockwise in the **Annexure-V** and it works out to be 561.94 MCM for the entire district.

Recharge due to seepage from canals:

For calculating recharge due to seepage from canals, data pertaining to the length of canals, wetted perimeter etc were collected from the canal office (State Govt. Deptt). The seepage factor was uniformly assumed to be 0.15 cumec/10^6 sq .m. of the wetted area for all the blocks. Recharge due to the seepage was separately calculated for the, monsoon and non monsoon periods and then added up. The recharge due to the seepage from canals during the monsoon and non-monsoon periods are **6.712** and **7.391 MCM**, respectively and the total recharge due to the seepage from canal worked out to be **14.103 MCM** for the entire district.

Return seepage from Applied Irrigation:

The return seepage from applied irrigation has been computed taking the following factors into consideration.

I. Total area irrigated in ha.
II. Volume of water applied for irrigation in ha.m &
III. Seepage factor.

Different values of volume of water applied for different types of crops have been adopted as under in **Table-6.5**.

TABLE: 6.5 Volume of Water Applied for Irrigation

S.No	Crops	Volume of water applied for irrigation per hectare (m)
1	Wheat and Barley	0.45
2	Potato	0.30
3	Pulses	0.22
4	Suger cane	2.43

5	Oil seeds	0.225
6	Paddy	0.40

The return seepage has been calculated block wise separately for the monsoon and non-monsoon periods. It is **106.53 MCM** during the non-monsoon and **15.58 MCM** during the monsoon periods while the total return seepage from applied irrigation for the entire district is **122.11 MCM.**

Groundwater Recharge from Tanks

The seepage from tank has been computed taking the following factors into consideration.

I. Water spread area in the hectare.

II. Seepage factor.

The seepage factor was uniformly assumed 0.5 m/year in respect of the surface water bodies. Total seepage in the district works out **3.18 MCM.**

Contribution from Influent seepage

It has been assumed that none of the perennial streams in the area is influent. Therefore, the contribution from the influent seepages has been assumed nil.

Normalization of the Monsoon Rainfall Recharge

With a view to eliminating the effects of drought or Surplus rainfall during the years under consideration, a normalization factor 'NF' is applied which is given by the formula.

$$NF = \frac{\textbf{Normal Monsoon Rainfall}}{\textbf{Monsoon rainfall of the year}}$$

Recharge during the monsoon is computed by the following formula.

$$Recharge = (\Delta S + DW - R_s - R_{IS} - R_{igw})\, NF$$

Where,

ΔS= Change in ground water storage during monsoon.

DW= Ground water draft during monsoon.

R_s= Recharge from canal seepage during monsoon.

R_{igw}= Return flow from groundwater irrigation during monsoon.

NF= Normalization factor.

The blockwise monsoon rainfall recharge figures are worked out and presented in **Annexure-V.** The monsoon rainfall recharge after normalization for entire district comes out to be 743.44 MCM.

Non Monsoon Rainfall Recharge (Rain fall Infiltration Index Method)

Winter rainfall is generally scattered and sparse both in terms of time space and intensity. As such there is negligible rise of water table due to winter rainfall. Hence the rainfall infiltration index method has been adopted for the calculation of non-monsoon rainfall recharge has been worked out to be **80.487 MCM** for the entire district. The blockwise figures are given in **Annexure-VI**

Calculation of Monsoon Rainfall Recharge as per Adhoc Norms and Check by Water Table Fluctuation Method

Ground water recharge due to monsoon rainfall is also calculated block wise as per NABARD's norms by using the following formula:

Recharge (MCM) = Area (Km^2)*IMD normal monsoon rainfall (m)* Rainfall infiltration expressed as fraction

The blockwise recharge thus arrived at are given in **Annexure-VII.** In order to estimate the groundwater balance a comparative study of the monsoon rainfall recharges as per the adhoc norms and monsoon recharge based on the water table fluctuation method is made and counter checked. If the variation between these two recharges is more than 20% the monsoon rainfall recharge, as estimated by adhoc norms, has been adopted otherwise, the recharge calculated by the water table fluctuation method is taken into consideration.

In the seven blocks of the Balrampur district the recharge is calculated by water table fluctuation method and for the rest of two blocks recharge is calculated by Adhoc norms. The total monsoon recharge thus calculated and worked out is **694.20 MCM** for the entire district.

6.2.6 Potential Groundwater Resources

I. Recharge in shallow water table areas:

For calculating the potential groundwater resource in water logged and shallow water table areas the depth to water level during pre-monsoon period should range within 5 meters and the areas showing water less than 1,1.00-2.00,2.00-3.00,3.00-4.00 and 4.00-5.00 mbgl is calculated. Potential recharge is computed by the formula:

(5-b)*a*Specific yield.

Where,

b=Average depth to water level.

a=area in Sq. km

Specific yield expressed as fraction.

The figures thus arrived at are given block wise in **Annexure-VIII.** Total ground water resource potential of shallow water table is worked out to be 529.94 MCM.

II. Potential ground water resource in flood prone areas

Due to paucity of data on flood prone areas this component could not be calculated.

Total Annual Recharge

The total annual recharge is worked out block wise and is given in **Annexure-IX.** It is estimated to be 13263.62 MCM for the entire district.

Utilizable Ground Water Resource for Irrigation

Eighty five percent of the total groundwater resource is taken as the utilizable ground water resource for irrigation in the district, that is 1363.62X0.85 =1159.08 MCM. **(Annexure-IX).**

6.2.7 Annual Ground Water Draft

Ground water draft estimates are based on the number of different types of ground water abstraction structures as per the statistical booklet of Gonda District. The unit draft values adopted for the different structures are as under in **Table-6.6.**

TABLE: 6.6, ANNUAL GROUND WATER DRAFT

Structures	Unit Draft (MCM) per year
State tube wells	0.128
Private tube wells	0.022
Pumping sets	0.014
Persian wheel	0.0092
Dug wells	0.0055

The gross draft value for each block has been worked out and given in **Annexure-X.** While the gross annual draft is minimum (**23.89 MCM**) in **Haraiya Satgharwa** block, the maximum draft (**102.16 MCM**) is in **Balrampur** block. The gross annual draft for the entire district is **473.91 MCM**, 25% of the gross i.e. 118.48 MCM is taken as draft during monsoon and non-monsoon period. Seventy percent of the gross annual ground water draft is taken as the net annual ground water draft i.e. 331.74 MCM for then entire district.

6.2.8 Ground Water Balance

Ground water balance (MCM) =Annual utilizable ground water resource for irrigation-Net annual ground water draft (MCM).

Ground water balance as per the above equation is worked out block wise and given in **Annexure-XI.** A perusal of the same shows the Rehra Bazaar block having the minimum balance i.e. 22.45 MCM while Gainsari block is having the maximum ground water balance of 183.82

MCM leaving a lot scope for further development of groundwater on large scale.

6.2.9 Categorization of blocks based on the level of Ground Water Development

Categorization of the blocks with regard to the present stage of ground water development has been done. Then an annual rate of 2% of ground water development is assumed and the level of ground water development that is envisaged after 5 years is estimated block wise and given in **Annexure-XI.**

The ground water estimation committee has set the following criteria for the categorization of blocks based on the level of ground water development.

Less than 65%	**White or safe**
Between 65-85%	**Grey or Semi critical**
More than 85%	**Dark or Critical**

A perusal of the **Annexure-XI** Shows that the maximum level of ground water development in the year **2005-06** is 73.09% in Rehra Bazaar block while Pachperwa block shows the minimum development i.e. 11.47%. Thus only one block Rehra Bazaar block falls in gray category and the rest of eight blocks fall in white or safe category.

6.2.10 Hydrochemical analysis

I. Chemical Quality

From key dug wells and hand pumps that were fixed to monitor the seasonal water level fluctuation in the area, water samples were collected from some of these wells for chemical analysis to know about the quality of formation water. Block wise extensive studies have been made for the assessment and characterization of Groundwater contamination and its impact on groundwater quality and human health in the district. Chemical analysis of these samples was done and the following maps of different chemical parameters have been prepared.

a) pH Map:

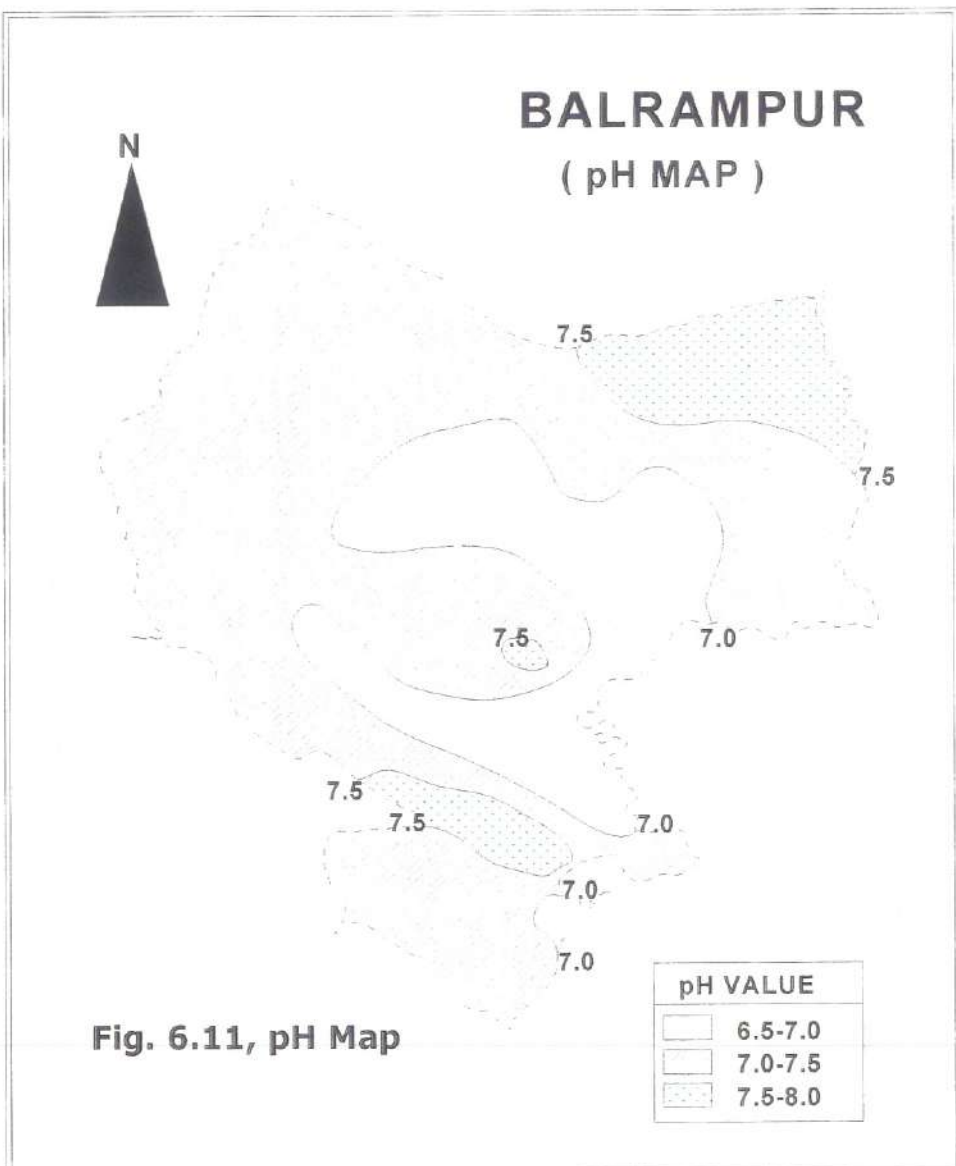


Fig. 6.11, pH Map

Fig. 6.11, above shows the pH map of the area. Based on the map the area can broadly be divided into 3 categories. The **first category** comprises of area having **pH ranging from 6.5-7.0**. The **second category** has a **pH range of 7.0-7.5** and the **third category** where the **pH ranges** from **7.5-8.0.** As per the standards prescribed in **IS:10500** the **pH of potable water** is in range of **6.5-8.5**. Thus comparing the obtained results with the available standards it can be inferred that the **pH of the water available in Balrampur area at tested locations is within the prescribed limits**. Refer **Annexure:IV** to have quick look into the pH chart. It is important to note that each decrease in pH by one pH unit means a tenfold increase in the concentration of hydrogen ions.

b) Total Dissolved Solids (TDS) Map:

TDS is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions. The **presence of dissolved solids** in water may **affect its taste.** High total dissolved solids may effect the aesthetic quality of the water, interfere with washing clothes and corroding plumbing fixtures. **Fig. 6.12** shows the **Total Dissolved Solids (TDS) map** of the area.

Based on the map the area can broadly be divided into 4 categories. The **first category** comprises of area having **TDS < 200 mg/l**. The **second category** comprises of area having **TDS** in the range of **200-400**. The third category where the **TDS** ranges from **400-600** and the fourth category where **TDS** is **>600.** As per the standards prescribed in

IS: 10500 the **TDS** of **potable water** should be in range of **500-2000 mg/l**. Thus comparing the obtained results with the available standards it can be inferred that TDS of the water available at tested locations in Balrampur area is within the prescribed limits.

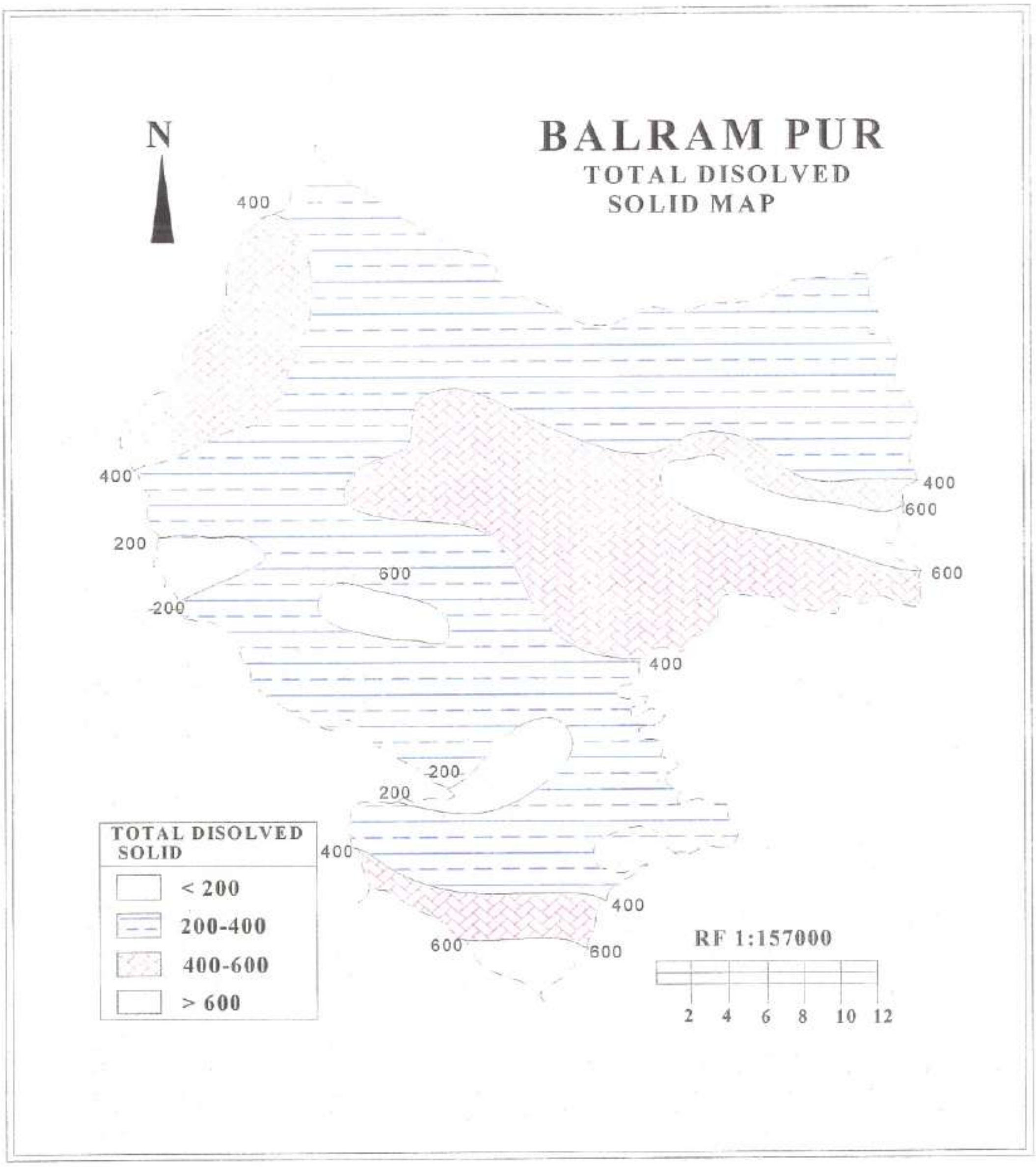


Fig. 6.12, TDS Map of Balrampur District

c) **Hardness Map**

Hardness is defined as the concentration of multivalent metallic cations in solution**. Fig. 6.13, below shows the hardness map pf Balrampur**. Based on the map the area can broadly be divided into 5 categories. The first category comprises of area having hardness < 100

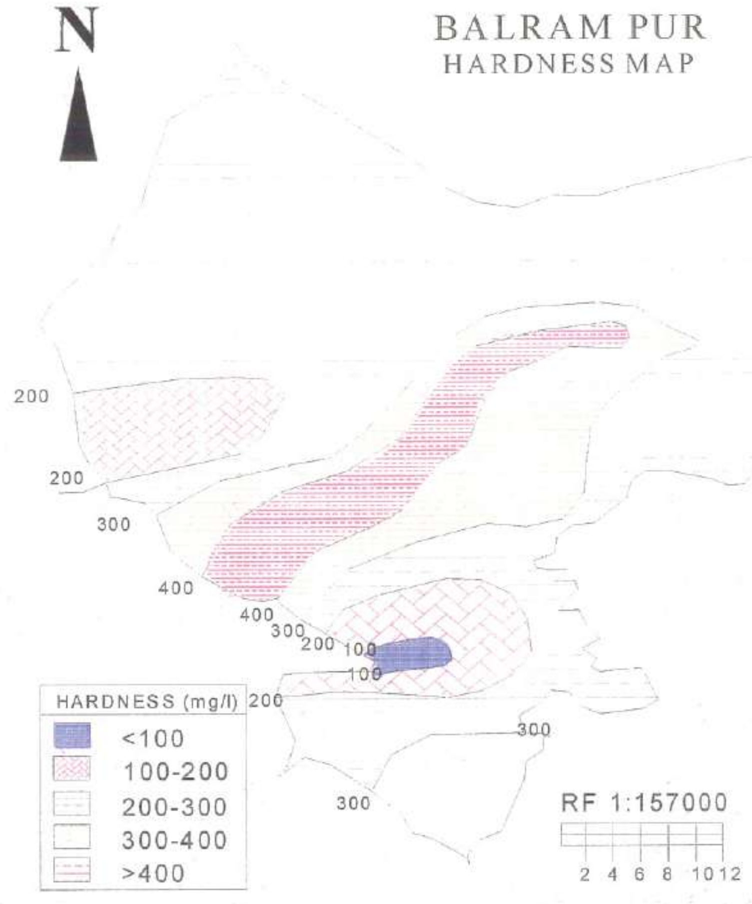


Fig. 6.13, Hardness Map

mg/l. The second category comprises of area having hardness in the range of 100-200 mg/l. The third category where the hardness ranges from 200-300, the fourth category where hardness is in range of 300-400 and the fifth category where hardness is > 400 mg/l. As per the standards prescribed in IS: 10500 the total hardness of potable water should be in range of 300-600 mg/l. Thus comparing the obtained results with the available standards it can be inferred that the **hardness of the water available in Balrampur area at tested locations is within the prescribed limits.**

The hardness of water varies considerable from place to place, and it reflects the nature of geological formations which water has been in contact. Hardness in water is generally derived from contact with the soil and rock formations. Hard waters are as satisfactory for human consumption as soft waters. Because of their adverse action with soap, however their use for cleansing purposes is quite unsatisfactory, unless soap costs are disregarded.

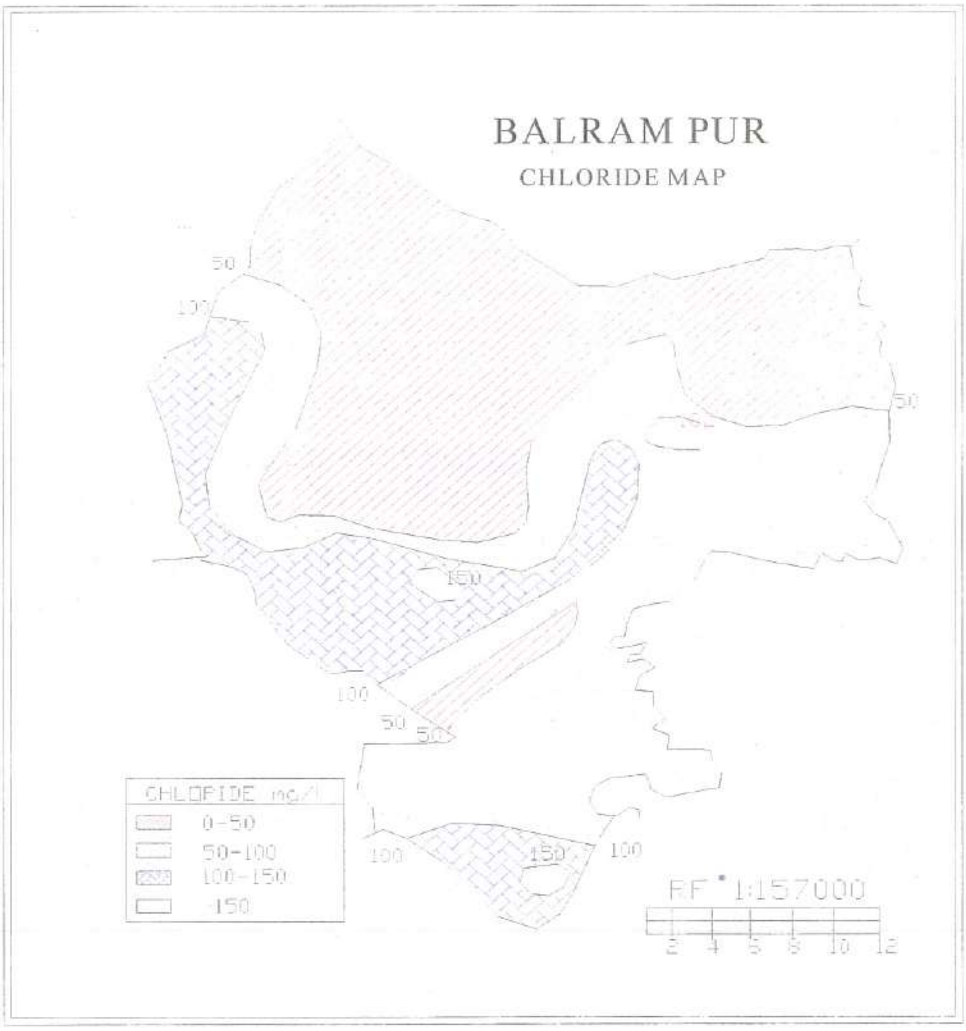


Fig. 6.14, Chloride Map

d) Chloride Map

Chlorides occur in all natural waters in widely varying concentration. The chloride content normally increases as the mineral content decreases. Upland and mountain supplies are usually quiet low in chlorides, whereas river and groundwater's usually have a considerable amount.

Fig. 6.14 above shows the **Chloride map** of the area. Based on the map the area can broadly be divided into 4 categories. The **first category** comprises of area having chloride in range of 0-50 mg/l. The **second category** comprises of area having **Chloride** in range of **50-100 mg/l**. The third category where chlorides range from **100-150** mg/l and the fourth category where **chloride** is **>150.** As per the standards prescribed in **IS: 10500** the **Chloride** of **potable water** should be in range of 2**00-300 mg/l**. Thus comparing the obtained results with the available standards it can be inferred that **TDS of the water available in Balrampur area at tested locations is within prescribed limits.**

Chlorides in reasonable concentrations are not harmful to humans. At concentrations above 250 mg/l they give a salty taste to water. Human excreta, particularly the urine, contain chloride in an amount about equal to the chlorides consumed with food and water. This amount is averages about 6 gm of chloride per person per day and increases the amount of Cl^- in municipal wastewater about 15 mg/l above that of the carriage water. Thus, wastewater effluents add considerable chlorides to receiving bodies.

f) Nitrate Map

Nitrate is a common nitrogenous compound due to natural processes of the nitrogen cycle, anthropogenic sources have greatly increased the nitrate concentration, particularly in groundwater. The largest

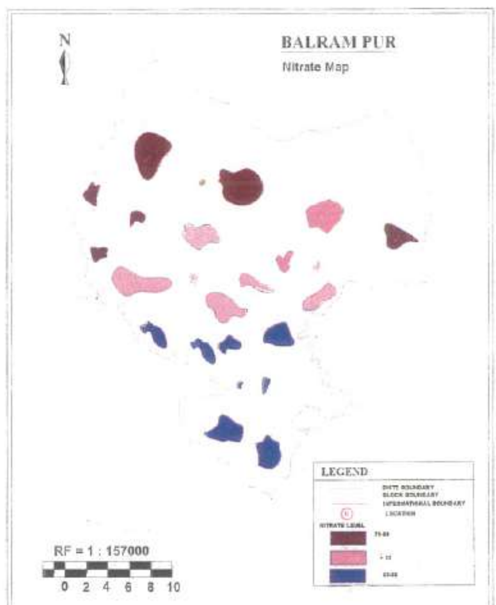


Fig. 6.15, Nitrate Map

anthropogenic sources are **septic tanks,** application of nitrogen-rich fertilizers and agricultural processes.

Fig. 6.15 above shows the **Nitrate map** of the area. Based on the map the area can broadly be divided into 3 categories. The **first category** comprises of area having **Nitrate** in range of 70-80 mg/l. The **second category** comprises of area having **Nitrate** in range of **80-88 mg/l**. The third category where Nitrate level is even> 88 mg/l.

As per the standards prescribed in **IS: 10500** the **Nitrate** of **potable water** should be in range of **10-45 mg/l**. Thus comparing the obtained results with the available standards it is found that the **Nitrate in water available in Balrampur area at tested locations is much higher than the prescribed limits.**

This call for development of suitable remedial measures to overcome the nitrate contamination problem. The most basic, unavoidable cause of nitrate contamination is that when biological materials decompose, most of the nitrogen in the materials ends up as nitrates. Nitrate is a very stable molecule and doesn't readily turn into anything else. It is also very soluble, and moves with the flow of water from the source into the groundwater, and eventually into an aquifer. **Nitrate migrates easily into aquifers because it is highly mobile in soils**. The movement of contaminants through soil to groundwater is affected by many variables, including properties of the contaminant itself, soil conditions and climatic factors. These combinations of factors make the likelihood of groundwater contamination a very site-specific science.

Nitrate thus poses a threat to human health. Particularly in rural, private wells, **incidence of methemoglobinemia appears to be the result of high nitrate levels**. **Methemoglobinemia, or blue baby syndrome, robs the blood cells of their ability to carry oxygen**. Due to the detrimental biological effects, treatment and prevention methods must be considered to protect groundwater aquifers from nitrate leaching and high concentrations.

The results of chemical analysis show the following range of variation of chemical constituents in the ground water. The chloride, nitrate contents along with the hardness data from different blocks is listed in **Annexure-XII**

The table shows that the nitrate content in the drinking water is much higher than the recommended value viz. 10 mg/l.

II. Bacteriological Quality

Microbiological analysis has been done with **INOVA 10B water testing kit**, designed for the examination of bacteriological parameters in drinking water using **Membrane Filter technique** (MF technique) in highly sophisticated environment. Membrane filter technique is an alternative to Most Probable Number (MPN) procedure and has the key benefit of processing a larger sample of water. It uses as much as 100 ml of the sample in contrast to MPN procedure using Pour Plate technique is limited to sample volume of 2 ml.

Microbiological Analysis of samples show clear presence of pathogens bacteria and they are represented by the presence of their big and small colonies in almost all the samples. The results are presented in - **XIII** and Bacteriological Map **(See Fig 6.16)**

Historically, water has played a significant role in transmission of human diseases. Typhoid, fever, cholera, infectious hepatitis and many varieties of gastrointestinal disease can be transmitted by water. The introduction of water treatment with disinfection and the implementation of bacteriological surveillance program worldover to ensure the delivery of safe water have resulted in dramatic decrease in occurrence of waterborne disease outbreaks.

Contamination by sewage or human excrement presents the greatest danger to public health associated with drinking water, and bacteriological testing continues to provide the most sensitive means for detection of such pollution.

Fig.6.16 below shows the **bacteriological map of Balrampur.**

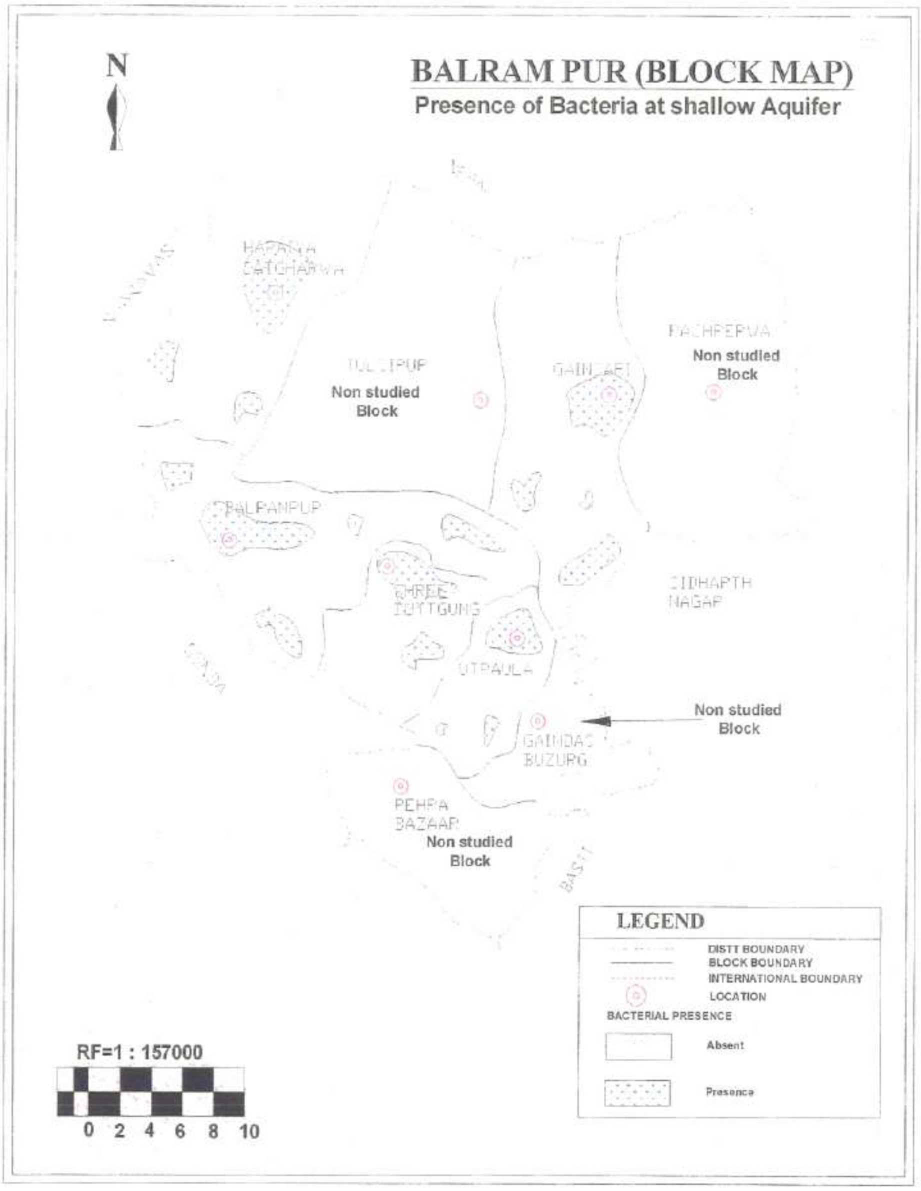


Fig. 6.16, Bactereological Map

6.3 SEPTIC TANKS AND POLLUTION OF GROUND WATER

Septic systems (also known as onsite wastewater disposal systems) are used to treat and dispose of sanitary waste. They are a significant source of ground water contamination leading to waterborne disease outbreaks and other adverse health effects.

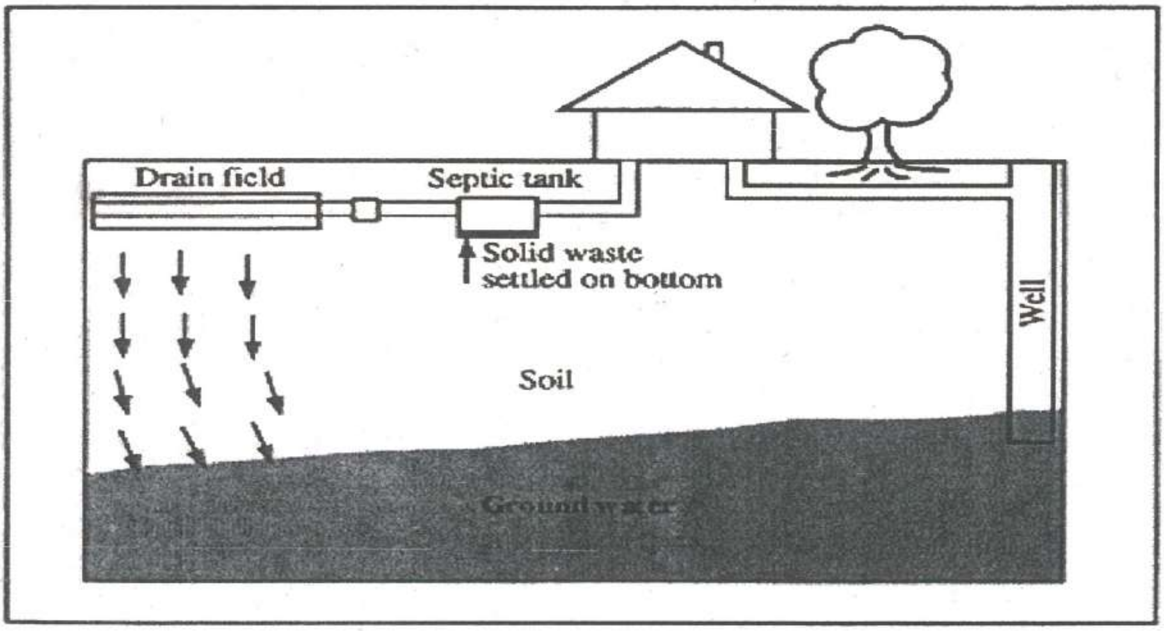


Figure 6.17: Septic systems can affect groundwater.

Improperly used or operated septic systems can be a significant source of ground water contamination that can lead to waterborne disease outbreaks and other adverse health effects. The bacteria, protozoa, and viruses found in sanitary wastewater can cause numerous diseases, including gastrointestinal illness, cholera, hepatitis A, and typhoid. On the other hand, when properly sited, designed, constructed, and operated, they pose a relatively minor threat to drinking water sources.

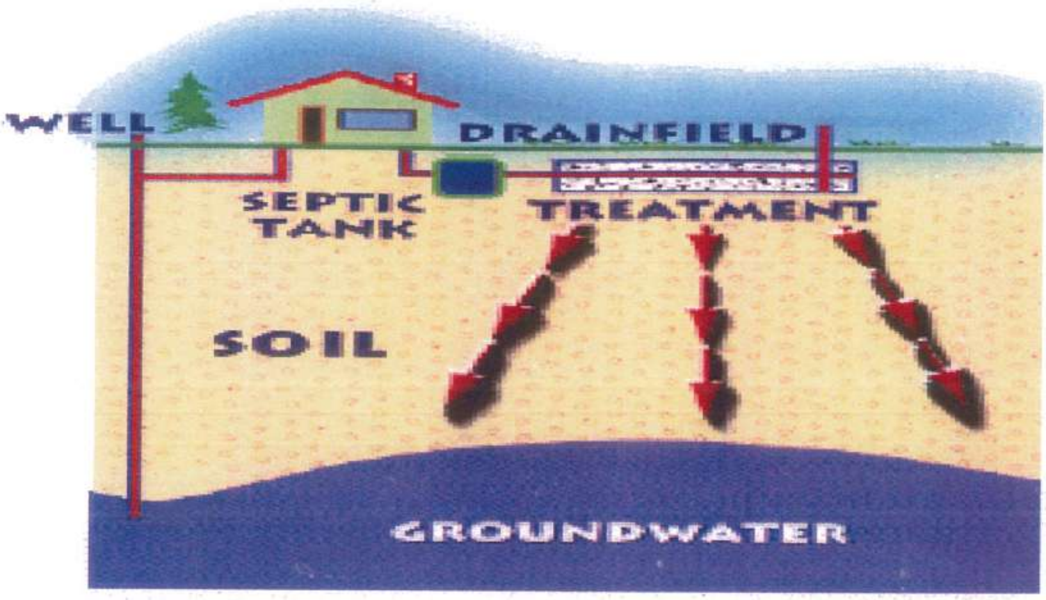


Figure 6.18: Properly designed and operated Septic Systems

A few rules of thumb tell us when septic systems are most likely to function properly and minimize groundwater contamination:

Good soil facilitates treatment and disposal of septic system wastewater. Soil profiles made of sand, silt and clay work well. If there is too much clay in the soil, the waste may percolate poorly. If the soil contains too much sand and large particles, wastewater may pass through to the groundwater without being treated by soil microbes.

Septic systems need space. Only part of the microorganisms and chemicals are removed from wastewater as it moves downward. Even properly operating systems can discharge some phosphates, nitrates and bacteria or viruses into the groundwater. To reduce loading of groundwater with effluent, install systems on lots with adequate space.
Proper design and use is important. Septic systems are designed to treat and dispose of a specific volume and type of wastewater in the conditions found at the site. The system must not be overloaded.

Hazardous chemicals or large amounts of grease should not be disposed in septic systems. Kitchen grease should be placed in the garbage, not the septic tank. Water conservation extends the life of the system.

Routine maintenance is critical. Septic tanks must eventually be pumped. Sludge and scum accumulate and, if allowed to remain, will eventually cause the tank to overflow and clog the drain field.
Good judgment in planning and design and diligent maintenance are the most important aspects of an effective septic system management program.

6.4 PREVALENT WATER-BORNE DESEASES

Water-borne diseases are infectious diseases spread primarily through contaminated water. Though these diseases are spread either directly or through flies or filth, water is the chief medium for spread of these diseases and hence they are termed as water-borne diseases.

Most intestinal (enteric) diseases are infectious and are transmitted through faecal waste. Pathogens – which include virus, bacteria, protozoa, and parasitic worms – are disease-producing agents found in the faeces of infected persons. These diseases are more prevalent in areas with poor sanitary conditions. These pathogens travel through water sources and interfuses directly through persons handling food and water. Hepatitis, cholera, dysentery, and typhoid are the more common water-borne diseases that affect large populations in the tropical regions.

Exposure to polluted water can cause diarrhoea, skin irritation, respiratory problems, and other diseases, depending on the pollutant that is in the water body.

To know the presence of water borne diseases and its spread throughout the district Balrampur many hospitals and private dispensaries have been visited. Also face-to-face discussion with people in some parts of district has been made to ascertain the different types of water borne diseases and severity of them in different parts of the study area. Balrampur district has engulfed by the symptoms of Nitrate effects. Nitrate is a potential health threat to infants causing Methemoglobinaemia. It has been seen that people of the area are always suffering from water-borne diseases especially Jaundice, Methemoglobinaemia, Decentry, and Typhoid etc. Iodine and iron deficiency causes havoc in the areas of Balrampur district. Cases of Goiter and Hydroceal are also reported in large number.

6.5 IMPACT OF PRESENCE OF NITRATE AND MICRO ORGANISMS

It is a well-known fact that clean water is absolutely essential for healthy living. Adequate supply of fresh and clean drinking water is a basic need for all human beings on the earth, yet it has been observed that Nitrogen, primarily from urine, feces, food waste, and cleaning compounds, is present in sanitary wastewater. Consumption of nitrates can cause methemoglobinemia (blue baby syndrome) in infants, which reduces the ability of the blood to carry oxygen. If left untreated, methemoglobinemia can be fatal for affected infants. Due to this health risk, a drinking water maximum contaminant level (MCL) of 10 milligrams per liter (mg/l) or parts per million (ppm) has been set for nitrate measured as nitrogen.

6.5.1 Health Effects in Humans

Infants less than 6 months of age are most affected by excess nitrates in the water. They may develop a condition called methemoglobinemia (blue baby syndrome), which causes a bluish color around the lips that spreads to the fingers, toes and face, and eventually covers the entire body. If the problem is not dealt with immediately, the baby can die.
This problem occurs because human infants have bacteria in their digestive systems that convert nitrate to nitrite, a very toxic substance. When nitrites are absorbed into the blood, they make the hemoglobin (red oxygen-carrying blood pigment) incapable of releasing the oxygen, and mild symptoms of asphyxiation appear.

Babies consume large quantities of water in relation to their body weight. This is especially true when water is used to mix powdered or concentrated formulas or juices. Some feeding practices will minimize the intake of nitrate and nitrite. Breast-feeding reduces risk, because little if any nitrate gets into breast milk. Formula that does not need to be diluted or formula mixed with low-nitrate water is also safe.

6.5.2 Health Effects in Animals

Ruminant animals (such as cows and sheep) and infant monogastrics (such as baby pigs and chickens) also have nitrate-converting bacteria in their digestive systems. For this reason, nitrate poisoning affects them the same way it affects human babies. Because adult animals that are monogastric generally do not have nitrate-converting bacteria, they are not affected by methemoglobinemia. Horses, however, are an exception. They are monogastric, but they also have a cecum, which is similar to a rumen. The nitrate-converting bacteria living in the cecum increase the risk of nitrate poisoning.

Livestock are exposed to nitrate in feed as well as in water. Crops harvested after weather stress (such as drought) may have high nitrate contents. To protect livestock, feeds can be tested for nitrate before being used. High nitrate water is generally a health hazard to animals only when it adds to high nitrate concentrations already present in some feeds.

Symptoms of methemoglobinemia in animals include: lack of coordination, labored breathing, blue coloring of mucous membranes, vomiting and abortions. Dairy cows, however, can have reduced milk production without showing any other symptoms. If animals show signs of nitrate poisoning or a problem is suspected, consult a veterinarian immediately. If the problem is diagnosed in time, animals can be treated and will usually recover fully.

As water moves through a watershed, it collects and drains into rivers, lakes, and groundwater. And it picks up microorganisms. Most are harmless microbes that normally live in the soil and water, but the mix can also contain organisms that cause disease in people.

The majority of waterborne microorganisms that cause human disease come from animal and human fecal wastes. These contain a wide variety of viruses, bacteria, and protozoa. Groundwater has historically been assumed to be safe without treatment to kill microorganisms.

Layers of soil act as a natural filter, removing microbes and other particles as water seeps through. While soil acts as a natural filter, it isn't 100% foolproof. Since Balrampur district has been engulfed by the symptoms of Nitrate effects. The nitrate content is high enough and hence water is unsuitable for drinking purposes. Nitrate is a potential health threat to infants causing Methemoglobinaemia. Chronic consumption may also cause some cancer. It also leads to reduced vitality, increased stillbirth and birth weight. There is an increased risk of bladder cancer. Poor sanitary condition may result in outbreak of other water borne diseases as shown in **Table-6.7**

Table-6.7, Water Borne Diseases Caused By Microbial Organisms

Water Borne Diseases Caused By Microbial Organisms	
Cause	**Water Borne Disease**
Bacterial Infection	Typhoid, Cholera, Paratyphoid fever, Bacillary Dysentry
Viral Infection	Infectious Hepatitis (jaundice), Poliomyelitis
Protozoal Infections	Amoebic Dysentry

CHAPTER # 7

7.0 CASE STUDY:

A case study was carried out at Utraula Block with the following methodology: -

1) The study area was surveyed on two scales Macro and Micro level.
2) Each bore well location was chosen in between soak pit and hand pump.
3) This hand boring was done at a depth of water level, which is 30 feet. These locations were taken in such a way that the hand pump and septic tanks were surrounded by these borings.
4) The water samples were also collected from the deep and shallow

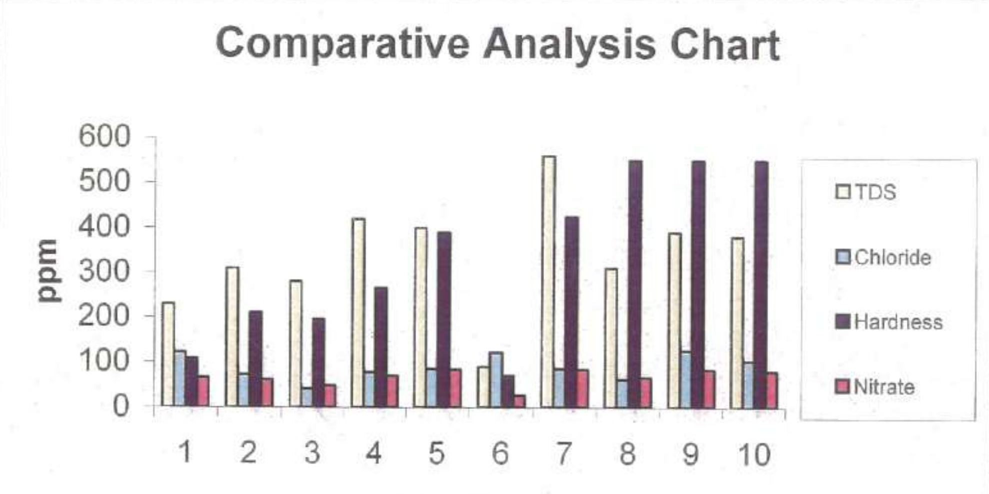


Fig. 7.1,

hand pump, which were located at 10 feet & 30 feet respectively from the soak pit.

5) The parameters like pH, TDS, Hardness, Chloride, Nitrate, MPN, etc were analyzed in order to get the idea about the

contamination of ground water comparing with shallow hand pumps, Deep India Mark – 2 hand pump and deep tube well located at District about 500 m from the soak pit and bar graphs were plotted for each location. **(See Fig-7.1)**

Case Study: I - House of Chhote

Area of the house	-	1000 m^2
Population	-	40 people
Toilet	-	03 Numbers
Soak Pit	-	01
Hand Pump	-	01

Details of soak pit:

(1)	Diameter	-	20 inches
(2)	Depth	-	15 feet
(3)	Filter Media	-	Broken bricks
(4)	Lining	-	RCC pipe with open hole

Description

(1)	Depth of hand pump	-	40 feet
(2)	Water level	-	20 feet
(3)	No. of Test Bore Dug	-	01 – 40 feet deep
(4)	No. of sample	-	01 at 20 feet 01 at 30 feet 01 at 40 feet

Water Analysis

(1) Sample no. 1

Ph	-	7.90
TDS	-	310 mg/l
Chloride	-	62 mg/l
Hardness	-	> 500 mg/l
Nitrate	-	66 mg/l

(2) Sample no. 2

Ph	-	6.76
TDS	-	310 mg/l
Chloride	-	72 mg/l

Hardness	-	210 mg/l
Nitrate	-	61.6 mg/l

(3) Sample no. 3

Ph	-	6.65
TDS	-	285 mg/l
Chloride	-	56 mg/l
Hardness	-	180 mg/l
Nitrate	-	45 mg/l

Case Study: II - Garahiya Talab

Area of the house	-	1000 m^2
Population	-	38 people
Toilet	-	03 Numbers
Soak Pit	-	01
Hand Pump	-	01

Details of soak pit:

(1)	Diameter	-	20 inches
(2)	Depth	-	15 feet
(3)	Filter Media	-	Broken bricks
(4)	Lining	-	RCC pipe with open hole

Description

(1)	Depth of hand pump	-	40 feet
(2)	Water level	-	20 feet
(3)	No. of Test Bore Dug	-	01 – 40 feet deep
(4)	No of sample	-	01 at 20 feet
			01 at 30 feet
			01 at 40 feet

Water Analysis

(1) Sample no. 1

Ph	-	6.95
TDS	-	230 mg/l
Chloride	-	122 mg/l
Hardness	-	108 mg/l
Nitrate	-	66 mg/l

(2) Sample no. 2

Ph	-	
TDS	-	310 mg/l
Chloride	-	72 mg/l
Hardness	-	210 mg/l
Nitrate	-	61.6 mg/l

(3) Sample no. 3

Ph	-	6.65
TDS	-	285 mg/l
Chloride	-	56 mg/l
Hardness	-	180 mg/l
Nitrate	-	45 mg/l

Case study: III - House of Imad Hasan

Area of the house	-	1000 m^2
Population	-	35 people
Toilet	-	03 Numbers
Soak Pit	-	01
Hand Pump	-	01

Details of soak pit:

(1)	Diameter	-	20 inches
(2)	Depth	-	15 feet
(3)	Filter Media	-	Broken bricks
(4)	Lining	-	RCC pipe with open hole

Description

(1)	Depth of hand pump	-	40 feet
(2)	Water level	-	20 feet
(3)	No. of Test Bore Dug	-	01 – 40 feet deep
(4)	No of sample	-	01 at 20 feet 01 at 30 feet 01 at 40 feet

Water Analysis

(1) Sample no. 1

Ph	-	7.26
TDS	-	400 mg/l
Chloride	-	85 mg/l
Hardness	-	390 mg/l

Nitrate	-	83.6 mg/l

(2) Sample no. 2

Ph	-	6.95
TDS	-	315 mg/l
Chloride	-	71 mg/l
Hardness	-	215 mg/l
Nitrate	-	61.6 mg/l

(3) From soak pit Sample no. 3

Ph	-	6.65
TDS	-	280 mg/l
Chloride	-	56 mg/l
Hardness	-	180 mg/l
Nitrate	-	41 mg/l

Case study: IV - House of Robin

Area of the house	-	1000 m^2
Population	-	39 people
Toilet	-	03 Numbers
Soak Pit	-	01
Hand Pump	-	01

Details of soak pit:

(1)	Diameter	-	20 inches
(2)	Depth	-	15 feet
(3)	Filter Media	-	Broken bricks
(4)	Lining	-	RCC pipe with open hole

Description

(1)	Depth of hand pump	-	40 feet
(2)	Water level	-	20 feet
(3)	No. of Test Bore Dug	-	01 – 40 feet deep
(4)	No of sample	-	01 at 20 feet
			01 at 30 feet
			01 at 40 feet

Water Analysis

(1) Sample no. 1

Ph	-	6.71
TDS	-	560 mg/l

Chloride	-	85 mg/l
Hardness	-	425 mg/l
Nitrate	-	83.6 mg/l

(2) Sample no. 2

Ph	-	6.56
TDS	-	295 mg/l
Chloride	-	68 mg/l
Hardness	-	280 mg/l
Nitrate	-	57.6 mg/l

(3) Sample no. 3

Ph	-	6.65
TDS	-	248 mg/l
Chloride	-	56 mg/l
Hardness	-	180 mg/l
Nitrate	-	42 mg/l

Case study: V - House of Hafiz

Area of the house	-	1000 m^2
Population	-	32 people
Toilet	-	03 Numbers
Soak Pit	-	01
Hand Pump	-	01

Details of soak pit:

(1)	Diameter	-	20 inches
(2)	Depth	-	15 feet
(3)	Filter Media	-	Broken bricks
(4)	Lining	-	RCC pipe with open hole

Description

(1)	Depth of hand pump	-	40 feet
(2)	Water level	-	20 feet
(3)	No. of Test Bore Dug	-	01 – 40 feet deep
(4)	No of sample	-	01 at 20 feet 01 at 30 feet 01 at 40 feet

Water Analysis

(1) Sample no. 1

Ph - 8.28
TDS - 390 mg/l
Chloride - 126 mg/l
Hardness - >500 mg/l
Nitrate - 83.6 mg/l

(2) Sample no. 2

Ph - 7.56
TDS - 295 mg/l
Chloride - 85 mg/l
Hardness - 380 mg/l
Nitrate - 55.6 mg/l

(3) Sample no. 3

Ph - 6.90
TDS - 220 mg/l
Chloride - 56 mg/l
Hardness - 180 mg/l
Nitrate - 39.6 mg/l

Table: 7.1

CHEMICAL ANALYSIS CHART

Sl No.	Location	Ph	TDS (mg/l)	Chloride (mg/l)	Hardness (mg/l)	Nitrate (mg/l)
01	Dahiroa Talab	6.95	230	122	108	66
02	Chote House	6.76	310	72	210	61.6
03	Zahiruddin Chacha	6.85	280	41	195	48.4
04	North Tab Dhareoa	6.9	420	78	265	70.4
05	Imadul Chacha	7.26	400	85	390	83.6
06	Talab Dwar Kathra	6.54	90	122	70	26.4
07	Robin Bhai	6.71	560	85	425	83.6
08	Chote House	7.9	310	62	550	66
09	Hafiz Bhai	8.28	390	126	550	83.6
10	South Talab Dahoreao	7.67	380	103	550	79.2

Table 7.2, BACTERIOLOGICAL ANALYSIS CHART

Sl No	Location	Total No. of colonies	Size	Colour
01	Dahiroa Talab	178	Small+Big	Gray
02	Chote House	65	Small+Big	Gray+Yellow
03	Zahiruddin Chacha	146	Small+Big	Brown
04	North Tab Dhareoa	467	Small+Big	Brown+Gray
05	Imadul Chacha	846	Small+Big	Yellow+Gray
06	Talab Dwar Kathra	68	Small+Big	Yellow
07	Robin Bhai	683	Small+Big	Brown
08	Chhote House	510	Small+Big	Light Yellow
09	Hafiz Bhai	317	Small+Big	Yellow
10	South Talab Dahoreao	403	Small+Big	Yellow+Gray

CHAPTER # 8

8.0 REMEDIAL MEASURES

Groundwater is water that is found underground in soil, sand and rock pores below the water level under the saturation zone. Groundwater can be found almost everywhere. The water table may be deep or shallow; and may rise or fall depending on many factors. Groundwater is stored in and moves slowly through layers of soil, sand and rocks called aquifers. Aquifers typically consist of gravel, sand, sandstone, or fractured rock, like limestone. These materials are permeable because they have large connected spaces that allow water to flow through.

Groundwater supplies are replenished, or recharged, by rain and snowmelt. In some areas of the world, people face serious water shortages because groundwater is used faster than it is naturally replenished. In other areas groundwater is polluted by human activities. In areas where material above the aquifer is permeable, pollutants can sink into the groundwater. Groundwater can be polluted by undersigned landfills, **undesigned septic tanks, soak pits,** leaky underground gas tanks, and from overuse of fertilizers and pesticides.

Ground water in the **Balrampur area** occurs both under confined and water table condition. It occurs in the zones of saturation within the granular zones encountered below the land surface. It is tapped mostly by open wells and Shallow tube wells. The principle source of replenishment to the groundwater body is seepage from septic tanks/soakpits. The depth of water level ranges from 1.52 m to 10.47 mbgl during pre monsoon and 1.25 to 5.29 mbgl in post monsoon period.

If groundwater becomes polluted, it will no longer be safe to drink. Groundwater is a major source of drinking water for masses world over and its quality is of vital economic and social importance.

An adequate supply of safe water is vital to human health and survival. Protecting the quality of drinking water, particularly from contamination by harmful organisms and chemicals is a pre-requisite for good health.

Based on the outcome of the study conducted, it has now been established that the **shallow aquifers of Balrampur are contaminated with Nitrate (See Fig. 6.15).** The contamination of shallow aquifers however is **limited to localized pockets only**.

While nitrate is a common nitrogenous compound due to natural processes of the nitrogen cycle, anthropogenic sources have greatly increased the nitrate concentration, particularly in groundwater. The largest anthropogenic sources are septic tanks, application of nitrogen-rich fertilizers and agricultural processes.

The most basic, unavoidable cause of nitrate contamination is that when biological materials decompose, most of the nitrogen in the materials ends up as nitrates. Nitrate is a very stable molecule and doesn't readily turn into anything else. It is also very soluble, and moves with the flow of water from the source into the groundwater, and eventually into an aquifer. Nitrate migrates easily into aquifers because it is **highly mobile in soils**. The movement of contaminants through soil to groundwater is affected by many variables, including **properties of the contaminant itself, soil conditions** and climatic factors. These combinations of factors make the likelihood of groundwater contamination a very site-specific science.

Nitrate thus poses a threat to human health. Particularly in rural, private wells, incidence of methemoglobinemia appears to be the result of high nitrate levels. Methemoglobinemia, or blue baby syndrome, robs the blood cells of their ability to carry oxygen. Due to the detrimental biological effects, treatment and prevention methods must be considered to protect groundwater aquifers from nitrate leaching and high concentrations.

Most methods of nitrate removal that have been applied for in situ groundwater treatment are based on chemical and/or biological denitrification. The methods apply redox reactions, often with biological catalysis, to reduce nitrate to nitrogen gas. The most important in situ groundwater treatment methods for nitrate and many other contaminants can be divided into the following three main groups:

- *Permeable Reactive Barrier (PRB) methods*
- *Biological methods*
- *Electrochemical methods*

Permeable Reactive Barrier (PRB) techniques (also called "passive treatment walls") involve the physical placement of a barrier, consisting of reactive material, into a trench excavated in the aquifer.

In other cases, a chemical reagent (e.g. a reducing agent) is injected into the aquifer to create the reactive barrier.

Biological methods are widely used for removal of nitrate and degradable organic compounds. This treatment method is a viable option when the rate of contaminant biodegradation is faster than the rate of contaminant migration.

Electrochemical methods are more complex than PRB or biological methods. These systems generally use an electrical current, applied via two in situ electrodes to control the movement and redox chemistry of ions and water in the subsurface.

As stated earlier the contamination is limited to localized pockets only, which are underlying the undesigned soakpits/sceptic tanks. **This calls for development of suitable remedial measures.**

Before suggesting the remedial measure a look into the site conditions is also vital since site conditions constitute an important component before selection and implementation of any technology, procedure or measure. Keeping in view the local site conditions the following methods are thought of as a possible measure for overcoming the problem of nitrate contamination in Balrampur.

1. Pumping out water from aquifers
2. Installation of deep handpumps and Use of Designed Septic Tanks
3. Root Zone Treatment System

1. Pumping out water from aquifers

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel and sand etc) from which groundwater can be usefully extracted using a water well. Aquifers can occur at various depths. Those closer to the surface are not only more likely to be exploited for water supply and irrigation, but are also more likely to be topped up by the local rainfall.

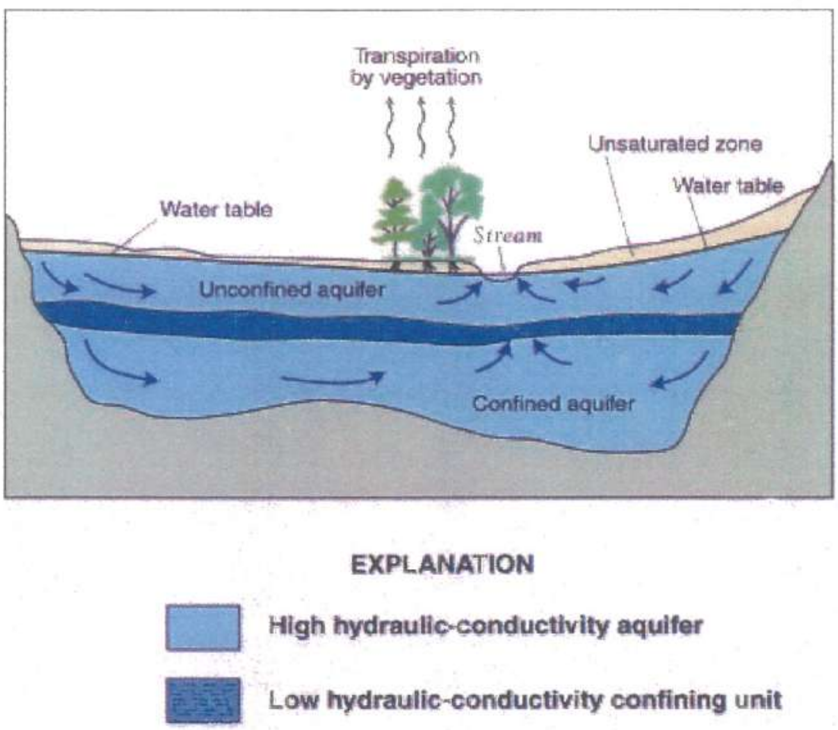


Fig. 8.1, Typical Aquifer Cross-section

A typical aquifer cross-section is shown in **fig. 8.1** above. It indicates typical flow directions in a cross-sectional view of a simple confined/unconfined aquifer system (two aquifers with one aquitard between them, surrounded by the bedrock aquiclude) which is in contact with a stream (typical in humid regions). The water table and unsaturated zones are also illustrated.

As stated earlier the contamination is limited to localized points. Thus pumping out water from these localized pockets can be one of the possible options for overcoming the problem of nitrate contamination. The water will be pumped out for irrigation uses. This will have two benefits, first the contaminated water will be pumped out from the aquifers and second that water will be utilized by the farmers for irrigating their fields. Since the water is rich in Nitrate, this will reduce their expenditure on fertilizer requirement, since water is rich in nitrate, one of the major fertilizers used for raising various crops in Balrampur.

The general arrangement of houses in a village is depicted in **Fig. 8.2** below, the settlement in a village comes up in such a way that the high areas have residential clusters and low lying area has pond. As is shown the pond is surrounded by houses, earlier villagers used pond water to meet the washing requirement, fishing and other recreational purposes.

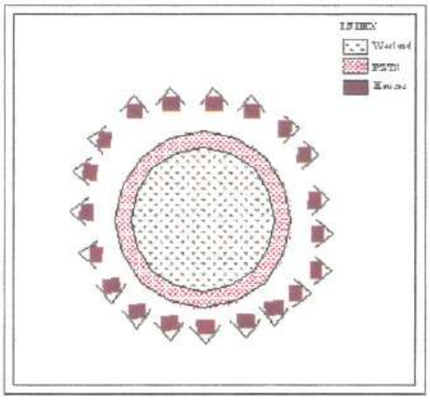


Fig. 8.2, rrangement of Houses in a Village.

The overflow from undersigned septic tanks is going to the ponds and contaminating same. The seepage from ponds and the septic tanks is going down to the aquifers underlying them. The handpumps and the septic tanks were almost at same level and thus the handpump water is also found to be contaminated.

2. Installation of Deep Handpumps and Use of Designed Hand Pumps

Another possible measure proposed keeping in view the local conditions is that water for drinking and cooking purposes should be with drawn from deep handpumps. Since the contamination is limited to shallow aquifers and that too at localized pockets which are near the septic tanks/soak pit and ponds, thus withdrawing water from deep handpumps will provide safe water to the villagers.

India Mark-II, Deep Well Hand Pump

Generally it was that **100 to 120 ft deep handpumps** are providing safe drinking water in Balrampur area.

Besides this the septic tanks being used should be converted to properly designed ones, so that no further contamination occurs.

The septic tank is an underground, watertight vessel (see **fig. 8.3** below) installed to receive wastewater from the home. It is designed to allow the solids to settle out and separate from the liquid, to allow for limited digestion of organic matter, and to store the solids while the clarified liquid is passed on for further treatment and disposal.

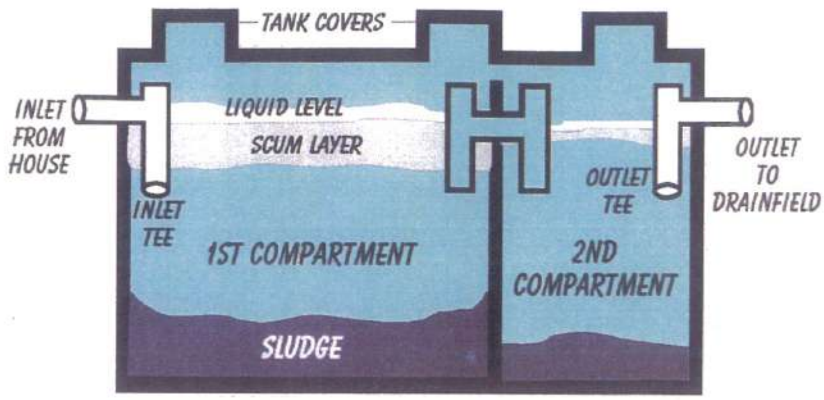


Fig.8.3, Septic Tank

Septic tanks may have one or two compartments. Two compartment tanks do a better job of settling solids and may be required for treatment systems. Tees and baffles are provided at the tank's inlet and outlet pipes. The inlet tee slows the incoming wastes and reduces disturbance of the settled sludge. The outlet tee keeps the solids or scum in the tank. All tanks should have accessible covers for checking the condition of the baffles and for pumping both compartments.

Solids that are not decomposed remain in the septic tank. If not removed by, solids will accumulate until they eventually overflow through outlet tee. It is thus important that the septic tanks should be cleaned at regular intervals because retention time, or the time available for solids to settle out of wastewater, decreases as the sludge layer increases in the septic tank.

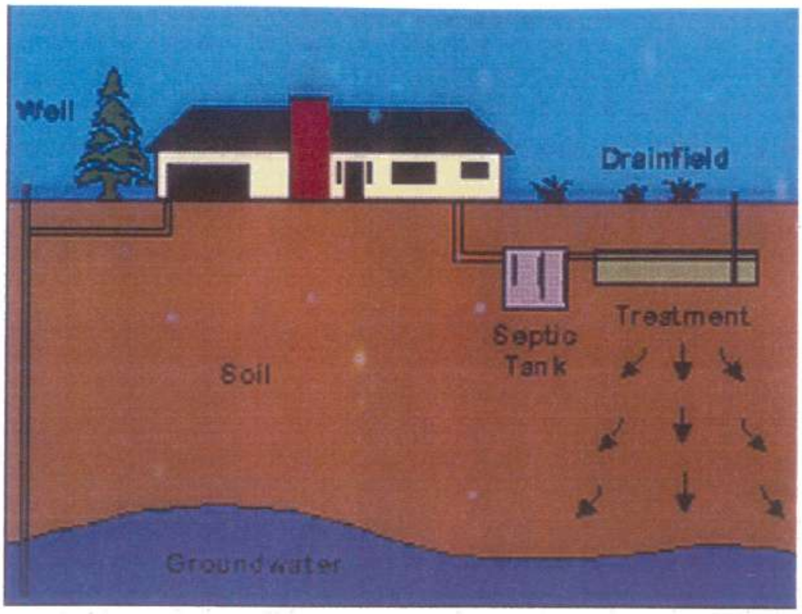


Fig. 8.4, Schematic of Water withdrawal from aquifer/groundwater

The schematic of water withdrawal from an aquifer/groundwater, it use, discharge into septic tank followed by final percolation back into groundwater is depicted in **Fig.8.4** above.

3. Root Zone Treatment System

Root Zone Treatment system is yet another possible solution which can be used for overcoming the problem. Root Zone Treatment System are planted filter-beds consisting of sand/gravel/soil. The Root Zone Treatment System uses a natural way to effectively treat domestic & industrial effluents. This Technology was developed in 1970's in **Germany** and is successfully running in different countries, mainly in **Europe, India and America.** The process incorporates the self-regulating dynamics of an artificial soil eco-system. **RZTS** are well known in temperate climates and are easy to operate on-site treatment facilities, which have less installation and low maintenance & operational costs.

ROOT ZONE TREATMENT SYSTEM (RZTS)

The term 'Root Zone' encompasses the life interactions of various species of bacteria, the roots of reed plants, soil, sun and water. They are also known as constructed wetlands or sub-surface flow systems. In this system, these plants conduct oxygen through their stems into their root systems and create favorable conditions for the growth of bacteria. The wastewater flows through the root zone in a horizontal or vertical way where the organic pollutants are decomposed biochemically by the bacteria present in the rhizosphere of root plants. A perusal of the RZTS is shown in **Fig.18.** The filter media are selected carefully to provide favorable conditions for both plants & bacterial growth and to avoid clogging. Organic pollutants are removed drastically from wastewater and are reduced to their elemental forms.

GENERAL DESIGN CRITERIA

The Root Zone Treatment installations are constructed according to the desired level of purification, the concentration of pollutants and hydraulic & organic loadings. The RZTS plants can be set-up as secondary or tertiary treatment for domestic and industrial wastewater treatment systems.

TABLE-7

General Design Criteria for Root Zone Treatment System

S.No. Type	Horizontal Bed (M^2/day)	Vertical Bed (M^2/day)

1.	Organic loading	10-30 gm BOD	20-40 gm BOD
2.	Hydraulic loading	40-100 litre	50-130 litre

For cold climates the design criteria are shown in **Table 7** & this criterion has been used while designing **Mother Dairy Pilot Project**. For tropical/subtropical condition, however, the design criteria concerning to performance are still not available. It is expected that area requirement should be less in tropical climate because of enhanced microbial degradation process. On the other hand, there are some indications that in warm climates the filter media have to be selected differently to avoid clogging problems.

GUIDELINES ON ROOT ZONE TREATMENT SYSTEM

On the basis of performance data of RZTS located in India & elsewhere, the work related to development of Guidelines for construction, use, operation & maintenance of Root Zone Treatment System has been prepared by Central Pollution Control Board (CPCB) and the detailed information related to Root Zone System can be obtained from CPCB. Besides this an experiment (pilot project) for optimization of efficiency parameters under Indian climatic conditions such as void ratio, evaporation rate, permeability, filter media, plant species (reed) etc. is being carried out at Mother Dairy, Delhi.

Selection of Plant Species

Following list of species can be tried:-

- Phragmites australis (reed)
- Phragmites Karka (reed)

- Arundo donax (Mediterranean reed)
- Typha latifolia (cattail)
- Typha angustifolia (cattail)
- Iris pseudacorus
- Schoenopletus lacustris (bulrush)
- Scirpus Lacustris

For horizontal **RZTS** all helophytes can be used which are deep-rooted and oxygenate the rhizosphere through the roots. For vertical systems, the plant selection is less critical, because the oxygen input is enhanced by the intermittent surface application. However, in mother dairy plant, Phragmites australis has been used in both horizontal and vertical filter beds.

Planting Techniques:

Planting of reeds can be done in the following ways:

- Reeds can be planted as rhizomes, seedlings or planted clumps.
- Clumps can be planted during all seasons. ($2/m^2$)
- Rhizomes grow best when planted in spring. ($4\text{-}6/m^2$)
- Seedlings should be planted preferably in spring. ($3\text{-}5/m^2$)

Planting should be done from supporting boards to avoid compaction of the filter media. Initially the plants should be kept well watered, but not flooded. With well-developed shoots in the growth period, a sufficient supply of nutrients is required. If wastewater is used for initial watering, precautions like avoidance of stagnation have to be taken to inhibit the formation of **H_2S** within the filter bed.

ADVANTAGE OF ROOT ZONE TREATMENT SYSTEMS

1. **RZTS** is a **decentralized** wastewater treatment facility and can be set-up within the premises of residential areas and colonies with no unhygienic condition created. Sanitation of even single house is also possible.
2. There is **no energy requirement** in this process, is particularly applicable in rural areas of India specially Balrampur since power supply is not regular in these areas.
3. Removal of bacteria and parasite is very effective, **recycling and reuse** of wastewater for secondary purposes (toilets, gardening) can be done effectively, especially in the water-scarce region.
4. **RZTS** requires low construction, operational and maintenance cost. Besides routine checks, only harvesting of the reeds is required once in 3-5 years. The reeds can also be used for commercial purposes.
5. **RZTS** are tolerant against shock loading or interrupted use. In temperate climates such as in India, this technology is being tried since last one decade. A number of RZTS plants have been set-up at different locations in India by various organizations for e.g. **Auroville, Chennai (Anna University), Pune, Tekkadi (Kerala), Bhopal, Gurgaon (TERI), Bilaspur (MP) etc.,** for treatment of both domestic & industrial effluents. But the performance efficiency of these plants is yet to be known. To collect more data on **RZT Plants,** CPCB has sponsored a project to **Center for Scientific Research (CSR),** Auroville to monitor performance efficiency of a few plants located in the Auroville for a period of one year. The initial analytical results of BOD & COD removal are appreciable.

APPLICATION OF ROOT ZONE TREATMENT TECHNOLOGY

1. Treatment of domestic wastewater especially for small towns **(Class-II & III),** village resorts, hotels, hostels, etc., is easily possible & affordable because it involves low capital, operation & maintenance cost
2. **RZTS** can also treat **Biodegradable Industrial Effluents** specially effluents from agro based industries as the same can be seen at **Kids Leather (Tannery effluent)**, Chennai, Industrial **effluent of Proctor & Gamble at Bhopal & CPCB project at Mother Dairy, Delhi.**
3. **RZTS** Technology can be applied in **Urban Watershed Management (UWM)** by treating the open nalas in decentralized way and receiving the treated waste either for irrigation or dilution purposes

In Balrampur area this technique can be successfully used, by diverting the generated sewage to the designed ponds. This will help not only in treating generated sewage but also will reduce the spot contamination of aquifers which is happening in Balrampur currently. The financial requirements for design of this system may be taken from the infrastructure development budget of Panchayati Raj or any other source may also be considered.

CHAPTER # 9

9.0 CONCLUSION AND RECOMMENDATION

1. The percolating contaminated water from septic tanks has raised the level of Nitrate and microbial organisms in underground water reservoir.
2. Shallow aquifer has been affected up to 40-70 feet, but deeper parts of them are still safe.
3. Ground water present in deep aquifers is still not affected and can be used for drinking purposes.
4. Abnormal behavior of groundwater quality in urbanized and populated area of the district was recognized. The impact of septic tank was very much visualized in the rural areas of Balrampur as well.
5. people of the area are always suffering from water-borne diseases especially Jaundice, Methemoglobinaemia, Decentry, Typhoid etc

The following remedial measures can be adopted.

1. Preventive measures:

Water-borne epidemics and health hazards in the aquatic environment are mainly due to improper management of water resources. Proper management of water resources has become the need of the hour as this would ultimately lead to a cleaner and healthier environment In order to prevent the spread of water-borne infectious diseases, people should take adequate precautions. The individual and the community can help minimize water pollution. By simple housekeeping and management practices the amount of waste generated can be minimized. Methods to reduce contaminant movement to groundwater depend on water management, appropriate loading rates, and soil and Vadose zone properties. Understanding the processes that control movement of contaminants is necessary for developing any successful strategy to protect groundwater from contamination levels that pose significant health risks.

2. Development of proper sewerage system:

Since long, waste disposal system appears to be inadequate/improper resulting in nitrate contamination in ground water. This is now high time to take special attention to rectify the mistakes and to develop proper sewerage system immediately. Also need of the hour is to take prompt action for repair and maintenance of the existing sewerage systems in order to check over leakages and seepage of the pollutant. Periodic maintenance programme for these sewerage systems should also be planned. Properly designed and installed septic tanks can function for many years. Annual inspection to determine sludge depth is desirable to prevent tank solids from overflowing and sealing the soil in the drain field.

3. Abandonment of soak pit system of sanitation:

Almost all the diseases result from pollution of water by human and animal faeces. Clean water and basic sanitation are closely interlinked. A leakage from soak pits is a common phenomenon and is a major source of pollution. Therefore, these old soak pits should be abandoned and law should also ban construction of new one. Door to door the concerned authorities in this regard may carry out survey. It should be made mandatory to connect all the houses with well-developed sewerage system only.

4. Lining of the drains:

Unlined drains carrying sewerage/effluents are the potential sources of contamination of ground water and therefore should be lined urgently.

5. Discourage use of nitrate fertilizers:

Nitrate fertilizers may also furnish significant quantum of nitrate constituents to the groundwater, so the use of these fertilizers should be discouraged.

6. Artificial recharge to ground water:

Rainwater during monsoon period can be fruitfully utilized for recharging ground water by various techniques. This will not only augment the ground water resources but also dilute and flush the polluted area gradually.

7. Marking ground water abstraction structures having high nitrate:

All the ground water abstraction structure including hand pumps with high nitrate concentration should be marked by red paint so as to avoid their utility by the common people for drinking purposes. Alternatively a signboard titled "unfit for drinking purposes" may also be given a thought.

8. Dual Water Supply Schemes:

Government should introduce dual water supply schemes i.e. bringing fresh water supply to the affected areas from other places for drinking purposes. High nitrate waters can be supplied separately for other domestic purposes like washing, cleaning, bathing or in the agricultural fields etc.

9. Technology Development:

Water has many uses, not all of which require the same level of treatment. For example, water for gardening need not be treated to the same level as water for drinking. But reducing standards for some uses and not for others would entail greater risks. Supplying different varieties of water for different commercial uses or for different consumers would be much more expensive than supplying the same quality of water for all purposes. Available technologies for the treatment of water for nitrates should be evaluated and cost effective and eco-friendly technologies adopted. **Root Zone Treatment System** can be adopted to treat sludge water. With RZTS Treatment of wastewater is easily possible & affordable because it involves low capital, operation & maintenance cost.

10. Public Awareness:

Awareness among the public and other NGOs about the adverse effects of chemical contaminants should be encouraged. The public should be made aware of the importance of hygiene, the dangers of pollution and the benefits of environmental preservation. Close partnerships involving all stakeholders, government authorities at different levels, industry, academia, NGOs and local communities should be encouraged.

11. Participatory Management:

Participatory management program can be initiated by the government through Panchayati Raj for introducing awareness in farmers for safe drinking water, health, hygiene with appropriate development of geo-environment. The framers should be educated to use only designed septic tanks and to know the impact of use of undersigned septic tanks. Further they should have the idea about safe drinking water and accessibility to deep hand pumps, further they should also learn the adaptation of root zone system for cleaning of ponds and to avoid any further contamination of shallow aquifers.

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Annexure-I

BLOCK WISE LAND UTILIZATION (IN HECTARE) IN BALRAMPUR DISTRICT, U.P

Sl. No.	Blocks	Total geographical area	Forest	Cultivable waste	Present fallow	Other fallow	Land Barren	Land under various use except Agriculture	Pasture land	Orchard	Net area cultivated
1	Rehra Bazaar	59747	16008	407	3708	352	555	4725	35	1358	32741
2	Sridutt gunj	45110	2570	315	3455	246	471	5535	37	1243	31318
3	Utraula	49694	9973	582	1252	3098	560	4251	86	835	29307
4	Gaindas Buzurg	51445	9027	374	990	4619	482	4396	65	625	30845
5	Pachperwa	55915	16768	455	1424	2731	438	3774	48	654	26716
6	Gainsari	18982	995	75	1668	767	348	2469	14	191	12519
7	Balrampur	16822	703	54	992	367	293	2472	9	226	11779
8	Tulsipur	16251	803	113	1094	545	241	2269	7	738	12561
9	Haraiya Satgharwa	23583	2797	370	2158	287	165	2142	11	305	15448
	Total	**337549**	**59644**	**2845**	**16741**	**3012**	**3553**	**32033**	**312**	**6175**	**203234**

Annexure-IIB

MONTHLY RAIN FALL DATA OF GAINSARI RAIN GAUGE STATION, BALRAMPUR, U.P

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Monsoon	Non-Monsoon
1989	31.4	11.8	0.0	0.0	7.2	126	535.8	253.6	295.7	24.6	0.0	65	1351.1	1211.1	140
1990	0.0	86.6	3.8	0.0	107.4	184.4	592.6	213	81	31.4	0.0	21.4	1356.6	1071	285.6
1991	31.4	21.0	0.0	1.8	3.6	489.2	53.2	448	79.8	0.0	4.6	28.2	1160.8	1070.2	90.6
1992	9.7	18.2	0.0	2.0	23.2	91.5	353.4	238.8	136.6	222.4	4.8	0.0	1100.6	820.3	280.3
1993	3.4	0.0	26	23.6	6.8	254.6	151.2	470.1	309.6	0.0	0.0	0.0	1306.5	1185.5	121
1994	11	30.2	0.0	6.4	14.6	243.6	229.8	360.2	178.4	0.0	0.0	0.0	1074.2	1012	62.2
1995	11.2	23.4	16.8	0.0	10.2	207.8	266.6	424.6	89	0.0	12	4.6	1066.2	988	78.2
1996	69	34.8	0.0	2.0	0.0	96.6	282.8	327.8	207.8	63.4	0.0	0.0	1084.2	915	169.2
1997	3.0	1.0	0.0	26.6	49.6	43.8	483.2	372	154.2	57.8	5.8	39.6	1236.2	1053.2	183.4
1998	18.6	17	13.2	8.6	19	158.6	445.4	383.4	100	20.6	24	0.0	1208.4	1087.4	121
SD	**19.7**	**23.3**	**13.2**	**9.4**	**32.8**	**119.1**	**165.1**	**85.0**	**80.8**	**64.2**	**7.3**	**21.3**	**108.8**	**110.5**	**74.1**
VAR.	**104.4**	**95.4**	**139.1**	**132.6**	**108.2**	**62.8**	**48.6**	**24.3**	**49.5**	**152.7**	**143.0**	**134.3**	**9.1**	**10.6**	**48.4**
AVG.	**18.9**	**24.4**	**9.5**	**7.1**	**30.3**	**189.6**	**339.4**	**349.2**	**163.2**	**42.0**	**5.1**	**15.9**	**1194.5**	**1041.4**	**153.2**

Annexure-IIA

MONTHLY RAIN FALL DATA OF UTRAULA RAIN GAUGE STATION, BALRAMPUR, U.P

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Monsoon	Non-Monsoon
1989	20.0	33.8	0.0	0.0	22.8	74.3	491.2	236.8	213.0	13.0	0.0	34.0	1138.9	1015.3	123.6
1990	0.0	181.8	22.6	0.0	98.8	59.2	563.0	166.6	129.2	33.4	0.0	30.0	1284.6	918	366.6
1991	9.2	23.4	0.0	21.4	9.4	263.3	31.0	210.1	207.8	0.0	0.0	24.4	800.0	712.2	87.8
1992	2.4	13.4	0.0	2.0	26.2	112.4	318.8	217.3	50.7	224.6	5.2	0.0	973.0	699.2	273.8
1993	2.4	0.0	20.4	22.4	52.6	229.0	135.6	401.4	273.0	0.0	0.0	0.0	1136.8	1039	97.8
1994	3.8	7.2	0.0	6.0	21.6	65.0	153.2	481.2	174.0	0.0	0.0	0.0	912.0	873.4	38.6
1995	7.4	14.2	2.2	0.0	3.2	169.2	269.5	252.9	191.6	19.0	27.6	7.9	964.7	883.2	81.5
1996	70.1	21.0	0.0	0.0	0.0	82.9	118.3	236.3	99.7	36.3	0.0	0.0	664.6	537.2	127.4
1997	0.0	0.0	0.0	3.5	20.0	17.8	430.1	268.8	64.0	43.8	5.8	0.0	853.8	780.7	73.1
1998	17.4	13.8	9.6	4.7	8.4	70.8	462.8	264.4	173.0	36.4	0.0	0.0	1061.3	971	90.4
SD	**20.1**	**51.3**	**8.5**	**8.2**	**28.0**	**75.9**	**174.4**	**90.2**	**67.0**	**63.3**	**8.2**	**13.4**	**173.8**	**150.9**	**97.3**
VAR.	**148.4**	**75.4**	**240.7**	**156.8**	**124.6**	**104.1**	**55.5**	**31.1**	**51.2**	**157.9**	**189.6**	**221.4**	**11.1**	**13.1**	**54.5**
AVG.	**13.3**	**30.9**	**5.5**	**6.0**	**26.3**	**114.4**	**297.4**	**273.6**	**157.6**	**40.7**	**3.9**	**9.6**	**979.0**	**842.9**	**136.1**

December	24.3	8.8	27.3	5.4	Morning	84	2.8
					Evening	63	
Annual Mean	31.5	18.8	44.8	4.1	Morning	71	5.2
					Evening	55	

Annexure-III

CLIMATOLOGICAL DATA OF BALRAMPUR DISTRICT, U.P

Month	Air Temperature Mean of (in ^{0}C)				Relative Humidity in %		Wind Velocity in km/hour
	Av. Max	Av. Min	Highest	Lowest			
January	22.9	8.3	26.4	4.5	Morning	84	3.9
					Evening	61	
February	25.7	10.5	30.4	6.2	Morning	73	5.1
					Evening	45	
March	32.2	15.4	37.4	10.4	Morning	52	6.5
					Evening	31	
April	37.6	21.0	41.8	16.2	Morning	39	7.4
					Evening	22	
May	39.9	25.6	43.9	20.6	Morning	49	7.7
					Evening	28	
June	37.4	26.9	43.3	22.5	Morning	69	7.3
					Evening	51	
July	32.9	26.2	37.3	23.3	Morning	84	6.4
					Evening	76	
August	32.2	25.9	35.4	23.4	Morning	85	5.2
					Evening	80	
September	32.5	24.9	35.6	22.1	Morning	82	4.6
					Evening	76	
October	32.1	20.0	34.9	14.9	Morning	79	3.0
					Evening	66	
November	28.6	12.6	31.5	8.5	Morning	78	2.4
					Evening	59	

Annexure-IV

LITHOLOGICAL LOGS OF BOREHOLES DRILLED IN THE AREA

Location: Belbharia

Block

Specific Capacity 2.152 LPS/m

S.W.L 8.56

Transmissivity 229.20 m^2/d

Discharge 39.11 lps

Thickness of Aquifer 42.00 m.

Drawdown 18.04 m

Hydraulic conductivity 5.46 m/day

Lithology	**Depth Range (mbgl)**		**Thickness (m)**
	From	**To**	
Clay, brown mixed with kankar	0.00	7.50	7.50
Sand, brown fine grained	7.50	17.35	9.65
Clay, brown mixed with kankar and minor sand	17.35	40.00	22.65
Sand medium to course grained with occasional gravel	40.00	43.00	3.00
Clay, brown mixed with kankar and minor sand	43.00	50.95	7.95
Sand medium to course grained with occasional gravel	50.95	56.00	5.05
Clay, brown mixed with kankar	56.00	68.15	12.15
Sand , brown fine to medium grained	68.15	75.00	6.85
Clay, brown mixed with kankar	75.00	81.00	6.00
Sand , brown fine to medium grained	81.00	85.00	4.00
Clay, grayish brown sticky mixed with kankar	85.00	115.00	30.00
Sand brown medium to course grained with gravel rounded to sub rounded	115.00	123.00	8.00
Clay, brown mixed with kankar	123.00	141.00	18.00
Sand , brown fine to medium grained	141.00	146.00	5.00
Clay, brown sticky with kankar	146.00	210.00	64.00
Sand , brown fine to medium grained	210.00	222.00	12.00

Clay, grayish brown sticky with minor kankar	222.00	240.00	18.00
Sand , brown fine to medium grained	240.00	245.00	5.00
Clay, grayish brown sticky with minor kankar	245.00	270.55	25.55

Location: Jarwa

Drilling commenced on: 28/12/86

Drilling completed on: 7/1/87

Lithology	Depth Range (mbgl)		Thickness (m)
	From	To	
Surface sand, fine grained with minor clay	0.00	7.04	7.04
Gravels and kankar gravels size 1-5 mm.	7.04	10.90	3.86
Gravels and kankar with minor clay	10.90	14.17	3.27
Gravels and kankar with minor sand and very minor clay	14.17	17.17	3.00
Clay, brown sticky in nature with kankar	17.17	23.40	6.23
Gravels and kankar gravels size 1-5 mm, kankars angular to sub angular in shape	23.40	36.50	13.10
Clay with minor sand and kankars	36.50	39.64	3.14
Clay sticky in nature with kankars	39.64	42.64	3.00
Gravels and pebbles with kankars with very minor medium grained sand	42.64	55.64	12.90
Clay sticky in nature with kankars	55.64	62.61	7.07
Gravels and pebbles	62.61	77.88	15.27
Gravels and pebbles with little kankars with very minor medium grained sand	77.88	91.30	13.42
Clay sticky in nature with kankars	91.30	104.68	13.38
Clay with minor sand with gravels and ferromagnesian minerals	104.68	108.18	3.50
Gravels and kankar with minor medium grained sand	108.18	111.68	3.50
Clay with minor sand with gravel and kankar	111.68	115.06	3.38
Clay yellow in color, sticky in nature	115.06	156.05	40.99

with little kankar			
Gravels and kankars with very minor clay and very minor sand	156.05	159.05	3.00
Clay yellowish brown in color, sticky in nature with kankar	159.05	323.47	164.42
Clay with kankar and very minor sand	323.47	327.52	4.05
Clay sticky in nature with minor sand	327.52	334.11	6.59
Clay with very minor sand and kankars	334.11	337.61	3.50
Clay yellowish brown in color, with minor kankars	337.61	409.00	71.79
Clay with minor sand and kankars	409.00	435.11	26.11
Clay sticky in nature with minor kankars	435.11	438.11	3.50
Clay with minor kankars	438.11	441.65	3.04
Clay with minor kankars and very minor sand	441.65	444.65	3.00
Clay with very minor sand and kankars	444.65	451.60	6.95

Location: Laxmi Nagar (27029'56":82042'31/11)

Depth drilled: 299.72 m. Static water level: 4.64 m.

(b.g.l)

Lithology	Depth Range (mbgl)		Thickness (m)
	From	To	
Surface clay	0.00	5.00	5.05
Clay mixed with kankar, clay of sticky nature and yellow brown colored	5.00	13.00	7.50
Kankar mixed with clay	13.00	16.00	3.00
Clay mixed with kankar, clay sticky and yellow colored	16.00	20.00	4.00
Clay mixed with gravel and kankar	20.00	27.08	7.08
Clay with kankar, clay sticky and plastic in nature, light yellow colored	27.08	79.10	52.11
Kankar mixed with clay	79.10	91.93	12.74
Clay with kankar, clay sticky, light yellow brown colored	91.93	104.03	12.20
Kankar mixed clay	104.03	116.05	12.02
Clay sticky and plastic in nature, of grey color	116.05	119.05	3.00

Kankar with clay mixed	119.05	122.43	3.38
Clay mixed with kankar, clay sticky light yellow colored	122.43	136.47	14.04
Kankar mixed with clay	136.47	143.55	7.08
Kankar mixed with gravel	143.55	147.63	3.06
Clay mixed with kankar, clay sticky natured	147.63	171.61	23.98
Kankar mixed with clay	171.61	175.68	4.07
Clay mixed with kankar, clay sticky and grey colored	175.68	178.68	3.00
Kankar mixed with clay	178.68	192.82	14.14
Clay mixed with kankar, clay sticky light yellowish grey colored	192.82	205.04	12.22
Kankar mixed with clay	205.04	211.30	6.26
Kankar mixed with fine grained sand	211.30	214.42	3.12
Fine sand mixed with clay	214.42	220.87	6.45
clay mixed with kankar,clay sticky and light yellow grey colored	220.87	251.76	30.89
Fine sand mixed with sand and clay	251.76	254.76	3.00
Fine sand mixed with fine sand and clay	254.76	260.82	6.06
Kankar	260.82	264.90	4.08
Clay mixed with kankar, clay sticky light yellow brown colored	264.90	270.49	5.59
Fine sand mixed with kankar and clay	270.49	292.62	22.13
Clay mixed with kankar, clay sticky light yellow grey colored	292.62	299.72	7.10

Location: Chaudhri-Dih (27044′:82011′:631/2)

Depth drilled: 300.00 m.

Lithology	Depth Range (mbgl)		Thickness (m)
	From	To	
Top soil, Silty clay with kankar	0.00	5.30	5.30
Clay yellow	5.30	9.00	3.70
Clay silt with fine sand and kankar	9.00	13.00	4.00
Clay yellow hard with grey clay balls sticky with kankar and course sand	13.00	16.00	3.00
Same with less kankar	16.00	19.06	3.06

Clay hard grayish yellow	19.06	23.06	4.00
Clay as above with fine sand and kankars	23.06	27.14	4.08
Gravels and pebbles with fine sand and kankar mixed some clay	27.14	30.14	3.00
Clay dirty, earthy yellow mixed with pebbles of sandstones, kankar and sand	30.14	34.21	4.08
Clay hard, dirty, earthy yellow mixed with pebbles of sandstones, kankar and sand	34.21	37.21	3.00
Pebbles and granules of grey and light brown color quartz, rounded to sub rounded with fine sand	37.21	41.27	4.07
Sand indurated	41.27	44.27	3.00
Same as above with fine sand and Kankar pieces	44.27	48.33	4.06
Clay and pebbles of fine grained sandstone rounded to sub rounded and flint of grey and light brown color	48.33	51.33	3.00
Granules and pebbles of fine grained sandstone light grey and brown colored, rounded to sub rounded	51.33	55.33	4.00
Granules and pebbles with dirty clay of yellow and earthy nature mixed with kankar	55.33	65.40	10.07
Clay with pebbles consisting of fine grey and dirty earthy colored sandstones with few quartz pieces	65.40	76.56	11.16
Granules and pebbles mixed with kankar and a little fine sand	76.56	79.56	3.00
Clay, sticky, soft, light yellow colored mixed with kankar and few pebbles	79.56	114.50	34.94
Clay, silty, dirty, earthy yellow with very fine sand	114.50	118.57	4.07
Granules and pebbles of very fine grained sand stone, light grey to light brown color with clay and little of sand	118.57	128.64	10.07
Clay, sticky, soft, earthy yellow with pebbles of kankar and sandstone rounded to sub rounded with angular chips	128.64	135.08	6.44

Sandy clay with pebbles of very fine grained sand stone, grey and light brown colored, rounded to sub rounded with angular pieces kankar	135.08	141.13	6.05
Clay, soft, silty, dirty, earthy yellow mixed with kankar	141.13	147.27	6.14
Sandy clay sand fine to course grains consisting of quartz, smaller pieces and of very fine grained sand stone of grey to light brown colored, mixed with kankar	147.27	150.37	3.10
Clay, earthy yellow hard sticky, with kankar	150.37	163.29	12.92
Clay silty and sandy with pebbles of sandstone and kankar	163.29	169.35	6.06
Clay mixed with granules and pebbles of sandstone and kankar with sand	169.35	175.28	5.93
Clay sticky and harder with few granules and of sandstone rounded to sub angular, siltstone grey and light brown color	175.28	207.09	31.81
Clay soft generally earthy yellow colored sandy with gravels and pebbles, sub angular to sub rounded	207.09	221.23	14.14
Clay, dirty earthy yellow soft sticky with lesser granules and pebbles	221.23	227.23	6.26
Clay lighter grey colored hard and silty with some granules and pebbles	227.23	248.79	21.30
Clay sandy sticky and light grey color with granules and pebbles of sub angular to sub rounded sand stone	248.79	255.22	6.43
Granules and pebbles of sub angular to sub rounded sand stone, silt stone fine sand with silt clay	255.22	268.12	12.90
Clay earthy yellow sticky with silt and some pebbles of sub angular to sub rounded sand stone siltstone	268.12	289.87	21.75
Clay earthy grey to yellow colored sticky with silt and kankar	289.87	299.94	10.07

Annexure-V

BLOCKWISE ESTIMATION OF MONSOON RECHARGE IN BALRAMPUR DISTRICT

BALRAMPUR, U.P

(ON WATER LEVEL FLUCTUATION APPROACH) MCM

Sl. No.	Blocks	Area in Km^2	Rise in water table (m)	Specific yield %	Monsoon recharge (MCM) 3*4*5	Monsoon ground water draft (MCM)	Monsoon canal Seepage (MCM)	Return flow from ground water irrigation (monsoon) (MCM)	Return flow from surface water irrigation (monsoon) (MCM)	Normal monsoon rainfall (mm)	Monsoon rainfall for the year (mm))	Monsoon recharge (mcm) after normalization due to rainfall
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	Rehra Bazaar	235.83	0.78	10.0	18.39	21.78	-	6.53	0.75	1212.9	971	41.83
2	Sridutt gunj	189.82	1.83	18.1	62.87	15.89	-	4.77	2.77	1212.9	971	91.73
3	Utraula	168.22	1.99	13.2	44.19	12.88	-	3.86	1.55	1212.9	971	66.08
4	Gaindas Buzurg	162.51	1.84	12.0	35.88	11.96	-	3.59	0.27	1212.9	971	55.21
5	Pachperwa	559.15	0.94	10.0	52.56	6.20	1.74	1.86	0.52	1212.9	1087.4	63.21
6	Gainsari	514.45	1.82	12.1	113.29	9.31	4.01	2.79	0.02	1212.9	1087.4	133.17
7	Balrampur	451.10	1.24	13.8	77.19	25.54	-	7.66	6.48	1212.9	1087.4	105.29
8	Tulsipur	496.94	1.13	12.1	67.95	8.95	0.662	2.69	3.19	1212.9	1087.4	82.33
9	Haraiya Satgharwa	597.47	1.50	10.0	89.62	5.97	0.300	1.79	0.03	1212.9	1087.4	104.59
		-	-	-	**561.94**	-	-	-	-	-	-	**743.44**
					S	Dw	Rs	Rigw	Ris		S+Dw-Rs-Ris-Rigw) * NF+Rs+Ris	

Annexure-VI

NON-MONSOON RAINFALL RECHARGE (RAINFALL INFILTRATION METHOD) IN BALRAMPUR DISTRICT, U.P

Sl. No.	Blocks	Area in Km^2	Non-Monsoon rainfall during the year 1998	Rainfall infiltration index in fraction	Non-Monsoon rainfall Recharge (MCM) 3*4*5/1000
1	Rehra Bazaar	235.83	90.3	0.25	5.32
2	Sridutt gunj	189.82	90.3	0.25	4.29
3	Utraula	168.22	90.3	0.25	3.80
4	Gaindas Buzurg	162.51	90.3	0.25	3.67
5	Pachperwa	559.15	121.0	0.20	13.53
6	Gainsari	514.45	121.0	0.20	12.45
7	Balrampur	451.10	121.0	0.20	10.92
8	Tulsipur	496.94	121.0	0.20	12.03
9	Haraiya Satgharwa	597.47	121.0	0.20	14.46
		-	-	-	80.47

Annexure-VII

MONSOON RAINFALL RECHARGE AS PER AD-HOC NORMS AND CHECK BY WATER LEVEL FLUCTUATION BALRAMPUR DISTRICT, U.P

Sl. No.	Blocks	Area in Km^2	I.M.D. Normal Monsoon Rainfall (mm)	Rainfall Infiltration Recharge index, (in fraction)	Monsoon rainfall recharge adhoc 3*4*5/1000 (MCM)	Monsoon Recharge water level fluctuation normalization (MCM)	Percentage of variation of Col. 6&7 7-6/6*100	Checked and adopted monsoon recharge (MCM)
1	Rehra Bazaar	235.83	1212.9	0.25	71.51	41.83	-41.50	41.83 WTF
2	Sridutt gunj	189.82	1212.9	0.25	57.56	91.73	59.36	57.56 RA
3	Utraula	168.22	1212.9	0.25	51.01	66.08	29.54	51.01 RA
4	Gaindas Buzurg	162.51	1212.9	0.25	49.28	55.21	12.03	55.21 WTF
5	Pachperwa	559.15	1212.9	0.20	135.64	63.21	-53.40	63.21 WTF
6	Gainsari	514.45	1212.9	0.20	124.80	133.17	6.71	133.17 WTF
7	Balrampur	451.10	1212.9	0.20	109.43	105.29	-3.78	105.29 WTF
8	Tulsipur	496.94	1212.9	0.20	120.55	82.33	-31.70	82.33 WTF
9	Haraiya Satgharwa	597.47	1212.9	0.25	181.17	104.59	-42.27	104.59 WTF
		-	-	-	-	-	-	**694.20**

Annexure-VIII

POTENTIAL RECHARGE IN WATER LOGGED AND SHALLOW WATER TABLE AREAS, BALRAMPUR DISTRICT, U.P

Sl. No.	Blocks	Depth to water level in m.b.g.l. (Pre-monsoon)	Area in Km^2 (a)	Average depth to water level (b)	Specific yield in the zone of water level fluctuation expressed as fraction.	Potential ground water resources (5-b)*a*Sp.Yield (MCM)
1	Rehra Bazaar	<5.00	235.83	3.33	0.10	39.38
2	Sridutt gunj	<5.00	189.82	3.40	0.181	54.97
3	Utraula	<5.00	168.22	3.72	0.132	28.42
4	Gaindas Buzurg	<5.00	162.51	3.66	0.12	26.13
5	Pachperwa	<5.00	559.15	2.30	0.10	95.05
6	Gainsari	<5.00	393.42	3.11	0.121	89.97
7	Balrampur	<5.00	451.10	3.45	0.138	96.49
8	Tulsipur	<5.00	455.53	3.24	0.121	97.01
9	Haraiya Satgharwa	<5.00	148.02	4.83	0.10	2.52
		-	-	-	-	529.94

Annexure-IX

GROSS ANNUAL RECHARGE IN BALRAMPUR DISTRICT BALRAMPUR, U.P

S. No.	Blocks	Adopted monsoon recharge (MCM)	Monsoon canal seepage (MCM)	Monsoon return flow from S.W.I (MCM)	Gross monsoon recharge 3+4+5 (MCM)	Non-monsoon recharge (MCM)	Seepage from canal during Non-monsoon (MCM)	Return flow from irrigation field during Non monsoon (MCM)	Recharge from influent river (MCM)	Recharge from tanks (MCM)	Ground water potential of shallow water table (MCM)	Gross ground water resources 6+8+9+10 +11+12 (MCM)
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Rehra Bazaar	41.08	-	0.75	41.83	5.32	-	11.41	-	0.22	39.38	98.16
2	Sridutt gunj	54.79	-	2.77	57.56	4.29	-	0.80	-	0.34	54.97	117.96
3	Utraula	49.46	-	1.55	51.01	3.80	-	0.68	-	0.46	28.42	84.37
4	Gaindas Buzurg	54.94	-	0.27	55.21	3.67	-	9.65	-	0.19	26.13	94.85
5	Pachperwa	60.95	1.74	0.52	63.21	13.53	2.06	3.80	-	0.33	95.05	177.98
6	Gainsari	129.14	4.01	0.02	133.17	12.45	4.74	6.31	-	0.28	89.97	246.92
7	Balrampur	98.81	-	6.48	105.29	10.92	-	3.81	-	0.69	96.49	217.20
8	Tulsipur	78.48	0.662	3.19	82.33	12.03	0.441	9.16	-	0.34	97.01	201.31
9	Haraiya Satgharwa	104.26	0.300	0.03	104.89	14.46	0.15	2.82	-	0.33	2.52	124.87
		-	-	-	-	-	-	-	-	-	529.94	1363.62

Annexure-X

GROUND WATER DRAFT THROUGH VARIOUS STRUCTURES (MCM) IN DISTRICT BALRAMPUR

Sl. No.	Blocks	Ground water draft by state tube wells		Ground water draft by private tube wells		Ground water draft by pumping sets		Ground water draft by Persian wheels		Ground water draft by dug wells		Gross draft annual (MCM)	Monsoon draft 25% of gross draft (MCM)	Non-Monsoon draft 75% of gross draft (MCM)
		No.	Draft@ 0.128 (MCM)	No.	Draft@ 0.022 (MCM)	No.	Draft@ 0.014 (MCM)	No.	Draft@ 0.092 (MCM)	No.	Draft@ 0.0055 (MCM)			
1	Rehra Bazaar	24	3.072	73	1.606	5864	82.096	24	0.2208	25	0.1375	87.1323	21.7831	65.3492
2	Sridutt gunj	34	4.352	88	1.936	4060	56.840	26	0.2392	37	0.2035	63.5707	15.8927	47.6780
3	Utraula	19	2.432	25	0.550	3428	47.992	37	0.3404	38	0.209	51.5234	12.8809	38.6425
4	Gaindas Buzurg	14	1.792	33	0.726	3196	44.744	38	0.3496	41	0.2255	47.8371	11.9593	35.8778
5	Pachperwa	03	0.384	60	1.320	1629	22.806	19	0.1748	20	0.11	24.7948	6.1987	18.5961
6	Gainsari	54	6.912	13	0.286	2124	29.736	20	0.1840	21	0.1155	37.2325	9.3034	27.9251
7	Balrampur	74	9.472	273	6.006	6150	86.100	39	0.3588	41	0.2255	102.1623	25.5406	76.6217
8	Tulsipur	49	6.272	18	0.396	2052	28.728	26	0.2392	27	0.1485	35.7837	8.9459	26.8378
9	Harriya Satgharwa	02	0.256	07	0.154	1653	23.142	23	0.2116	24	0.132	23.8956	5.9739	17.9217
		273	34.944	590	-	-	-	-	-	-	-	473.91	118.48	355.43

Annexure-XI

GROUND WATER BALANCE AND CATEGORIZATION OF BLOCKS OF BALRAMPUR DISTRICT

BASED ON THE LEVEL OF GROUND WATER DEVELOPMENT-1998

Sl. No.	Blocks	Gross annual ground water resource (MCM)	Annual utilizable resource for irrigation 85% of Col.2 (MCM)	Gross annual ground water Draft (MCM)	Annual ground water draft 70% of 4 (MCM)	Ground water balance 3-5 (MCM)	Level of ground water development on date 5/3*100	Annual rate of ground water development % assumed	Net ground water draft at years 5 col. 5*(1+5+8)/100	Level of ground water development at 5 years % 9/3*100	Categorization
	1	2	3	4	5	6	7	8	9	10	11
1	Rehra Bazaar	98.16	83.44	87.13	60.99	22.45	73.09	2%	67.089	80.40	Grey
2	Sridutt gunj	117.96	100.27	63.57	44.50	55.77	44.38	2%	48.95	48.82	White
3	Utraula	84.37	71.71	51.52	36.06	35.65	50.29	2%	39.67	55.32	White
4	Gaindas Buzurg	94.85	80.62	47.84	33.49	47.13	41.54	2%	36.839	45.69	White
5	Pachperwa	177.98	151.28	24.79	17.35	133.93	11.47	2%	19.085	12.62	White
6	Gainsari	246.92	209.88	37.23	26.06	183.82	12.42	2%	28.666	13.66	White
7	Balrampur	217.20	184.62	102.16	71.51	113.11	38.73	2%	78.661	42.61	White
8	Tulsipur	201.31	171.11	35.78	25.05	146.06	14.94	2%	27.555	16.10	White
9	Harriya Satgharwa	124.87	106.14	23.90	16.73	89.41	15.76	2%	18.403	17.34	White
		1363.62	1159.08	473.90	331.74	827.33	-	-	-	-	-

Annexure-XII

CHEMICAL ANALYSIS OF GROUND WATER FROM DIFFERENT BLOCKS OF BALRAMPUR

Sl No	Location	DWL (In Ft)	Blocks	Chloride (mg/l)	Hardness (mg/l)	Nitrate (mg/l)
01	Lalpur Labuddi	13	Haraiya Sat	48	210	88
02	Bahadurgunj Bazar	13	Haraiya Sat	126	265	83.6
03	Chaudhridih	23	Haraiya Sat	38	265	88
04	Badaulia Village	23	Haraiya Sat	44	280	79.20
05	Nakti Nala Village	15	Tulsipur	38	265	74.80
06	Dhandhra Village	08	Tulsipur	56	280	88
07	Palapur	17	Tulsipur	133	425	>88
08	Jarwa Eidgah	17	Gainsadi	50	250	83.6
09	Gainsadi Bazar 1	10	Gainsadi	182	465	>88
10	Gainsadi Bazar 2	10	Gainsadi	36	265	88
11	Basantpur	14	Gainsadi	38	265	83.6
12	Purshottampur	15	Gainsadi	97	355	83.6

	(Jeetpur)					
13	Bishunpur Tantanwa	15	Panchperwa	40	235	83.6
14	Pachperwa	17	Panchperwa	54	250	>88
15	Sisai	14	Balrampur	44	235	70.4
16	Bhagwati Gunj	19	Balrampur	137	390	83.6
17	Shekhui kalan	17	Balrampur	46	175	83.6
18	Gaura Chauraha	10	Balrampur	100	355	88
19	Mallhipur	17	Balrampur	56	325	88
20	Sridutt Gunj	16	Sridutt gunj	158	465	>88
21	Mahdeya Village	10	Sridutt gunj	48	108	88
22	Dhusua	25	Utraula	66	115	70.4
23	Chirkutya peer Village	17	Utraula	56	108	88
24	Baurihar	12	Utraula	42	90	83.6
25	Narainpur-Saadullah Nagar Road	10	Gaindas Buzurg	76	250	>88
26	Rehra Bazaar	20	Rehra	85	280	79.20
27	Fatehpur	25	Rehra	97	325	74.80
28	Kotwa Dargah	20	Rehra	166	355	>88

Annexure-XIII

MICROBIOLOGICAL ANALYSIS OF GROUND WATER FROM DIFFERENT BLOCKS OF BALRAMPUR

Sl No	Location	Blocks	Total No. of colonies	Size	Colour
01	Lalpur Labuddi	Haraiya Sat	78	Small+Big	Gray
02	Bahadurgunj Bazar	Haraiya Sat	65	Small+Big	Light Yellow
03	Chaudhridih	Haraiya Sat	195	Small+Big	Brown
04	Badaulia Village	Haraiya Sat	267	Small	Gray
05	Nakti Nala Village	Tulsipur	346	Big	Light Gray
06	Dhandhra Village	Tulsipur	517	Small+Big	Yellow
07	Palapur	Tulsipur	883	Small+Big	Light Brown
08	Jarwa Eidgah	Gainsadi	210	Big	Yellow
09	Gainsadi Bazar 1	Gainsadi	817	Small+Big	Yellow+Brown
10	Gainsadi Bazar 2	Gainsadi	1234	Small+Big	Yellow+Gray
11	Basantpur	Gainsadi	712	Small	Brown
12	Purshottampur (Jeetpur)	Gainsadi	510	Small+Big	Brown+Yellow
13	Bishunpur Tantanwa	Panchperwa	305	Small	Light Yellow
14	Pachperwa	Panchperwa	608	Small+Big	Light Yellow + Gray
15	Sisai	Balrampur	82	Small	Yellow

16	Bhagwati Gunj	Balrampur	73	Small+Big	Yellow+Gray
17	Shekhui kalan	Balrampur	115	Small+Big	Brown+Gray
18	Gaura Chauraha	Balrampur	53	Big	Gray
19	Mallhipur	Balrampur	46	Big	Light Yellow
20	Sridutt Gunj	Sridutt gunj	211	Small+Big	Brown
21	Mahdeya Village	Sridutt gunj	36	Small	Light Gray
22	Dhusua	Utraula	416	Small+Big	Gray
23	Chirkutya peer Village	Utraula	118	Small+Big	Yellow
24	Baurihar	Utraula	96	Small+Big	Brown
25	Narainpur-Saadullah Nagar Road	Gaindas Buzurg	184	Small+Big	Yellow+Brown
26	Rehra Bazaar	Rehra	34	Small	Yellow
27	Fatehpur	Rehra	45	Small+Big	Yellow+Gray
28	Kotwa Dargah	Rehra	58	Big	Light Yellow

Annexure-XIV

pH SCALE

Concentration of Hydrogen Ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH= 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Gastric Acid Vinegar
10,000	pH = 3	Grapefruit, Orange Juice, Soda
1,000	pH = 4	Acid rain Tomato Juice
100	pH = 5	Soft drinking water Black Coffee
10	pH = 6	Urine Saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Sea water
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake Milk of Magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH = 13	Bleaches Oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

Annexure-XV

PAPER SUBMITTED TO INDIAN WATER WORKS ASSOCIATION

TITLE: Nitrate contamination of shallow aquifers of Balrampur district, Uttar Pradesh: A case of urbanization

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Abstract

Balrampur district of Uttar Pradesh is a classic example where there is development of urbanized condition due to improvement of socio-economic condition of the masses. People opted for latrines instead of agricultural fields for disposal of night soil. This led to a situation where improperly designed soak pits and septic tanks are constructed. There is gradual seepage of sewer material to the shallow aquifers of region. The groundwater has become highly contaminated with nitrate as a result. This process gets contaminated during monsoon. Methemoglobinaemia in infants and cancer in adults are the effects of this concentration.

Key words: Balrampur, septic tank, shallow aquifers, urbanization, Methemoglobinaemia

1. Introduction

Ninety-five percent of all fresh water on earth is ground water. The quality of groundwater reflects inputs from the atmosphere, from soil and water-rock reactions (weathering), as well as from pollutant sources such as mining, land clearance, agriculture, acid precipitation, domestic and industrial wastes. Groundwater is almost globally important for human consumption, and changes in quality can have serious consequences. The indicators that are important to understand the pollution of groundwater are: Salinity, Acidity and Redox status, Radioactivity, Agricultural pollution, Mining pollution and Urban pollution. Among all these indicators, Urbanization has dramatic effects on groundwater systems with ramifications for water management. Some water-quality issues that relate to urban development are: Population growth, Erosion and Sedimentation, Urban Runoff, Nitrogen, Phospohorous, Sewage Overflows, Waterborne Pathogens, Toxic Metals, Pesticides and PCBs and Chloradane in Fish (U.S. Geological Survey Water-Resources Investigations Report 96-4302, 1996). Urbanisation in India has encouraged the migration of people from villages to the urban areas. This has given rise to a number of environmental problems such as water supply, wastewater generation and its collection, treatment and disposal in urban areas. In most cases wastewater is let out untreated and it either percolates into the ground and in turn contaminate the groundwater or is discharged into the natural drainage system causing pollution in downstream areas.

In Balrampur district of Uttar Pradesh, a population growth from 4 lacs to 11 lacs has taken place. The betterment of socio-economic condition of the masses has led to the development of better-urbanized condition. Earlier people had kuchha houses and there was no toilet facility. People used agricultural fields for night soil disposal. However, due to enhancement

of the socio-economic condition and awareness towards health and hygiene, improperly designed soak pits and septic tanks have occupied most of the areas in Balrampur. It has lead to plethora of problems. The night soil pollutes ground water when it directly goes into the water table or through their overflow the sewage water is collected in the pond by virtue of which the polluted water of pond further pollutes ground water as recharge (Yates, 1985; Wakida and Lerner, 2005). People in these areas have mostly been using hand pumps for drinking water, which has not been changed for a long time. Since the ground water is polluted and hand pumps are installed at shallow level therefore, the chances of ground water contamination leading to the occurrence of many water borne diseases like, Cholera, Typhoid, Methemoglobinaemia i.e. Blue Baby Syndrome, Jaundice, etc is high in these areas. Therefore, the aim of this paper is to make assessment and characterization of groundwater contamination and its impact on groundwater quality and human health due to the possible spread of water borne diseases in Balrampur district of Uttar Pradesh. Apart from it there is also a need to find out some possible remedial measures and evolving sustainable strategies that can be applied to check the ground water contamination from improper design of Septic Tanks and spread of water borne diseases in the district. Findings of the study can also be used as a guideline in several other parts of India, which are facing similar problems.

2. Aims and Objectives

The aims and objectives include the following points:

9. Detailed characterization of hydro geological framework of the study area through analysis of available information and detailed field inventory.
10. To study the impact of wastewater originating from septic tanks on the quality of ground water.

11. To ascertain the kind of water borne diseases in the locality and its spatial distribution.

3. Methodology

The study area will be studied following the methodology given below:

a) The area will be studied both in the micro level and macro level.

b) The bore wells will be located between the soak pits and the hand pumps.

c) The hand borings will be done at a depth of water level, which is 30 feet. The sites for hand boring will be chosen in such a way that the hand pumps and septic tanks are surrounded by these borings.

d) The water samples will be collected from the shallow and deep hand pumps.

e) The parameters like pH, TDS, hardness, chloride and nitrate have to be analyzed to get an idea on the extent of contamination of groundwater from shallow and deep hand pumps.

4. Analysis and Discussion

Balrampur district (Fig. I) has a total area of 2883 square kilometer and lies at an elevation of 105m above the mean sea level. The area is sloping from north to south and then towards east. The area is spotted with jheels, ditches, ponds, canals, rivers upland hilly areas. Geologically, the study area forms a part of the northern most fringe of Indo-Gangetic plane. Hence the area lies between Himalayan fold mountain chain in the north and stable peninsular block in the south. The plane is formed by the detritus and alluvium brought down by the Himalayan rivers from the north and the peninsular rivers from the south. Previously the area was a depression. From Upper Eocene onwards the sediments gradually fill up this trough. The alluvial deposits of clay, silt and sand occur with occasional gravel, calcareous nodules and

organic matter (8-15m below the ground level). The alluvial deposit is further classified into older or bhangar and newer or khaddar (locally called kachhar). The physiographic division is

given in Fig. II. The distribution of different soil types in the area is shown in Fig. III. The water level occurs mainly below the clay and silt formations and within medium to coarse-grained sand (Fig. IV).

The deposition of aquifer system has extensively been earlier. The northern belt ranging from 25 to 75 km. in width (bordering to Nepal) is characterized by thick clay, Clay with Kankar and a few thin sandy horizons. This is evident by a number of exploratory tube wells drilled by Central ground Water Board. The water level fluctuation in the study area is tabulated in Table I.

Systematic well inventory of dug wells, shallow wells and deep tube wells has been carried out and relevant data were collected to study the general groundwater condition, behavior of the water table and its occurrence and the movement in the area. In all the 28 key wells were fixed to monitor the seasonal water label fluctuation in the area and water samples were collected. Ground water occurs under water table condition in upper aquifers. It is tapped mostly by open wells and Shallow tube wells. The depth of water level ranges from 1.52 m to 10.47 mbgl during pre monsoon and 1.25 to 5.29 mbgl in post monsoon period. The depth to water level map is shown in Fig. V.

The chloride, nitrate contents along with the hardness data from different blocks is listed in Table II. As per the standards prescribed in IS: 10500 the Nitrate of potable water should be in range of 10-45 mg/l. Thus comparing the obtained results with the available standards it is found that the Nitrate in water available in Balrampur area is much higher than the permissible limits.

The most basic, unavoidable cause of nitrate contamination is that when biological materials decompose, most of the nitrogen in the materials ends up as nitrates. Nitrate is also very soluble, and moves with the flow of water -- from the source into the groundwater, and eventually into an aquifer.

Nitrate thus poses a threat to human health. Particularly in rural, private wells, incidence of methemoglobinemia appears to be the result of high nitrate levels. Methemoglobinemia, or blue baby syndrome, robs the blood cells of their ability to carry oxygen. Ruminant animals (such as cows and sheep) and infant monogastrics (such as baby pigs and chickens) also have nitrate-converting bacteria in their digestive systems. For this reason, nitrate poisoning affects them the same way it affects human babies. Chronic consumption may also cause some cancer. It also leads to reduced vitality, increased stillbirth and birth weight. There is an increased risk of bladder cancer. Poor sanitary condition may result in outbreak of other water borne diseases.

Microbiological analysis has been done with INOVA 10B water tasting kit, designed for the examination of bacteriological parameters in drinking water using Membrane Filter technique (MF technique) in highly sophisticated environment.

The nirate map in the depth of 10 to 27 m below ground level is is shown in Fig.VI. Fig. VII depicts the nitrate concentration at a depth range of 35 m below ground level. The presence of high nitrate concentration matches well with the occurrence of bacteria in the area (Fig. VIII).

The septic tanks in the area are made randomly and in totally unplanned manner. Septic systems (also known as onsite wastewater disposal systems) are used to treat and dispose of sanitary waste. Improperly used or operated septic systems can be a significant source of ground water contamination that can lead to waterborne disease outbreaks and other adverse health effects. The bacteria, protozoa, and viruses found in sanitary wastewater can cause numerous diseases, including gastrointestinal illness, cholera, hepatitis A, and typhoid. On the

other hand, when properly sited, designed, constructed, and operated, they pose a relatively minor threat to drinking water sources.

There are too many septic tanks occurring in a small area. The drainage network is poor and too many latrines are there in a very small stretch. Gradual seepage from numerous septic tanks accumulates and reaches the groundwater. This is explained well from the Fig. IX. From the figure, it is well understood that the groundwater in the shallow aquifers is highly contaminated due to unplanned soak pits. Since the area receives a very heavy rain during the monsoon, the contamination process is accelerated during this period.

The nirate map in the depth of 10 to 27 m below ground level is is shown in Fig.VI. Fig. VIIdepicts the nitrate concentration at a depth range of 35 m below ground level. The presence of high nitrate concentration matches well with the occurrence of bacteria in the area (Fig. VIII).

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Thus the review has shown that the major sources of N in rural aquifers are mostly related to wastewater disposal (Somasundaram,1993).

Summary and Conclusion

The major portion of water supply in villages comes from groundwater. From depth to water level data, the occurrence of shallow aquifers is confirmed in the region. The quality of groundwater is a very important issue in villages. The quality of groundwater is not taken as a

serious issue in these areas and as a result the untreated groundwater is the root cause for some of the major health hazards in the villages. The present study area Balrampur is a case of urbanization of village due to betterment of socio-economic condition of the masses. People opted for improperly designed septic tanks and soak pits over a very small area. The septic tanks are not always constructed in the downstream of the flow of water, as result when water is withdrawn there is a chance of contamination of the groundwater and sewer materials. This has a direct impact on the groundwater quality. Contamination is accelerated during monsoon. This is the main source of nitrate contamination in the area. The older septic tanks are not cleaned regularly and they are let to overflow. The concentration of nitrate in groundwater is higher than the permissible limit. Methemoglobinaemia in infants and cancer in adults are the effects of this concentration.

To keep the Groundwater free from contamination free from nitrate contamination, the following recommendations are made:

- Since long, waste disposal system appears to be inadequate/improper resulting in nitrate contamination in ground water. This is now high time to take special attention to rectify the mistakes and to develop proper sewerage system immediately. The position of latrines should be well planned. The septic tanks should be constructed in the downstream side of the water flow to avoid contamination when the water is withdrawn.

- The water quality should be monitored on a regular basis so as to prevent the growing crisis.

- Unlined drains carrying sewerage/effluents are the potential sources of contamination of ground water and therefore should be lined urgently.

- Rainwater during monsoon period can be fruitfully utilized for recharging ground water by various techniques. This will not only augment the ground water resources but also dilute and flush the polluted area gradually.

- Available technologies for the treatment of water for nitrates should be evaluated and cost effective and eco-friendly technologies adopted. Root Zone Treatment System can be adopted to treat sludge water. With RZTS Treatment of wastewater is easily possible & affordable because it involves low capital, operation & maintenance cost.

- Awareness among the public and other NGOs about the adverse effects of chemical contaminants should be encouraged.

Acknowledgement.

The authors are grateful to Indian National Committee On Hydrology for supporting the project financially. They pay their sincere gratitude towards the officials of these organizations especially Dr. Ramakar Jha (Scientist E 1 & Member Secretary INCOH), Mr. Omkar Singh (Scientist E1), Dr. Masood Husain (Director R&D Division MoWR) and Dr. S C Mehta (Asstt. Director R&D Division MoWR) for their kind support.

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Wakida, Fernando T., Lerner, David N. 2005. Non-agricultural sources of groundwater nitrate: a review and case study. Water Research, 39, 3–16.

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Table I. Range of Seasonal Water Level Fluctuations and Average Fluctuation

Blocks	Range of Water Level Fluctuation (m)		Average Fluctuation (m)
	From at Place	To at Place	
HARAYA SATGHARWA	0.68 Bankatwa	2.31 Harriya	1.495
BALRAMPUR	-0.58 Jua	2.17 Baraipur	1.238
TULSIPUR	-0.31 Tulsipur	2.54 Narainpur	1.131
GAINSARI	0.32 Bhojpur	5.36 Jarwa	1.816
PACHPERWA	-0.34 Pachperwa	1.69 Ram Nagar	0.940
SHRI DUTT GANJ	0.93 Pachautha	2.30 Sridutt gang	1.828
UTRAULA	1.31 Pipra ekdanga	2.4 Bajar Mudwa	1.985
GAINDAS BUZURG	1.55 Pindia Khurd	2.32 Itai Rampur	1.835
REHRA BAZAR	-1.37 Intwa	1.97 Sadullah Nagar	0.775

Table II. Chemical Analyses of groundwater from different blocks of Balrampur district

Sl No.	Location	Ph	TDS (mg/l)	Chloride (mg/l)	Hardness (mg/l)	Nitrate (mg/l)
01	Dahiroa Talab	6.95	230	122	108	66
02	Chote House	6.76	310	72	210	61.6
03	Zahiruddin Chacha	6.85	280	41	195	48.4
04	North Tab Dhareoa	6.9	420	78	265	70.4
05	Imadul Chacha	7.26	400	85	390	83.6
06	Talab Dwar Kathra	6.54	90	122	70	26.4
07	Robin Bhai	6.71	560	85	425	83.6
08	Chote House	7.9	310	62	550	66
09	Hafiz Bhai	8.28	390	126	550	83.6
10	South Talab Dahoreao	7.67	380	103	550	79.2

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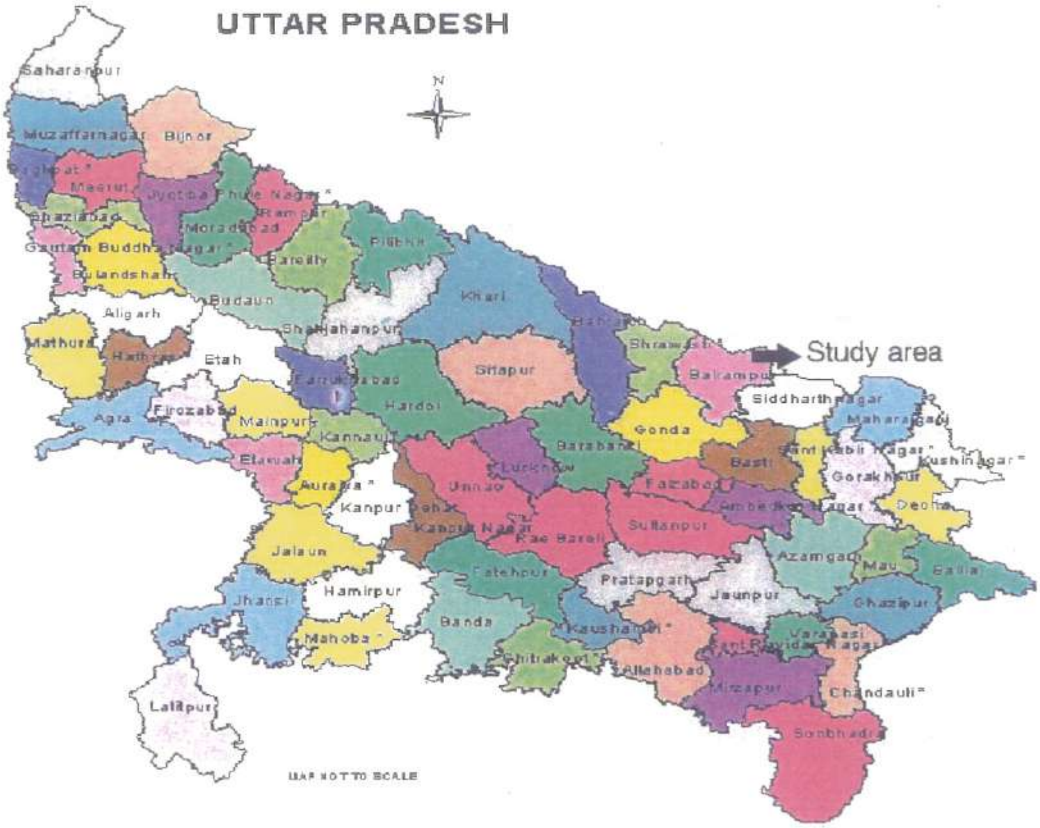


Fig. I

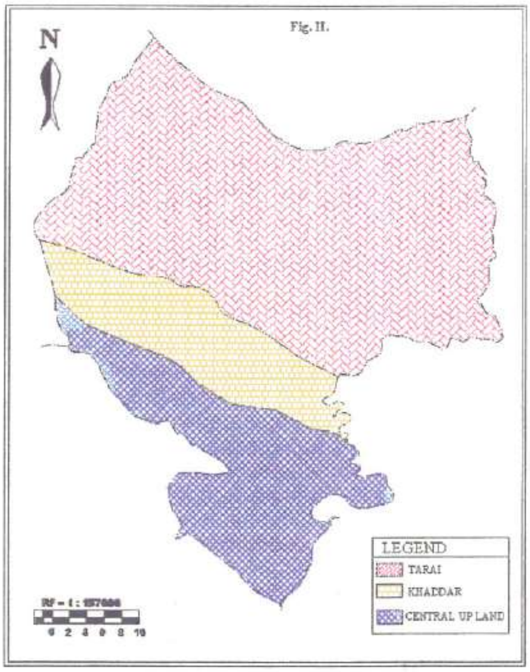


Fig. II.
N
LEGEND
TARAI
KHADDAR
CENTRAL UP LAND

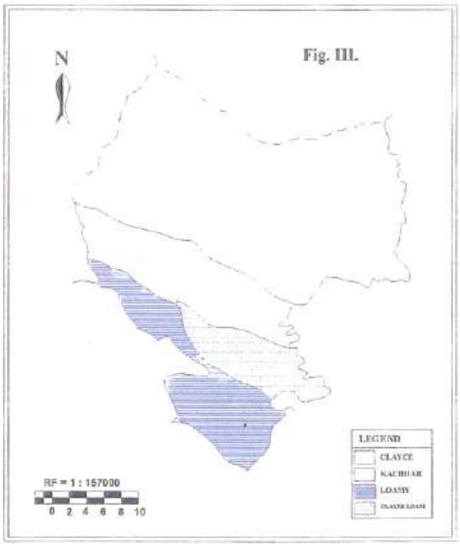

N
Fig. III.
LEGEND
KACHHAR
LOAMY
RF = 1 : 157000
0 2 4 6 8 10

Fig. IV

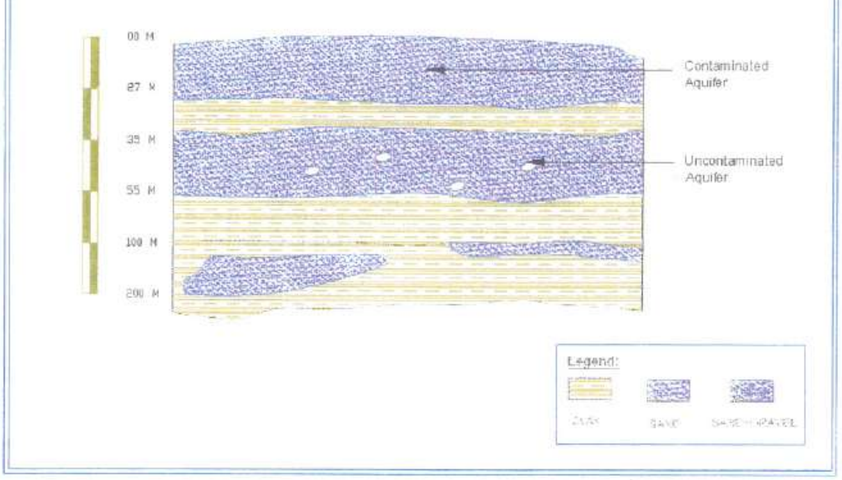
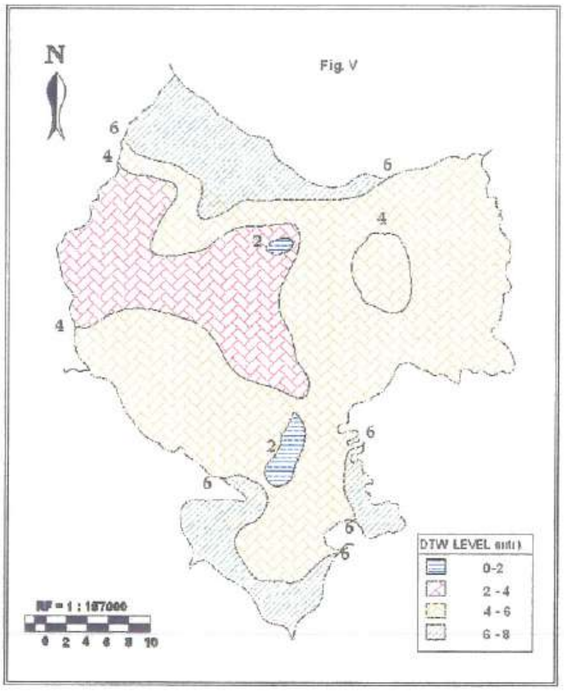

00 M
27 M
35 M
55 M
100 M
200 M
Contaminated Aquifer
Uncontaminated Aquifer
Legend:
SAND

Fig. V


N
6
4
2
DTW LEVEL
0-2
2 - 4
4 - 6
6 - 8
0 2 4 6 8 10

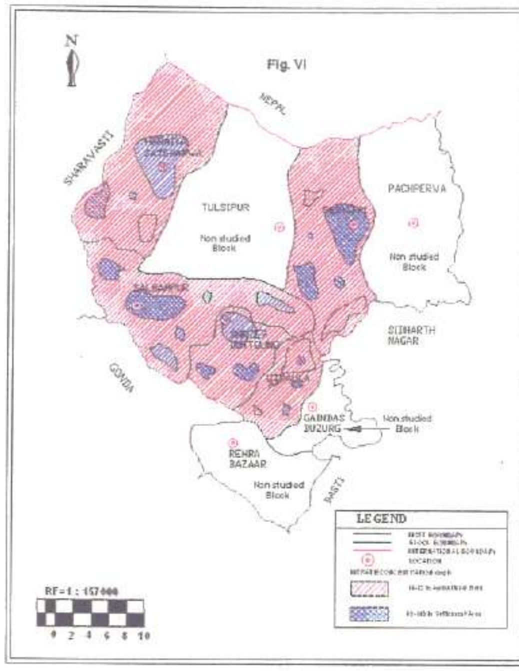
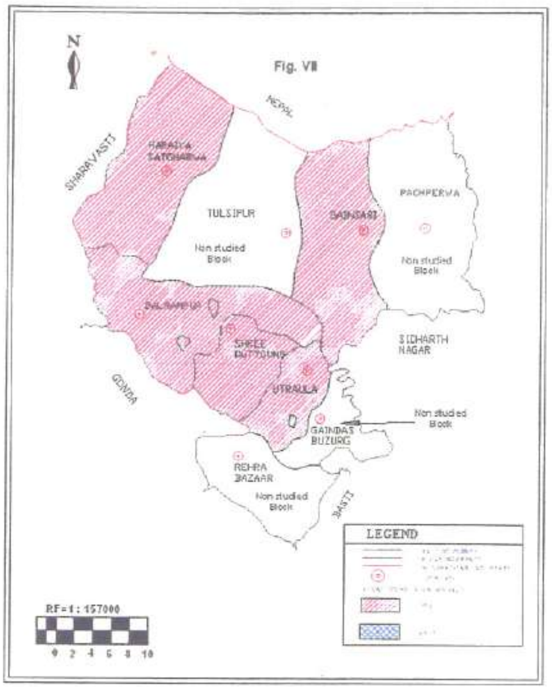
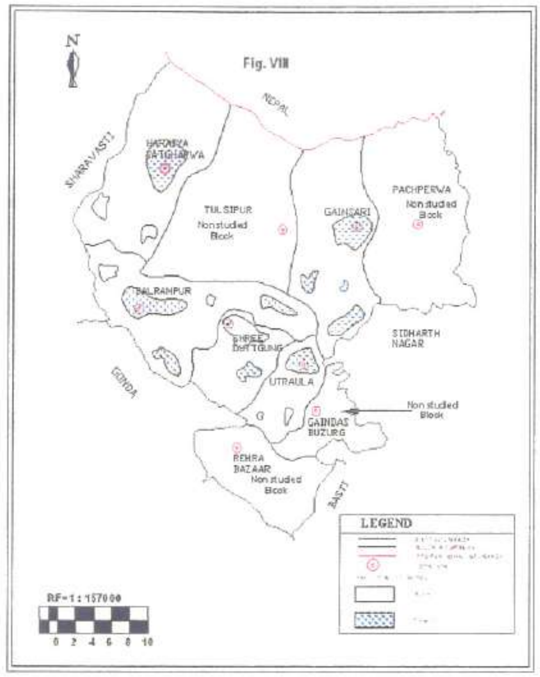


Fig. VI
N
NEPAL
SHRAVASTI
TULSIPUR
Non studied
Block
PACHPERVA
Non studied
Block
SIDHARTH
NAGAR
GONDA
GAINDAS
BUZURG
Non studied
Block
REHRA
BAZAAR
Non studied
Block
BASTI
LEGEND
RF=1 : 157000
0 2 4 6 8 10


N
Fig. VII
NEPAL
SHARAVASTI
TULSIPUR
Non studied
Block
PACHPERVA
Non studied
Block
SIDHARTH
NAGAR
GONDA
SHREE
DUTTGUNJ
UTRAULA
Non studied
Block
GAINDAS
BUZURG
REHRA
BAZAAR
Non studied
Block
BASTI
LEGEND
RF=1:157000
0 2 4 6 8 10


N
Fig. VIII
NEPAL
SHARAVASTI
HARAIYA SATGHARWA
TULSIPUR
Non studied Block
GAINSARI
PACHPERWA
Non studied Block
BALRAMPUR
SHREE DATTGUNG
UTRAULA
SIDHARTH NAGAR
GONDA
Non studied Block
GAINDAS BUZURG
REHRA BAZAAR
Non studied Block
BASTI
LEGEND
RF=1:157000
0 2 4 6 8 10

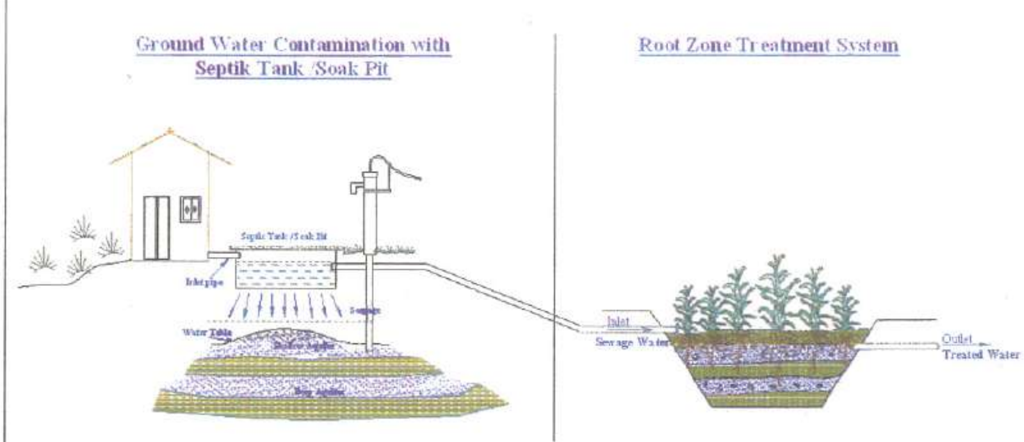

Ground Water Contamination with Septik Tank /Soak Pit
Root Zone Treatment System
Septic Tank / Soak Pit
Inlet pipe
Seepage
Water Table
Inlet
Sewage Water
Outlet
Treated Water

Fig. IX

Annexure-XVI

SURVEY OF THE PRIMARY HEALTH CLINICS, DISTRICT BALRAMPUR

सामुदायिक स्वास्थ्य केन्द्रों की रोगी उपचार सम्बन्धी मूलभूत सूचनायें जनपद बलरामपुर

सामु0स्वा0 केन्द्र का नाम	2003						2004					
	वाह्य रोगी नये	भर्ती रोगी	शैय्या उप0 दर	एक्स रे की संख्या	पैथालोजी जाँच की संख्या	ऑपरेशन की संख्या	वाह्य रोगी नये	भर्ती रोगी	शैय्या उप0 दर	एक्स रे की संख्या	पैथालोजी जाँच की संख्या	ऑपरेशन की संख्या
पचपेड़वा	22429	250	21.28	247	135	0	35984	202	1.84	312	160	0
तुलसीपुर	44962	218	24.22	0	0	0	38735	50	5.55	0	0	0
शिवपुरा	13885	115	0	0	0	65	20105	201	0	0	0	86
उतरौला	11235	101	1.3	0	0	0	18956	317	3.5	0	0	0
महिला अस्पताल, बलरामपुर	17626	816	0	0	0	0	18037	918	0	0	0	0

सामु0स्वा0 केन्द्र का नाम	2005						द्वितीय त्रैमास 2006					
	वाह्य रोगी नये	भर्ती रोगी	शैय्या उप0 दर	एक्स रे की संख्या	पैथालोजी जाँच की संख्या	ऑपरेशन की संख्या	वाह्य रोगी नये	भर्ती रोगी	शैय्या उप0 दर	एक्स रे की संख्या	पैथालोजी जाँच की संख्या	ऑपरेशन की संख्या
पचपेड़वा	41351	130	1.15	85	110	0	5201	87	3.22	29	0	0
तुलसीपुर	35606	144	0.16	0	0	0	5557	44	1.6	0	0	0
शिवपुरा	10205	175	0	0	0	95	4200	70	0	0	0	32
उतरौला	25893	458	4.3	0	0	0	6468	88	8	0	0	0
महिला अस्पताल, बलरामपुर	12543	685	0	0	0	0	2785	394	0	0	0	11

सामु0स्वा0 केन्द्र का नाम	क्रमिक, 2006					
	वाह्य रोगी नये	भर्ती रोगी	शैय्या उप0 दर	एक्स रे की संख्या	पैथालोजी जाँच की संख्या	ऑपरेशन की संख्या
पचपेड़वा	12593	101	3.74	49	10	0
तुलसीपुर	5557	44	1.6	0	0	0
शिवपुरा	8072	101	0	0	0	62
उतरौला	6468	88	8	0	0	0
महिला अस्पताल, बलरामपुर	2785	394	0	0	0	11

कार्यालय मुख्य चिकित्सा अधिकारी, बलरामपुर।

पत्रांक : मु0चि0अ0 / उप0रोगी / 2006–07 / 1780-81

दिनांक जुलाई 6 2006

प्रतिलिपि : निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित।

1. महानिदेशक, चिकित्सा एवं स्वास्थ्य सेवायें, उ0प्र0 लखनऊ चिकित्सा उपचार अनुभाग स्वास्थ्य भवन लखनऊ।
2. अपर निदेशक, चिकित्सा स्वास्थ्य एवं परिवार कल्याण फैजाबाद मण्डल फैजाबाद।

मुख्य चिकित्सा अधिकारी
बलरामपुर

Annexure-XVII

SURVEY OF THE DISPENSERIES, DISTRICT BALRAMPUR

प्राथमिक स्वास्थ्य केन्द्रों की रोगी उपचारित मूलभूत सूचनायें, जनपद बलरामपुर।

ब्लाक स्तरीय प्रा0स्वा0केन्द्रों की संख्या		नवीन प्रा0स्वा0केन्द्रों की संख्या		शैय्याओं की संख्या		2003		2004		2005		2006 द्वितीय त्रैमास		क्रमिक	
कुल संख्या	त्रैमास में सूचना भेजने वालों संख्या	कुल संख्या	त्रैमास में सूचना भेजने वालों संख्या	कुल संख्या	त्रैमास में सूचना भेजने वालों इकाइयों की कुल शैय्या संख्या	वाह्य रोगी नये	भर्ती रोगी	वाह्य रोगी नये	भर्ती रोगी	वाह्य रोगी नये	भर्ती रोगी	वाह्य रोगी नये	भर्ती रोगी	वाह्य रोगी नये	भर्ती रोगी
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
5	**. 5**	**13**	**13**	**46**	**46**	**63616**	**1021**	**87578**	**710**	**112332**	**926**	**33862**	**199**	**61506**	**745**

कार्यालय मुख्य चिकित्सा अधिकारी, बलरामपुर।

पत्रांक : मु0चि0अ0 / उप0रोगी / 2006–07 / 1780-81 दिनांक जूलाई 6, 2006

प्रतिलिपि : निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित।

1. महानिदेशक, चिकित्सा एवं स्वास्थ्य सेवायें, उ0प्र0 लखनऊ चिकित्सा उपचार अनुभाग स्वास्थ्य भवन लखनऊ।
2. अपर निदेशक, चिकित्सा स्वास्थ्य एवं परिवार कल्याण, फैजाबाद मण्डल फैजाबाद।

मुख्य चिकित्सा अधिकारी
बलरामपुर

Annexure-XVIII

SURVEY OF THE EPIDEMIC DISEASES, DISTRICT BALRAMPUR

संक्रामक रोगों सम्बन्धी सूचना

जनपद - बलरामपुर

वर्ष 2006

जनवरी 2006 से 16 ९.

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संक्रामक रोग
जनपद-बलरामपुर

Annexure-XIX

REFERRED JOURNALS ON ROOTZONE SYSTEM AND WETLANDS

Temperature and Wetland Plant Species Effects on Wastewater Treatment and Root Zone Oxidation

Winthrop C. Allen,* Paul B. Hook, Joel A. Biederman, and Otto R. Stein

ABSTRACT

Constructed wetlands are widely used for wastewater treatment, but there is little information on processes affecting their performance in cold climates, effects of plants on seasonal performance, or plant selection for cold regions. We evaluated the effects of three plant species on seasonal removal of dissolved organic matter (OM) (measured by chemical oxygen demand and dissolved organic carbon) and root zone oxidation status (measured by redox potential [Eh] and sulfate [SO_4^{2-}]) in subsurface-flow wetland (SSW) microcosms. A series of 20-d incubations of simulated wastewater was conducted during a 28-mo greenhouse study at temperatures from 4 to 24°C. Presence and species of plants strongly affected seasonal differences in OM removal and root zone oxidation. All plants enhanced OM removal compared with unplanted controls, but plant effects and differences among species were much greater at 4°C, during dormancy, than at 24°C, during the growing season. Low temperatures were associated with decreased OM removal in unplanted controls and broadleaf cattail (*Typha latifolia* L.) microcosms and with increased removal in beaked sedge (*Carex rostrata* Stokes) and hardstem bulrush [*Schoenoplectus acutus* (Muhl. ex Bigelow) A. & D. Löve var. *acutus*] microcosms. Differences in OM removal corresponded to species' apparent abilities to increase root zone oxygen supply. Sedge and bulrush significantly raised Eh values and SO_4^{2-} concentrations, particularly at 4°C. These results add to evidence that SSWs can be effective in cold climates and suggest that plant species selection may be especially important to optimizing SSW performance in cold climates.

Subsurface-flow wetlands (SSWs) are widely used in wastewater treatment systems, but design guidelines for cold climates, which we define as climates with temperatures near or below freezing over extended periods, are not well tested. The USEPA (1993) conducted a SSW technology assessment and identified high-priority research topics including (i) temperature and seasonal effects on wastewater treatment, (ii) the role of plants in providing oxygen for root zone processes, and (iii) investigation of additional plant species suited for use in treatment wetlands. A better understanding of temperature effects and their possible seasonal interactions with plant species may be particularly important to optimizing design and management of SSWs in cold climates.

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Reviews of operational data for full-scale systems indicate that SSWs can meet effluent criteria in cold climates, and that temperature effects on removal of organic matter (OM) may be less than expected (Kadlec and Knight, 1996; USEPA, 2000). The lack of significant temperature effects on OM removal in full-scale SSWs has been attributed to sedimentation, temperature adaptation of microbes, variation in decomposition rates, and thermal buffering by plant litter, snow, and ground heat, but mechanistic explanations remain speculative (Kadlec and Knight, 1996; Wittgren and Maehlum, 1997). It is also possible that seasonal differences in oxygen release from plant roots may contribute to the lack of temperature response; however, the relative contribution of plant oxygen transport to wastewater treatment remains controversial. Some wetland designers assume that plant oxygen transport is significant (e.g., Campbell and Ogden, 1999; DeBusk and DeBusk, 2001), while others dismiss it as negligible compared with oxygen demand and undependable due to seasonal senescence (USEPA, 2000).

Wetland plants are known to transport oxygen into their roots to support aerobic respiration and to oxidize phytotoxic reduced compounds (Fe^{2+}, Mn^{2+}, S^{2-}) in the rhizosphere. Some wetland plants can release enough oxygen into the root zone to support aerobic microbial activity (Reddy et al., 1989b; Bodelier et al., 1996; Armstrong et al., 1990), and this may sometimes represent as much as 90% of the total oxygen entering a wetland substrate (Reddy et al., 1989a). Quantification of oxygen flux from entire root systems has been complicated by species and seasonal differences, spatial heterogeneity, and other measurement issues such as oxygen demand of the root zone solution and root to solution volume (Bedford et al., 1991; Sorrell and Armstrong, 1994). Plants' capacity to supply oxygen to the root zone varies among species due to differences in vascular tissues, metabolism, and root distribution (Gersberg et al., 1986; Steinberg and Coonrod, 1994; Jackson and Armstrong, 1999). Because root and rhizome respiration consumes most oxygen that diffuses through plant shoots and oxygen demand for root and rhizome respiration declines with temperature, the potential for plants to release oxygen into the root zone may increase during cold periods (Howes and Teal, 1994; Callaway and King, 1996).

Abbreviations: COD, chemical oxygen demand; DO, dissolved oxygen; DOC, dissolved organic carbon; OM, organic matter; SSW, subsurface-flow wetland.

Based on the temperature and species effects on oxy-
gen release reported in the ecological literature, we hy-
pothesized that (i) plants would modify the effects of temperature on root zone oxidation and wastewater treatment in SSWs and (ii) plant effects on temperature responses would vary among species. We tested these hypotheses in a relatively long-term (28-mo) greenhouse experiment using batch incubations in subsurface-flow wetland microcosms at temperatures from 4 to 24°C. In this paper, we contrast results for incubations at the maximum and minimum temperatures (August 1998 and January 1999), which illustrate major differences between the growing season and winter.

MATERIALS AND METHODS

A controlled-temperature greenhouse experiment using subsurface-flow wetland microcosms ("columns") was conducted at Montana State University in Bozeman, Montana (45°40′ N, 111°03′ W; 1490 m elev.) from April 1997 through July 1999. A series of 20-d incubations of simulated wastewater was conducted over 20 mo at temperatures ranging from 4 to 24°C (Fig. 1). Hourly temperatures fluctuated around the set thermostat temperatures, but the temperatures shown in Fig. 1 represent average daily greenhouse temperatures. Supplemental lighting was not used; cumulative daily net solar radiation ranged from 1 to 8 MJ m^{-2} d^{-1} and was about 25% of locally recorded net solar radiation throughout the year (Towler, 1999). Net solar radiation was relatively low as a fabric light filter was employed to improve temperature control. Relative humidity ranged from 30 to 70%, with no seasonal pattern. The combination of greenhouse temperatures and natural light patterns was sufficient to support robust plant growth and to induce seasonal cycles of plant dormancy and growth.

Thirty-two columns (eight replicates per treatment) were constructed from polyvinyl chloride (PVC) pipe (60 cm in height × 20 cm in diameter) and filled to a depth of 50 cm with washed pea-gravel (0.3–1.3 cm in diameter). The local alluvial gravel was derived from noncalcareous rock of igneous and metamorphic origin. Porosity was 0.27; pore volume was 4.3 L and did not differ significantly among treatments or with time throughout the experiment. Access tubes (1.1-cm-i.d. PVC) for permanently installed platinum redox electrodes and solution sampling tubes (0.3-cm-i.d. vinyl tubing) were installed from above with openings at 5-, 15-, and 30-cm depths (Fig. 2). The tops of redox electrode access tubes were sealed with a rubber stopper. Water level was automatically maintained at the gravel surface by replacing evaporative losses with dechlorinated tap water (at greenhouse temperature) added to the bottom of the columns. Each column functioned as an independent batch reactor.

Mature sedge, bulrush, and cattail plants were collected locally in March and April 1997 and were dormant or had minimal new growth. Rhizomes were washed free of sediments and planted in the gravel-filled columns. Columns were filled with a standard nutrient solution (50 mg L^{-1} Peter's 20–10–20 GP; The Scotts Company, Marysville, OH) from April 1997 to September 1997 and with simulated wastewater starting in October 1997. Following preliminary incubations in November and December 1997, standardized incubations were conducted from January 1998 through July 1999 (see Allen, 1999 for details). This paper reports results for August 1998 (24°C) and January 1999 (4°C) only, when the experimental units were 16 and 21 mo old, respectively, and had been receiving wastewater for 11 and 16 mo.

A synthetic wastewater simulating secondary domestic effluent was mixed from sucrose, hydrolyzed meat protein, and inorganic nutrient and metal salts to ensure consistent, known composition for all incubations (Allen, 1999). Mean influent concentrations of the main constituents were measured to be 151 mg organic C L^{-1} (chemical oxygen demand [COD] = 470 mg L^{-1}), 44 mg N L^{-1} (27 mg amino N L^{-1} [TN persulfate digestion; 0–150 mg L^{-1} test, Hach Company, Loveland, CO], 17 mg NH_4–N L^{-1} [modified Berthelot method]), 8 mg PO_4–P L^{-1} (Dionex [Sunnyvale, CA] Model DX-500), and 14 mg SO_4–S L^{-1}. Columns were gravity-drained and filled with fresh, synthetic wastewater 3 d before each incubation, and then again at the start of each incubation. Dilution of the influent wastewater attributed to water retained in the porous media was determined to be ≤5% using a bromide tracer, and showed no significant difference among plant treatments.

Calculations were made to determine the significance of dissolved oxygen (DO) inputs associated with water added to replace evaporative losses. Evaporative losses were greater

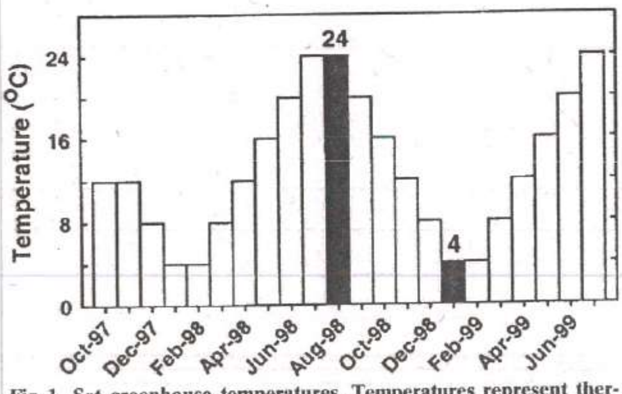

Fig. 1. Set greenhouse temperatures. Temperatures represent thermostatically set, mean daily operating temperatures. Data collected during August 1998 and January 1999 are discussed in this paper.

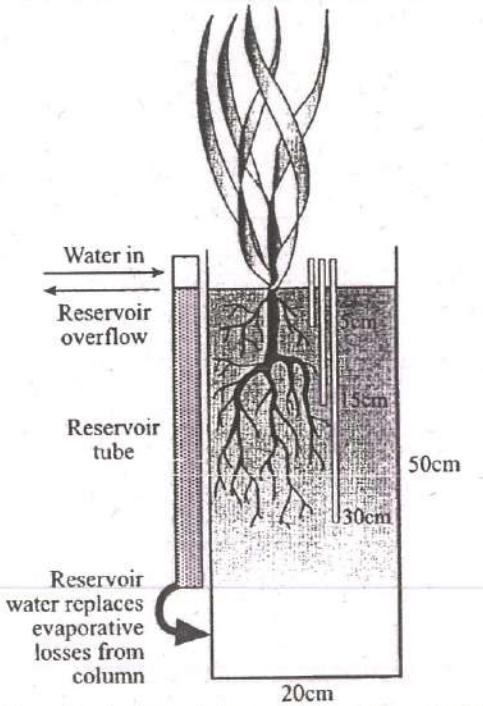

Fig. 2. Schematic of column design and water delivery system. Dechlorinated tap water was continually supplied to the reservoir tube.

for planted columns than for unplanted controls, but did not vary among species. The maximum evapotranspiration (ET) rate for planted columns at 24°C was measured to be 0.7 L d^{-1} column^{-1}. Assuming an oxygen solubility of 8.5 mg O_2 L^{-1}, this corresponded to an input of approximately 6 mg O_2 d^{-1} column^{-1} or 1% of the influent COD per day. The maximum ET rate for planted columns at 4°C was less than 0.4 L d^{-1} column^{-1}. Assuming an oxygen solubility of 13 mg O_2 L^{-1}, this corresponded to an input of less than 5 mg O_2 d^{-1} column^{-1} or 1% of the influent COD per day.

Column solution samples were collected with a 60-mL syringe after three sampling tube volumes (approximately 25 mL) had been withdrawn and discarded. Solution samples collected from 5-, 15-, and 30-cm depths during preliminary incubations showed no measurable vertical gradients for COD, dissolved organic carbon (DOC), or SO_4^{2-}. Samples were subsequently collected from 15 cm only. Samples were collected from four replicates immediately after filling columns and on Days 1, 3, 6, 9, 14, and 20 of each incubation. Samples were analyzed immediately for chemical oxygen demand (COD; 0–1500 mg L^{-1} test; Hach Company), then filtered to sterilize (0.22-μm cellulose acetate filter), stored in sterile test tubes at 2°C, and analyzed for SO_4^{2-} using ion chromatography (Dionex Model DX-500). Two replicates were also sampled (i) every 4 h for the first 16 h, (ii) at 32 and 48 h, and (iii) on Days 3, 6, 9, 14, and 20 for additional dissolved organic carbon (DOC) analyses. These samples were filtered (0.20-μm nylon filter), acidified with 20% H_3PO_4, and analyzed using a Dohrmann DC-80 carbon analyzer (Xertex Corp., Santa Clara, CA).

Two flow-through cells, one housing a standard O_2 electrode (Yellow Springs Instruments [Yellow Springs, OH] Model 5739) and the other a flat-surface pH electrode, were operated in series to measure DO and pH when collecting samples for COD, DOC, and SO_4^{2-} analyses. As described above, one solution sample was collected using a 60-mL syringe. After aliquots for laboratory analyses were removed, approximately 10 pore volumes (40 mL) of the original solution sample were passed through the flow cells and DO and pH readings were recorded. The DO and pH probes were checked against reference solutions before and after sampling.

Platinum redox electrodes (Faulkner et al., 1989) were permanently installed in all 32 columns at 5-, 15-, and 30-cm depths, connected to a computer via a multiplexer, and read automatically every 4 h. Columns were connected by a salt bridge with two saturated calomel reference electrodes located centrally (Veneman and Pickering, 1983). Redox potential (Eh) was estimated from measured electrode potential by adding 244 mV (Stumm and Morgan, 1996). Because pH was consistently circumneutral (average 6.8 with and 7.0 without plants) and the effect of temperature on measured potential is relatively small (Stumm and Morgan, 1996), Eh was not corrected for pH or temperature. Redox probes were checked periodically against a ferrous–ferric standard solution (Light, 1972).

Data were analyzed by repeated measures analysis of variance, with time and depth (for Eh) as within-subjects factors. Data for both temperatures and all incubation times, plant treatments, and depths were first analyzed together. Because statistical interactions among factors were common, separate analyses were then performed for different temperatures, times, treatments, or depths as needed to clarify results. Analyses were conducted using SAS Version 6.12 (SAS Institute, 1996). All differences reported below were statistically significant at $p = 0.05$. There were four replicates for COD, SO_4^{2-}, DO, and pH, and two for DOC. There were eight replicates for Eh normally, but only five for cattail and controls in August 1998.

RESULTS

Temperature significantly affected COD and DOC removal and the two indicators of root zone oxidation status, Eh and SO_4^{2-} (Fig. 3 and 4). However, presence and species of plants also significantly influenced these variables, in some cases negating the effects of temperature. Compared with unplanted controls, the effects of plants were greater at low than high temperatures. Differences among plant species were also much larger at low temperatures. Concentrations of DOC and COD were strongly correlated (COD = 3.0 × DOC + 16.8, $R^2 = 0.96$, $n = 124$), and patterns of DOC removal closely paralleled those for COD; therefore, only data for COD are presented graphically.

Effects of temperature on COD and DOC removal depended on plant treatment and varied through time (temperature × treatment and temperature × time interactions significant). In unplanted controls, COD and DOC removal were significantly less at 4 than 24°C (Fig. 3). Cold also tended to reduce COD and DOC removal in cattail columns, but differences between 4 and 24°C were not significant. In sedge and bulrush columns, COD and DOC removal was relatively complete at both temperatures, but removal was more rapid at 4 than 24°C. Plants did not significantly affect COD and DOC removal at 24°C. At 4°C, all plant species enhanced COD removal compared with controls, and removal was greater in sedge and bulrush columns than in cattail columns.

At both temperatures, COD and DOC removal was initially rapid, slowed over time, and asymptotically approached a relatively persistent residual level. Temperature and plant effects developed rapidly after the start of incubations. After 4 h at 24°C, DOC removal averaged 40% for all treatments; at 4°C, 4-h removal averaged 41% for controls and cattail but 58% for sedge and bulrush, though only sedge and controls differed significantly. After 24 h at 24°C, COD removal averaged 52% and DOC removal averaged 59%, with no significant differences among treatments. At 4°C, COD re-

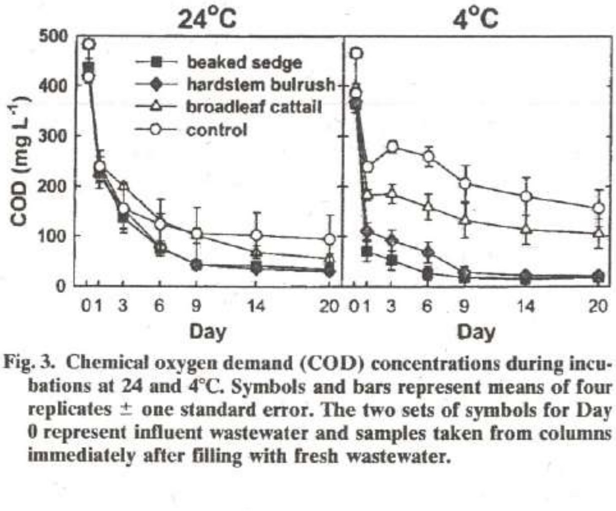

Fig. 3. Chemical oxygen demand (COD) concentrations during incubations at 24 and 4°C. Symbols and bars represent means of four replicates ± one standard error. The two sets of symbols for Day 0 represent influent wastewater and samples taken from columns immediately after filling with fresh wastewater.

moval over 24 h was significantly less in control and cattail columns (55%) than in sedge and bulrush columns (80%); DOC removal was significantly lower in controls (50%) than sedge and bulrush columns (80%).

The greater COD removal for sedge and bulrush at 4°C generally continued throughout time within each incubation. Differences were greatest on Days 3 and 6 and then diminished somewhat (Fig. 3). Final COD removal was relatively complete for sedge and bulrush at both temperatures (93–96%). At 24°C final COD removal for cattail and controls was also relatively complete (89 and 81%, respectively). However, at 4°C final removal was 77% for cattail columns and 67% for unplanted controls.

The two indicators of root zone oxidation status, Eh and SO_4^{2-} concentration, were affected significantly by plant treatment, temperature, and incubation time, and Eh sometimes varied significantly with depth (Fig. 4). Patterns of Eh and SO_4^{2-} concentration were consistent with those for COD and DOC removal: plant effects on Eh and SO_4^{2-} were greater at low temperatures, and sedge and bulrush enhanced root zone oxidation. Dissolved oxygen was consistently below 1 mg L^{-1} and did not vary with temperature or plant treatment.

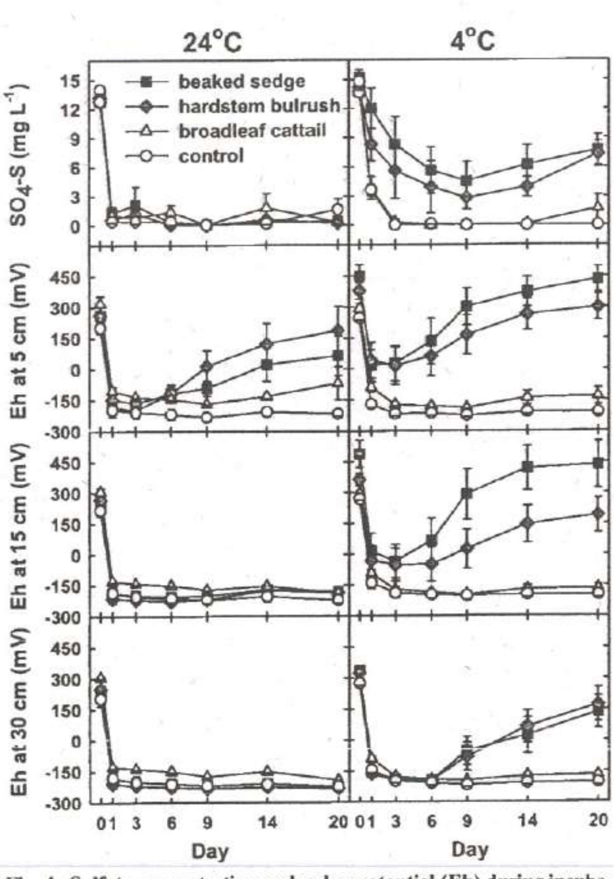

Fig. 4. Sulfate concentration and redox potential (Eh) during incubations at 24 and 4°C. Symbols represent means of four replicates for SO_4^{2-} and eight replicates for Eh (five for broadleaf cattail and controls at 24°C). Error bars represent ± one standard error. The two sets of symbols for SO_4^{2-} on Day 0 represent influent wastewater and samples taken from columns immediately after filling with fresh wastewater.

Averaged across all depths and times at 4°C, Eh values were significantly higher in sedge and bulrush columns than in cattail and control columns (Fig. 4). In contrast, when averaged across all depths and times at 24°C, Eh did not differ significantly among treatments. At 24°C, Eh values were higher in sedge and bulrush columns than cattail and control columns at the 5-cm depth, but not at 15 or 30 cm. In sedge and bulrush columns, Eh was higher at 4 than 24°C at all depths, but in cattail and control columns, Eh remained low at both temperatures.

Redox potentials and sulfate concentrations were high immediately after filling the columns with fresh wastewater and generally decreased rapidly within 24 h (Fig. 4). At 4°C and all depths, Eh decreased from an initial range of approximately +250 to +450 mV to a range of approximately −170 to +40 mV within 24 h. In cattail and control columns, Eh reached a minimum of approximately −220 to −170 mV by Day 3 and remained near this level for the rest of the incubation. In contrast, Eh in sedge and bulrush columns reached a minimum of approximately −200 to +20 mV by Day 3, but values increased continuously after Days 3 to 6 and reached final values of approximately +140 to +430 mV, which were approximately 340 to 640 mV greater than in controls. As depth increased, minimum Eh values in sedge and bulrush columns decreased and persisted longer, and the final values decreased. Plant species effects on Eh at 4°C were significant except during the time period 8 to 48 h.

Plant species and depth effects on Eh were far less pronounced at 24°C (Fig. 4). No plant effects were observed at 15 and 30 cm, and values were approximately −230 to −130 mV from Day 1 through Day 20. At 5 cm, however, plant species effects were similar to those observed at 4°C, but weaker. Again, Eh approached minimum values in 1 d in all columns, but in bulrush and sedge columns Eh values increased after 3 to 6 d, while values remained low in cattail and control columns. Unlike at 4°C, the increase was more pronounced in bulrush than sedge.

As with COD, DOC, and Eh, plant effects on sulfate concentration were more pronounced at low temperature (Fig. 4). Across all times at 4°C, plant species influenced SO_4^{2-} concentrations significantly, with higher values in sedge and bulrush columns than in cattail and control columns. At 24°C, SO_4^{2-} concentrations were uniformly low and were not influenced significantly by plants. Sulfate concentrations in sedge and bulrush columns were higher at 4 than 24°C, but temperature did not affect SO_4^{2-} concentrations in cattail and control columns.

DISCUSSION

In subsurface-flow wetlands (SSWs), influent dissolved organic matter is believed to be removed primarily by anaerobic microbial metabolism, with some aerobic metabolism near roots and at the gravel bed surface (USEPA, 1993, 2000). Because microbial metabolism generally decreases with decreasing temperature, wetland design criteria transferred from conventional wastewater treatment engineering have generally assumed the same temperature dependency (Reed et al., 1995; Campbell and Ogden, 1999). The cold-season decline in dissolved OM removal (measured by COD and DOC) we observed for unplanted controls, and to a lesser extent cattail columns, reflected this. However, greater OM removal in sedge and bulrush columns at low temperature supports the conclusion of many researchers, as summarized in Kadlec and Knight (1996), that low temperatures need not decrease OM removal in operational SSWs. In fact, our results indicate that factors that enhance electron acceptor availability or root zone oxidation status can be at least as important as temperature in controlling OM removal. The most rapid and extensive OM removal was associated with the highest observed Eh values and SO_4^{2-} concentrations, in sedge and bulrush columns at 4°C. In cattail and control columns, Eh values and SO_4^{2-} concentrations were not affected by temperature and OM removal was depressed in winter.

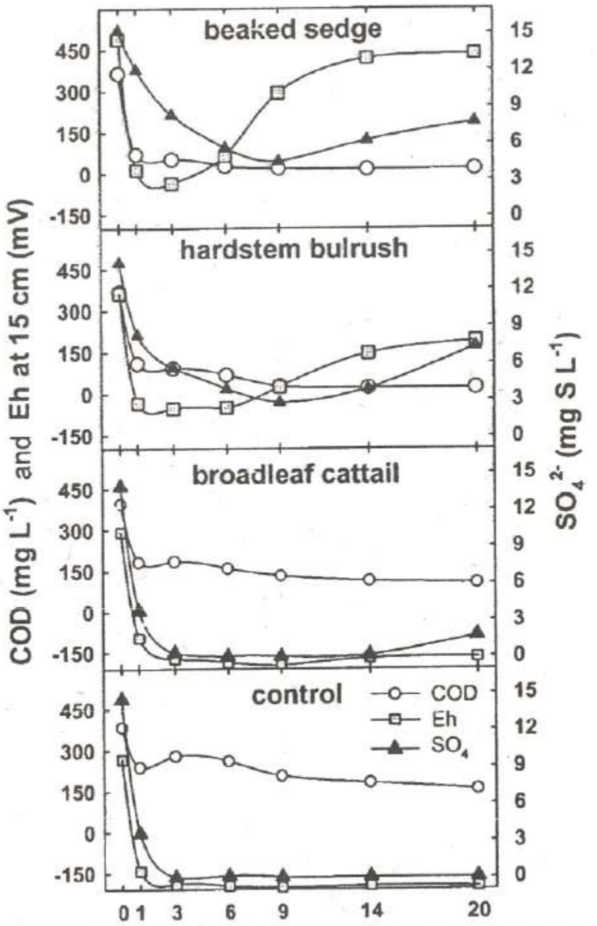

Fig. 5. Chemical oxygen demand (COD) and root zone oxidation status during incubations at 4°C. Mean values from Fig. 3 and 4 are combined to show consistencies among temporal patterns of COD, Eh, and SO_4^{2-}. Collectively, these results suggest that increased COD removal with beaked sedge and hardstem bulrush at low temperature reflects their greater ability to oxidize the root zone compared with broadleaf cattail and unplanted controls.

Greater dissolved OM removal and increased root zone oxidation for sedge and bulrush columns at low temperature were potentially due to both an increase in oxygen flux from plant roots and a decrease in root zone decomposition processes that produce dissolved OM, but the absence of this temperature response in cattail and control columns suggests that oxygen flux from sedge and bulrush root systems was significant. Our indirect indicators of root zone oxygen supply, Eh and SO_4^{2-} in the bulk solution, represent the net effect of plants and microbes on root zone oxidation status, and should not be confused with measurements of actual oxygen flux from roots (Bedford et al., 1991; Steinberg and Coonrod, 1994; Jespersen et al., 1998). Nonetheless, other studies have suggested greater potential for plants to supply oxygen for root zone processes at low than high temperatures (Gries et al., 1990; Howes and Teal, 1994; Callaway and King, 1996). Oxygen consumption by root respiration, which varies seasonally with temperature and plant growth, appears to be the major variable influencing root zone oxygen supply (Howes and Teal, 1994). In our study, plant effects on Eh and SO_4^{2-} concentrations generally developed when oxygen consumption by plants and microbes was probably lowest; that is, at low temperature, as described above, or in later days of 24°C incubations, after most dissolved OM had been consumed. Studying a reed bed system, Griffin et al. (1999) reported indirect evidence for seasonal differences in root zone oxidation; sulfide odor was a problem during summer but not during winter at low temperatures. Sulfate is converted to sulfide by sulfate-reducing bacteria only after oxygen and other more thermodynamically favorable electron acceptors have been depleted.

We interpret the relationships among changes in COD, Eh, and SO_4^{2-} during low-temperature incubations as reflecting a strong connection between total oxygen demand and root zone oxidation status (Fig. 5). For all planted and unplanted columns, the majority of COD removal at 4°C occurred within 24 h and was associated with a rapid reduction in Eh values and SO_4^{2-} concentrations. However, removal of COD was more rapid in sedge and bulrush columns than in cattail and control columns even though the associated decreases in Eh values and SO_4^{2-} concentrations were less pronounced, suggesting greater oxygen supply to the bulk solution, presumably due to oxygen flux from plant roots. In cattail and control columns, COD depletion slowed after 24 h and Eh values and SO_4^{2-} concentrations remained low, indicating there was insufficient oxygen supply to meet all respiratory demands. In sedge and bulrush columns, COD was largely depleted after 3 to 6 d; thereafter, Eh values rose steadily. Sulfate concentrations began to rise after Day 9, indicating that oxygen supply may have exceeded respiratory demands and was sufficient for some sulfide oxidation. Similar to other findings that measurement of oxidation around root tips is influenced by the reducing capacity of the soil (Flessa and Fischer, 1992), there appeared to be a threshold of low dissolved OM (in this case COD equal to approximately 30 mg L^{-1} for sedge and bulrush) that had to be reached before oxygen flux from plant roots could be expressed as an increase in Eh of the bulk solution. This threshold was reached in sedge and bulrush columns at 4°C and to a more limited extent at 24°C, but it was not reached in cattail columns. Seasonal patterns of OM removal, Eh, and SO_4^{2-} over the entire study period were consistent with these interpretations (Hook et al., 2002).

Our inference that species' differences in OM removal and root zone oxidation reflected differences in oxygen release from roots is consistent with observations by other researchers. More iron oxide accumulated on roots of sedge than cattail growing together in an Ontario, Canada wetland (Crowder and MacFie, 1986). Better performance of bulrush than cattail with respect to ammonium removal in a California wetland was attributed to better nitrification (Gersberg et al., 1986), consistent with greater oxygen release reported by Bedford et al. (1991). Variation in oxygen flux from roots of different plant species results from differences in aerenchyma development, permeability of root surfaces, oxygen transport mechanisms, and metabolic pathways (Reddy et al., 1989a; Jackson and Armstrong, 1999), and differences in root densities and depth distributions (Gersberg et al., 1986; Campbell and Ogden, 1999; Moorhead and Reddy, 1988). While not evaluated in our study, these characteristics offer possible reasons for increased OM removal and root zone oxidation in sedge and bulrush columns than in cattail columns.

Our results, together with evidence from field studies (Kadlec and Knight, 1996; Smith et al., 1997; Wittgren and Maehlum, 1997) and recent research on arctic and alpine soil microbiology (Brooks et al., 1996; Schmidt et al., 1999), reinforce doubts about two common assumptions in SSW design: (i) that biological treatment processes are insignificant at temperatures near freezing, and (ii) that plants have a minimal role in treatment processes. There is substantial evidence that even at temperatures near and below 0°C soil microbial processes can be significant and regulated by factors other than temperature, such as organic matter quantity and quality, electron acceptor availability, or nutrient availability (Brooks et al., 1996; Schmidt et al., 1999). In operational SSWs, water temperatures often remain above freezing even when air temperatures are well below 0°C for long periods (Kadlec and Knight, 1996; Smith et al., 1997). Our microcosm results suggest that effective organic matter removal in SSWs is possible at temperatures near freezing, depending on the presence and species of plants. Somewhat surprisingly, differences in OM removal and root zone oxidation among species were greatest at low temperatures, suggesting a key role for plants especially during dormancy.

Reviews that question the importance of plant selection to SSW performance (USEPA, 2000) may reflect emphasis on continuous high organic matter loading and warm temperatures in comparative studies, as well as the greater complexity and lack of statistical replication in operational treatment wetlands. The controlled environments used here were not intended to recreate realistic winter conditions of operational SSWs, and the relatively small size of our experimental units may have accentuated root and shoot density and, therefore, altered plant effects. Nonetheless, our experiments represented a wide range of temperatures and OM levels (due to depletion over time within incubations), achieved a degree of control and replication not feasible in the field, and allowed for careful evaluation of the relative performance of species tested. The success, especially in winter, of sedge, which is much less researched than bulrush or cattail, points to the need to investigate additional plant species and to quantify the role of oxygen flux from root systems in operational cold-climate SSWs.

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Guidance on Land Treatment of Nutrients in Wastewater, with Emphasis on Nitrogen

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Background

In Washington State, waste water from some municipalities and industries is applied to cropland to obtain biological treatment. Ecology's Water Quality Program permits the land treatment of waste water provided all known, available, and reasonable methods of prevention, control, and treatment (AKART) is described and approved in an engineering report. Documents have been developed to help define AKART, guide site selection, and design land application treatment systems (Ecology, 1993; Ecology, 1996; Department of Health, 1994). The treatment process (AKART) and treatment capacity are determined in an engineering report that follows Chapter 173-240 WAC (Construction of Wastewater Treatment Facilities) and the Ground Water Quality Standards, Chapter 173-200 WAC (Water Quality Standards for Ground Waters of the State of Washington). Currently, Ecology approves as AKART the design, and operation and maintenance for land treatment systems that includes: 1) the application of wastewater and its nutrients at rates, times, and durations that do not exceed the crop's agronomic rates, and 2) the storage of wastewater in properly lined lagoons that is produced in excess of the crop's requirement or outside of the growing season.

A well-managed land treatment system limits wastewater application to rates that do not exceed the treatment capacity of the crop or soil and minimizes adverse impacts to groundwater quality by all contaminants. Management of the timing and volume of wastewater application is required to avoid exceeding the treatment capacity of the crop or soil.

This guidance document refers to management and treatment of nutrients in wastewater, but emphasizes nitrogen. Ecology uses the term nutrients in the broad sense. However, among the general class of nutrients readily available and used by crops, only nitrate is specifically regulated in the Ground Water Quality Standards and would be considered as a design limiting contaminant at most land treatment sites. Other nutrients discharged to a land treatment site can create water quality or other problems and, as a result, may require careful management. For example, nitrogen and phosphorus discharged from a land treatment site to a nearby surface water body via hydraulic continuity can promote algal growth and eutrophication; excess potassium in the soil can cause grass tetany in grazing animals; and sodium in drinking water is a concern for people on low sodium diets.

A viable crop must be established and maintained to achieve the level of treatment necessary to protect ground water. Ecology recognizes that in some circumstances maintenance of a viable crop for treatment of nutrients requires periodic flushing of salts from the crop root zone. Salt flushing should not conflict with the requirement to minimize leaching of contaminants below the crop root zone and to comply with the Ground Water Quality Standards. Through AKART, careful water management, and pollution prevention these requirements should be achievable at a properly designed and managed land treatment site.

Significance of Agronomic Rate

The primary goal of a land treatment system is to achieve the level of treatment necessary to meet the requirements of the Ground Water Quality Standards. A fundamental requirement of the Ground Water Quality Standards is that AKART must be applied to all discharges to ground water. For nutrients, AKART includes two basic concepts: 1) that nutrient uptake by the crop is maximized and leaching below the root zone to the uppermost aquifer is minimized, and 2) that the land treatment system provides maximum treatment when the application rate does not exceed the agronomic rate for the design limiting contaminant as identified in the design engineering report.

The term agronomic rate, when used for land treatment, is defined as:

> Rate at which a viable crop can be maintained and there is minimal leaching of chemicals downwards below the root zone. Crops should be managed for maximum nutrient uptake when used for wastewater treatment. (Ecology, 1996)

The most common use of agronomic rate is applied to certain contaminants, such as nutrients, which can be readily treated through crop uptake and bacterial or biological processes that naturally occur in the soil column. The capacity of the crop and soil to treat these contaminants is determined by the design engineering report and is based on reasonable assumptions or site specific information regarding agronomic rates, mineralization of organics, nitrification/denitrification, volatilization, and irrigation efficiency and uniformity. For some contaminants there is literature to support the determination of agronomic rate. Treatment is substantiated from information given to Ecology in an annual irrigation and crop management plan and a monitoring plan that are conditions of the discharger's state waste discharge permit. Monitoring may be required for waste water, soils, crops, and ground water.

Wastewater Management

A critical element in defining AKART and achieving treatment of waste water to meet the Ground Water Quality Standards is management of the waste water during the non-growing season. This goes beyond water management using a checkbook approach. For land treatment systems, the goal is to fully apply AKART to protect groundwater quality at the facility and for the beneficial use by neighboring landowners. This means that the annual distribution of waste water applied to the land treatment site is confined to the growing season when nutrients are readily treated by crop uptake and soil microbial activity. These treatment processes are diminished by low temperatures during the non growing season. Ecology has collected and interpreted data from soils monitoring and from groundwater monitoring at a number of permitted land treatment facilities around the state. The period of record for some sites is more than a dozen years. Ecology's evaluation of these monitoring data shows a correlation between excessive, non growing season wastewater application and groundwater contamination. Conversely, when facilities have converted from year round application to seasonal application, groundwater quality has improved.

Some soil moisture is lost during the non-growing season through evapotranspiration during temporary warm periods. Replacement of this moisture is a reasonable sprayfield management tool that maintains the viability of the crop. The problem is that many facilities operate year round. As a result, the volume of water necessary to replenish and maintain adequate soil moisture during the non-growing season is likely to be small compared to the volume of waste water actually generated by the facility. Further, Washington's climate regime of winter precipitation can be expected to provide some, if not all, of this soil moisture.

This means that wastewater storage or alternative methods of treatment and discharge may be needed for periods when land application may be precluded by climatic or other conditions. Among the options available for management of excess waste water are storage in a properly constructed lined lagoon, discharge to a surface water body in accordance with Chapter173-201A WAC and Chapter 173-220 WAC, or discharge to a publically owned treatment works (POTW) in accordance with Chapter 173-216 WAC. All of these options have been approved and permitted by Ecology and are being used by different dischargers.

The factors cited above were among those considered during the preparation of Ecology's land application design guidance (Ecology, 1993.) and in the determination of AKART.

Nitrogen Fate and Transport

A Washington State University report, *Nitrogen Use by Crops and the Fate of Nitrogen in the Soil and Vadose Zone* (WSU 2000), was completed with EPA grant funding through Ecology. The report is an extensive literature review on nitrogen dynamics in the soil, especially as it relates to the application of high strength organic waste waters to land treatment systems. It provides technical background information on nitrogen use by crops and describes the complex interactions between crops, soils, nitrogen, and water.

A vast majority of the literature contained in the report is from research and studies conducted outside the state of Washington. However, given the diversity of crops and soil systems in the state, some general principles and recommendations (WSU 2000) were developed for the use of nitrogen by crops, and the fate of nitrogen in the soil and vadose zone:

- The estimation of the agronomic rate for a crop must factor in all sources of nitrogen available during the growing season.
- All nitrogen applied to the soil, that is not volatilized, will eventually convert to nitrate.
- Soil nitrogen that moves below the root zone will eventually leach to the ground water as nitrate.
- Denitrification may reduce nitrate loading to ground water under some conditions, though it is of little importance in well drained soils.
- Nitrogen applied at agronomic rates will minimize the buildup of soil organic nitrogen.
- Wastes applied substantially before or after maximum crop demand may result in nitrate leaching.
- Organic wastes applied during the non-growing season will partially or totally convert to nitrate before the next growing season.
- Nitrates leached beyond the root depths of the crop to be grown during the following season will be susceptible for transport to the ground water.

- Steps should be taken to minimize movement of nitrogen below the root zone during the growing and non-growing season.
- Applying organic wastes during the non-growing season has an inherent risk in terms of leaching nitrogen to the ground water.
- The use of storage facilities to minimize waste applications during the non-growing season is a safe alternative.

The report (WSU 2000) does not completely rule out the application of waste water outside of the growing season. However, from the literature it is apparent that the many uncertainties associated with nitrogen dynamics in the vadose zone support a position that applying waste water to crops and soil systems during the non-growing season is not reliably protective of ground water.

Conclusions

Nitrogen processes are complex and difficult to precisely control or predict in the environment. Nitrate is the most chemically stable form of the nitrogen species and other forms of nitrogen readily convert to nitrate in the environment. Nitrate is also the most mobile nitrogen species and moves readily with water through the subsurface. Once nitrogen is applied to the soils, the grower must address this mobility through careful management of the land treatment site to avoid groundwater contamination. The diversity of climates and soils in Washington State combined with cropping and irrigation practices influence the fate of nitrogen once applied to the soil. Ecology concludes that nitrogen applied in the form of ammonia or organic nitrogen is likely to convert to nitrate during the time of the year when it is not adequately treated by the crop and, under excessive hydraulic load, will leach out of the soils and migrate to ground water.

Ecology has extensive experience reviewing soil and groundwater quality data at land treatment sites in Washington State. Based on the evidence presented in the WSU report and Ecology's experience with land treatment systems, Ecology concludes that the current AKART definition addresses the many uncertainties and potential negative consequences for groundwater quality associated with the fate and transport of nitrogen in the vadose zone, especially during the non-growing season.

Ecology will consider site specific demonstrations of innovative approaches to achieving treatment of nitrogen in waste water during the non growing season that are determined to be equivalent in effectiveness for protecting groundwater quality to the current AKART approach. Lacking such determination, Ecology concludes that applying waste water to crops and soil systems for the purpose of land treatment of nutrients in waste water during the non-growing season does not reliably protect groundwater quality, and therefore does not meet the AKART requirement for permit issuance according to the Ground Water Quality Standards.

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Aspects of design, structure, performance and operation of reed beds – eight years experience in north eastern New South Wales, Australia

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Abstract Reed beds (horizontal subsurface flow constructed wetlands) have been employed as secondary treatment devices in on-site and decentralised wastewater management systems in the north east of the Australian state of New South Wales (NSW) for over a decade. This paper summarises some of the practical and research findings that have come to light in that time. Experience with various aspects of reed bed structure is discussed. A study of the evaporative performance of four small beds planted with *Phragmites australis* yielded an annual crop factor of 2.6. A total of 28 studies on reed beds treating a variety of commonly encountered wastewater streams yielded the following mean pollutant removal efficiencies: total suspended solids (TSS) 83%, biochemical oxygen demand (BOD) 81%, total nitrogen (TN) 57%, total phosphorus (TP) 35% and faecal coliforms (FC) 1.9 logs. The reed bed is becoming the preferred on-site technology for removing TN and BOD and polishing TSS from primary settled domestic wastewater. Sizing beds for a residence time of approximately 5 days has become standard practice. A study of six reed beds found six different species of earthworm present, mainly *Perionyx excavatus* (Indian Blue). A mesocosm experiment subsequently showed that the worms were translocating clogging material from the substrate interstices to the surface of the bed thereby indicating a possible method for prolonging reed bed life.

Keywords Earthworms, evaporative performance, reed beds, substrate clogging, subsurface flow wetlands, treatment performance

Introduction

It is becoming increasingly common in Australia to include a secondary treatment device in the treatment train of on-site and decentralised wastewater management systems. Current options for secondary treatment include aerated wastewater treatment systems (AWTS), single pass sand filters (SPSF), recirculating sand filters (RSF) and reed beds (also known as subsurface flow wetlands). Compared to the other three technologies the reed bed has a number of advantages. It is relatively cheap to build, requires no power to operate and very little personal effort or money to maintain. In addition, a reed bed can become an aesthetically pleasing functional part of a garden. From the treatment perspective, the reed bed has been found to exhibit a superior nitrogen removal capacity to the SPSF and the AWTS. On the other hand reed beds tend to require larger land areas than comparable AWTS or sand filter systems. In the last eight years approximately one hundred reed beds have been installed in the Lismore City and Byron Shire Council areas in the north eastern corner of New South Wales (NSW). The first of three aims of this paper is to summarise some of the lessons learned in relation to reed bed construction and operation.

The second aim of this paper is to summarise the findings of a number of studies conducted by the authors which have investigated evaporative and treatment performance of reed beds operating on four types of commonly encountered wastewater.

The major life-limiting factor for reed beds is the tendency, over a number of years, for the substrate (in particular at the inlet end) to become clogged with solids. Consequently, the hydraulic conductivity of the substrate can be reduced to the point where water is forced to flow above surface with resulting reduction in treatment efficiency. While source control of TSS by means of a well designed, installed and maintained primary treatment device is the first line of defence against entrance zone substrate clogging, at least one natural mechanism for substrate declogging has been observed. Pratt (2002) studied several reed beds in northern NSW which had been colonized by earthworms. In one bed subjected to greywater loadings with a high solids content the inlet zone was found to be densely populated by small red worms. The surface of the bed was covered to a depth of approximately 5 cm with a layer of rich humic material, while the substrate at depths greater than 10 cm below gravel surface (ie below the water level) was relatively clean. Even though the reed bed had been operating for six years at a relatively high hydraulic loading rate (HLR) of ~70mm/day (< 3 days residence) no surface flow was observed. These observations led to the hypothesis that the worms were grazing on solids deposited in the interstices of the substrate and excreting the material as castings on the surface. The third aim of this paper is to describe an experiment which tested this hypothesis.

Methods

A reed bed typically consists of a *substrate* (usually gravel) confined within an impermeable *skin* supporting *macrophytes* such as reeds or rushes (Figure 1). Water enters via an *inlet structure* and flows horizontally over a period of days to the *outlet structure*. Treatment occurs within the bed as a result of a number of physical, chemical and biological processes that occur during the water's passage through the bed. A standpipe or swivel control in the outlet box can be used to adjust the water level

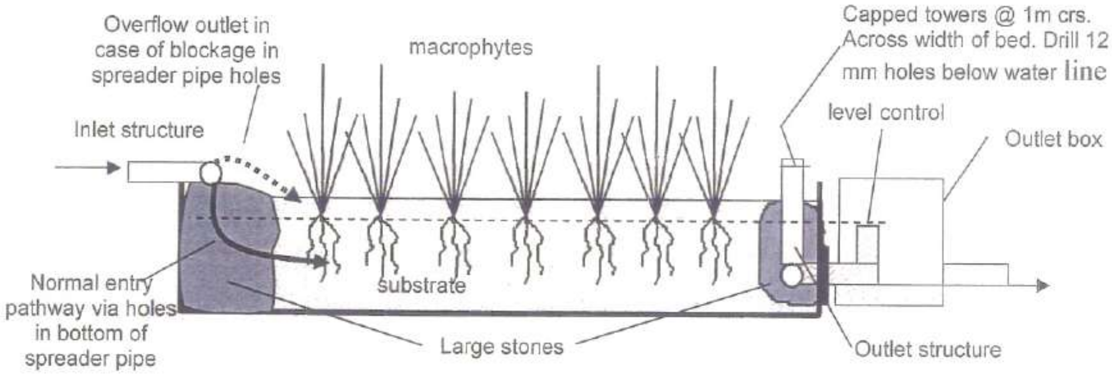

Figure 1 Elevation of typical reed bed showing major components

In the years since 1994 the principal and second authors of this paper have built, maintained, observed and monitored a number of reed beds and have been involved in the development of local government guidelines for their design and construction. The comments in this paper relating to reed bed structure are based on observations of the evolution of the various structural elements developed by the authors and other local reed bed designers and are reported more fully in Davison and Headley (in press).

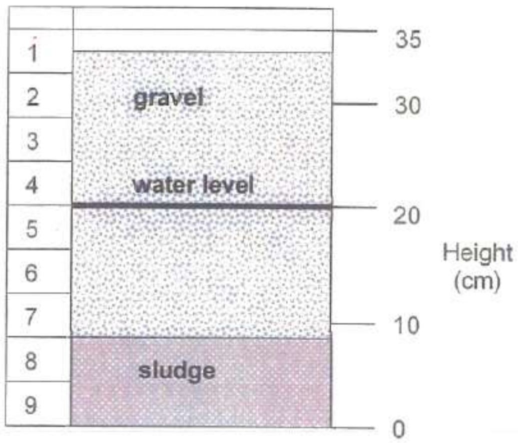

Figure 2 Design of mesocosm showing layers of gravel and sludge, water level and the nine sections used in monitoring.

The hydraulic performance data presented in this paper comes from a water balance study described in Headley (2004). The findings relating to treatment performance are based on 28 monitoring regimes conducted over the past eight years on 13 reed beds described more fully in Davison et al. (2001), Davison et al. (2002) and Headley and Davison (1999). The derivation of the first order models for BOD and TN removal performance is described in Headley and Davison (2003).

The hypothesis that earthworms may be cleaning the interstitial spaces in reed bed media was tested using a controlled laboratory-based experiment involving seven mesocosms (Figure 2). These were 40cm x 20cm x 4cm and constructed from waterproofed timber and clear Perspex to create a 'slice' of reed bed where worm behaviour and the movement of solids could be easily observed. The height of each container was divided vertically into nine sections so that the movement of solids could be accurately recorded. A scale was created on one side of the mesocosms to easily record water level and locations of specific worms. Clogging material (sludge) from the surface of a reed bed was collected and oven dried at 100 degrees C. Six hundred grams of this material was placed at the base of each mesocosm. Three kilograms of clean, dry reed bed media (10 mm gravel) was then weighed and placed over the sludge. Effluent from the same reed bed was used to saturate all mesocosms to a depth of approximately 20cm. Thirty six worms of the species *Perionyx excavatus*, *Metaphire posthuma* and *Amynthas spp.* were added to six of the mesocosms, with the seventh acting as a control (no worms). The mesocosms were kept in a dark, cool place and were monitored regularly (every few days, at night if possible to minimise disturbance) and photographed (once a week). Because initial photographs did not satisfactorily show the position of sludge within the mesocosms, a template was made to represent sludge movement. A sheet of clear plastic was taped to the Perspex of the mesocosm and the position of the sludge layer was traced onto the plastic. This image was then traced onto paper and reduced using a photocopier. This process was carried out in week 6 of the experiment and again at the conclusion of the experimental period (a template of the control mesocosm was also made to compare soil movement). In order to get an approximate idea of how long it took worms to move solids to the surface, one mesocosm (no. 6) was monitored every 6 hours after worms were introduced until solids were observed in the surface layers. Effluent was added to each mesocosm as required (to keep the water level at around 20 cm). The duration of the experiment, which is fully described in Pratt (2002), was nine weeks, after which time a worm census and dry matter budget of the sludge were conducted.

Results and discussion

Local experience in relation to choice of reed bed components

The substrate surface of a reed bed provides the site for growth of the microbial biofilms which mediate many of the pollutant removing chemical reactions. Choice of substrate size is governed by the tradeoffs between maximisation of specific surface area (favoured by small particles) and the need to avoid clogging of interstices (favoured by large particles). In most cases 10 mm gravel is chosen. Larger stones (eg rail ballast 60-80 mm) are placed in the first metre of the bed (inlet zone) where clogging is most likely to occur, and sometimes adjacent to the outlet structure. The roots of most macrophytes have been observed to grow poorly in stones > about 40 mm, presumably because the roots find it difficult to push through.

Materials that have been used for reed bed skin or containment in north eastern NSW include fabricated reinforced concrete slabs, ferro-cement, stainless steel, polyethylene and concrete cattle troughs, fibreglass troughs, sealed concrete blocks laid on concrete slabs, and flexible liner membranes. The use of a liner membrane in a prepared hole is the cheapest approach for all but the smallest applications. When using a liner, care should be taken to ensure that it is laid onto consolidated surfaces, as voids behind the liner can provide penetration sites for macrophyte rhizomes. *Pharagmites australis* (common reed) has a particularly aggressive rhizome and, while this is an advantage from the treatment perspective, it has caused membranes to be pierced. The practice of using a geo-textile protector both below and above the liner to lessen the chance of root penetration and to protect it against damage by sharp particles is now recommended. A plastic tank manufacturer in northern NSW has developed a 3m x 2m x 0.68m deep polyethylene tub specifically for use as reed bed containment. These tubs are proving popular for use in single dwelling units. A typical family home would require from two to four tubs to accommodate the needs of four or five people as explained more fully below under "sizing reed beds".

Most reed beds built in north eastern NSW had until recently been planted with *Phragmites australis*. The aggressive nature of its rhizome system and a tendency for senescence in the top growth (leading to a rather ragged appearance) in the winter months have prompted a search for other species. Macrophytes that have been used with success in this region are *Schoenoplectus validus* (river club rush), *Typha orientalis* (bull rush), *Bolboschoenus fluviatilis* (marsh clubrush) and *Baumea articulata* (jointed twigrush).

In choosing a design for the inlet structure there are tradeoffs to be made between capacity to spread the influent evenly across the inlet end of the bed (critical for the establishment of hydraulic efficiency) and ability to resist clogging of openings in the spreader pipe (usually ~12 mm diameter in the bottom of a 100mm UPVC pipe). It has been found that primary treated greywater is particularly prone to causing slime buildup in the plumbing upstream of the inlet structure. Sloughed slime can block openings and an alternative overflow pathway should be designed as shown in Figure 1. An outlet structure design that minimises the possibility of intrusion by macrophyte roots incorporates a series of 150 mm diameter, capped, vertical towers spaced evenly across the width of the bed. Effluent enters the towers from the bed via 15-25 mm diameter holes surrounded by stones > 50 mm diameter. Hand access to the towers is available should clogging of the holes occur. A swivel pipe or a series of variable length stand pipes in the outlet box can be used to vary the water level in the bed. In this way the wetland can be flooded to help with control of terrestrial weeds during macrophyte establishment. Periodic water level lowering can encourage downward root penetration, promoting oxygenation of the lower level of the bed and thereby enhancing treatment at that level. Drying of the upper layers of the bed will also enhance breakdown of carbon and nitrogen trapped in substrate interstices and its return to the atmosphere.

Evaporative performance

Headley (2004) performed a two-year study on four pilot scale (4m x 1m) reed beds planted with *Phragmites australis*. Accurate water balances enabled monthly evapotranspiration (ET) rates to be determined. Figure 3 shows a plot of the monthly averages of daily ET from the four beds commencing in September 1999, four months after the reeds were planted. ET rates ranged from 3.2 mm/d to 15.1 mm/d over the two year period of the study. The effects of seasonality and maturity are apparent with summer ET rates being higher than the cooler months and the second year showing a higher average rate (10.6 mm/d) than the first (7.0 mm/d) due to greater leaf area present. Annual crop factors relative to class A Pan Evaporation varied from 1.9 in the first year to 2.6 in the second with a maximum monthly crop factor of 4.5 occurring in April and May of the second year when the standing leaf crop was at its maximum. A similar water balance performed on small reed beds (5m x 2m), also planted with *Phragmites australis*, in the same area of northern NSW (Davison and Headley in press) came to similar conclusions with respect to ET quantity, seasonality and maturity effects. It is probable that the high ET rates recorded in these small beds are partly a result of edge effects and that larger beds would record lower evaporative performance. Nevertheless these beds are of similar dimensions to those typically used in on-site applications and are therefore relevant to that situation.

Treatment performance

Table 1 contains a summary of reed bed treatment performance, as measured by percent reduction in concentration, obtained from 28 studies, on four different types of wastewater, conducted since 1995. Wetted depth of the beds in these studies varied between 40 cm and 60 cm.

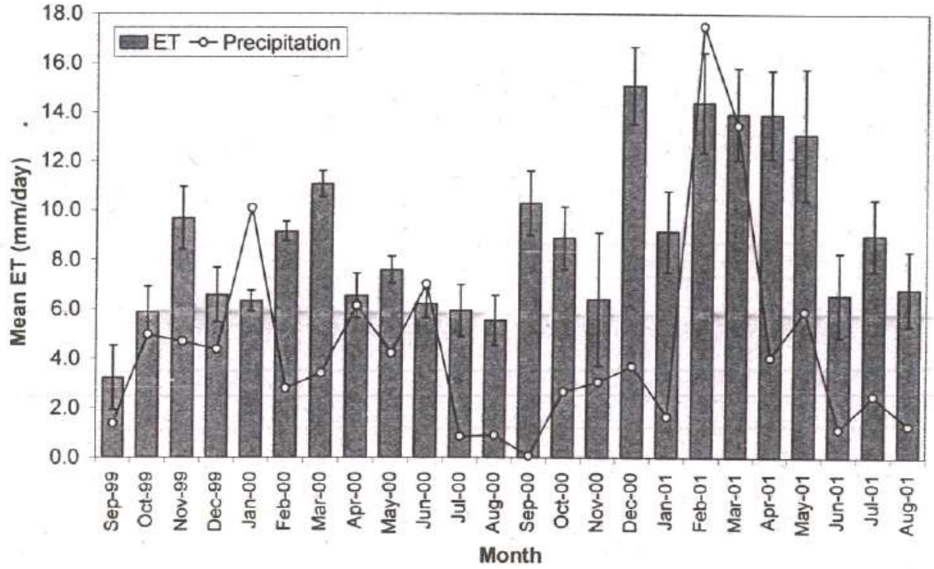

Figure 3 Mean monthly evapotranspiration (ET) and precipitation rates (mm/d) for the four reed beds. Error bars represent +/- one standard error of the mean.

Table 1 Treatment performance summary (as measured by percent reduction in concentration) from 28 studies on reed beds treating four types of wastewater. (HRT = mean hydraulic residence time).

wastewater type		HRT days	BOD %reduction	TSS %reduction	TN %reduction	TP %reduction	FC log reduction
Combined*	Mean	8.9	92.5	88.7	60.2	25.0	2.5
Greywater	Mean	5.2	83.8	81.5	62.0	46.8	1.8
Laundry	Mean	6.1	61.2	82.7	62.4	31.9	0.8
School	Mean	11.5	74.9	79.3	38.1	33.7	1.7
All studies	Mean	8.3	81.3	82.9	56.5	34.9	1.9
	Min	3.7	34.7	55.9	8.1	-21.7	0.4
	Max	17	96.6	97.9	93.8	76.6	3.3
	n	32	28	23	24	26	27

* combined wastewater = domestic blackwater and greywater

Overall, the data indicate that the reed beds are effective at removing BOD (mean 81%), TSS (mean 83%) and TN (mean 57%). In general removal of TP has been found to be temporary because the main removal processes for this nutrient are adsorption and precipitation onto a finite number of sites on the substrate. Overall mean reduction in FC was 1.9 logs. It can be seen from the differences in minimum and maximum reduction for all studies that performance for all five parameters varies considerably from study to study. In many cases this variation is caused by differences in hydraulic residence time (HRT). The decline in concentration of some pollutants as a function of residence time can be approximated using the first order model presented in Equations 1 and 2.

$$C_o = C^* + (C_i - C^*)\exp(-k_v HRT) \qquad \text{(Eq. 1)}$$

where C_o = pollutant concentration at reed bed outlet (mg/L)

C_i = pollutant concentration at reed bed inlet (mg/L)

C^* = background concentration due to return of pollutant (mg/L)

k_v = volumetric rate constant (d^{-1}) which varies with temperature according to Equation 2.

$$k_v = k_{v20}\theta^{(T-20)} \quad \text{(Eq. 2)}$$

where k_{v20} = value of volumetric rate constant at 20°C
θ = temperature correction factor
T = water temperature (°C)

Headley and Davison (2003) used data on BOD and TN decline obtained from the studies mentioned above to estimate values for the model parameters k_{v20}, C^* and θ for these two pollutants. These values are presented in Table 2. Predicted treatment performance is depicted in Figure 4. The model parameters result in an accurate prediction of the BOD removal from combined (ie black plus grey water) wastewater and greywater but give an under-estimate of the BOD concentration (i.e. over-predict performance) in the laundry and school wastewaters. The TN model parameters achieve a reasonably accurate prediction of the TN concentration in combined, grey and laundry wastewaters, but considerably over-estimate performance for the school wastewater.

Table 2 Suggested 1st order model parameters for TN and BOD removal from gravel horizontal flow wetlands with a wetted depth 0.4 m to 0.6 m.

Pollutant	Volumetric rate constant k_{v20} (d^{-1})	Background conc., C^* (mg/L)	Temp. correction factor, θ
BOD	0.52	5	0.953
TN	0.18	1.5	1

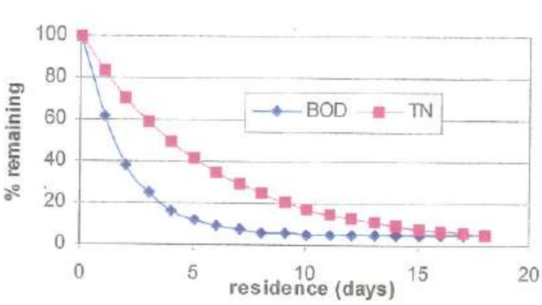

Figure 4 Percent of pollutant remaining vs HRT predicted by 1st order models at 20° C.

Sizing reed beds

The reed bed's strength is its capacity to remove BOD and TN from effluents. Therefore a reed bed's size is usually based on the need to achieve a certain treatment objective with respect to one or both of these pollutants. Equations 1 and 2 can be used to determine the HRT required to achieve a given effluent concentration from an influent of known concentration. For example at 20°C the model predicts that a HRT of 4.3 days will reduce BOD from an assumed concentration of 144 mg/L to a secondary level concentration of 20 mg/L. The model also predicts that TN concentration will be halved with a residence of 4 days. Assuming that these are desirable effluent quality objectives and adopting a conservative approach it is common practice in north eastern NSW to design reed beds for a 5 day HRT. For a family home assuming 4 people generating 200 L/d of wastewater, a pore volume of (5 x 200 x 4) 4,000 L in the reed bed would achieve this. Assuming a substrate porosity of 0.4 a total wetted volume of (4,000/0.4) 10,000 L would be required. This could be accomplished using three of the 6 m^2 plastic tubs, mentioned in the "components" section above, wetted to 55 cm depth (3 x 6 x 0.55 x 1,000 = 9,900 ~10,000).

Earthworms as substrate declogging agents

As noted in the introduction, the presence of earthworms was first observed in a heavily loaded bed treating greywater from a domestic source. Three species of worm were identified in that bed. Five additional reed beds were investigated and all were found to contain varying numbers of earthworms. Table 3 summarises some of the features of the worms which were found. By far the most common species was *Perionyx excavatus* (Indian Blue) which was found in four of the beds. This small red worm is one of three species commonly used in commercial composting operations and is classified as an epigeic feeder. In terrestrial situations epigeic worms ingest mainly surface organic material and very little mineral soil. The only non epigeic feeder found during this investigation was the anecic feeder (ingests some mineral soil material), *Pontoscolex corethrurus*. The large garden worm *Metaphire posthuma* was found in three of the four beds occupied by *P. excavatus*. In the three beds co-occupied by these two species it was generally found that *P. excavatus* was more abundant towards the inlet end of the bed.

Intensive observation of Mesocosm 6 immediately after addition of the worms revealed that a number of worms had migrated to below the water level within 6 hours. Within 18 hours small amounts of sludge could be observed above the water level. By week two, sludge had been transported vertically to the top layers of gravel in all mesocosms. The smaller composting worms such as *Perionyx excavatus* were observed in the bottom layers of the mesocosms below the water level within the sludge layer while the larger worms (*Metaphire posthuma*) were observed just above water level. The relative niches occupied by the two worm species were fairly constant throughout the study period. At week 5 a distinctive band of sludge approximately 3-4 cm thick was observed just above the water level in all mesocosms (being more pronounced in some than others). At the same time worms were noticed congregating around this zone of sludge accumulation. This trend continued in all mesocosms until the conclusion of the experiment in week 9. In week 8 the water level in Mesocosm 6 was increased to a depth of approximately 30cm (from the top of section 5 to the top of section 3 – Figure 2). As a result, the band of sludge at section 5 was seen to disperse and begin to reform at the new water level within the final week of the study. No movement of sludge was observed in the control (no worms) mesocosm. Over the nine week study the average worm survival rate was 94%. Of the 600 g (dry weight) of sludge added to the mesocosms an average of 267 g was lost, presumably decomposed or consumed.

Table 3 Details of earthworm species identified in six reed beds (after Pratt 2002).

Species	Common Name	Ecotype	Colour	Length (mm)	Frequency of Occurrence
Perionyx excavatus	Indian Blue	epigeic	can appear red when young adults begin to phosphoresce deep blue/purple on exposure to light	30 - 180	4
Esenia fetida	Tiger Worm	epigeic	rusty colour with a distinct yellow band on each segment	60 - 120	1
Metaphire posthuma		epigeic	brown in colour, phosphoresce blue in sunlight	45 - 270	3
Amynthas morrisi		epigeic	grey/ brown in colour	50 - 250	1
Amynthas rodericensis		epigeic	grey/ brown in colour	50 - 250	1
Pontoscolex corenthrurus		anecic	dark brown with tinge of yellow	60 - 120	1

Over nine weeks, observations of the mesocosms confirmed the hypothesis that worms are responsible for cleaning the substrate and depositing organic matter on or near to the surface. A management outcome of this finding could be the inoculation of reed beds with earthworms to clean the substrate and prolong their useful life.

Conclusions

Reed beds have been found to be effective, low maintenance secondary treatment devices in a number of Council areas in northern NSW with BOD and TN removal rates in excess of 90% and 50% respectively being regularly achieved. Reed bed designers have adopted a number of approaches to the structural elements which comprise a reed bed and there has been some experimentation with macrophyte species used. With combined wastewater, a five day HRT will usually accomplish secondary treated quality (BOD<20mg/L) and a halving of TN concentration. While 2 logs FC attenuation can be expected after 5 days residence in a reed bed it is rare to achieve concentrations < 1,000 cfu/100mL. TP removal will occur at high rates initially, but taper off as adsorption and precipitation sites fill up. While reed beds are effective at removing TSS, overloading with solids can cause substrate clogging and lead to hydraulic failure. Therefore they should only be used in conjunction with a well maintained primary treatment device fitted with an outlet filter. Nonetheless a natural mechanism for cleaning clogged substrates does exist. A mesocosm experiment showed that worms of the species *Perionyx excavatus* and *Metaphire posthuma*, among others, were translocating clogging material from the substrate interstices to the surface of the bed thereby indicating a possible method for prolonging reed bed life. A study of six reed beds found a total of six colonizing earthworm species. A study of four small reed beds planted with *Phragmites australis* demonstrated the high evaporative performance of this species with an annual crop factor relative to Class A Pan Evaporation of 2.6 being measured in the second year of growth.

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PARALLEL PERFORMANCE COMPARISON BETWEEN AQUATIC ROOT ZONE - AND TEXTILE MEDIUM -INTEGRATED FIXED-FILM ACTIVATED SLUDGE (IFFAS) WASTEWATER TREATMENT SYSTEMS.

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ABSTRACT

Aquatic root zone treatment depends on contact of wastewater with roots from plants growing at the water surface. Combining extended-air, activated sludge treatment with biofilms growing on roots creates an integrated fixed-film activated sludge treatment system (IFFAS). This study made parallel, pilot scale comparisons of an aquatic root zone - IFFAS treatment system with a synthetic textile medium - IFFAS treatment systems, and an activated sludge treatment system. Flow to each treatment train was 1000 gpd of raw domestic influent. Both IFFAS treatment systems exhibited the same COD treatment (95% removal +/- 3%). Seventy percent of root zone – IFFAS total nitrogen effluent values were ≤ 10 mg/L, but less than 20% of the textile medium – IFFAS effluent values were ≤ 10 mg/L. Retention of biosolids in plant roots appeared to enhance treatment performance and stability. Yield was apparently lowest in the planted train.

KEYWORDS

aquatic treatment, fixed-film, wetland treatment, activated sludge, root zone, biofilm, wastewater

INTRODUCTION

Aquatic root zone (ARZ) wastewater treatment systems rely on the roots of plants floating or supported at the water surface to treat wastewater. Termed aquatic treatment systems in wastewater treatment literature, the term ARZ is used here to distinguish between fundamentally different aquatic treatment technologies. Roots have no direct role in treatment in *Lemna* lagoons (Crites and Tchobanoglous 1998), but a direct major treatment role in water hyacinth lagoons (Reed, Crites, and Middlebrooks 1995). Water hyacinth systems are classified here as ARZ systems, but *Lemna* ponds are not. The treatment performance of ARZ systems has been extensively documented (WCPH and EOA 1996, EPA 1988, Tchobanoglous et al., 1987, Jewel et al., 1983), but parallel comparison of ARZ and other treatment systems appears absent in the literature. Parallel comparisons elucidate the treatment role provided by plant roots in aquatic treatment systems. This study compared the role of roots in ARZ treatment to both activated sludge and integrated fixed-film activated sludge (IFFAS) treatment systems. In both studies the planted system was also an IFFAS system with plant roots serving as a fixed-film substrate.

BACKGROUND

Planted surfaces create a superficial resemblance between ARZ and wetland treatment systems, but wetland treatment literature is of little value to elucidate the treatment role of roots in ARZ systems. Plant roots have no direct treatment role in surface flow wetlands, but ostensibly play a significant treatment role in subsurface flow wetlands. Results from studies comparing vegetated and unvegetated subsurface flow wetland treatment systems indicate that plants do not significantly impact treatment (USEPA 2000, Watson and Danzig 1993) even though there is strong evidence that the presence of roots in subsurface flow wetlands significantly affects the composition of microbial populations (Hatano, et al. 1993). Findings of a minor treatment role for plants in subsurface flow wetlands are valid, but offer little insight into the potential treatment role of roots because of inherent confounding factors.

The inherent confounding factors arise from the relationship between roots and media, and the growth characteristics of roots. The treatment effect of roots is likely to be poorly distinguished from that of media if the media surface area is very large compared with that of plant roots. Moreover, in horizontal subsurface flow wetlands roots tend to grow little below the permanently wetted media surface and tend to create a dead zone through which little wastewater flows (USEPA 2000). Obviously, the potential treatment role of roots cannot be determined if there is minimal root contact with wastewater. Comparative studies of surface loaded, vertical flow wetlands (Watson and Danzig 1993) theoretically avoid the root-zone flow problems of horizontal subsurface flow wetlands because surface loading forces flow through the root zone. Distinguishing between the treatment effects of media and roots may still be difficult, however. Root zone architecture may also be a confounding factor because it differs significantly between species used in treatment wetlands and evolves as plantings mature (Meyer 1999). Species-specific root architecture may affect treatment directly (Potter and Karathanasis 2001), and indirectly by altering media porosity (USEPA 2000) and thus altering wetland hydraulics. The confounding factors presented above prevent extraction of strong conclusions on the potential treatment role of roots from the wetland treatment literature.

The treatment role of plant roots has been investigated without the presence of media or soil in water hyacinth (WCPH and EOA 1996, USEPA 1988, Tchobanoglous et al., 1987) and nutrient film[1] treatment systems (Jewel et al., 1983). The clear finding of these studies is that, in a properly designed treatment system, plant roots alone can reliably provide stable tertiary quality BOD and TSS treatment. Data on nitrification performance are inconsistent even with long hydraulic residence times, positive dissolved oxygen, and sufficient alkalinity. Nutrient film treatment systems have poor nitrification performance (Jewel et al., 1983). Aerated water hyacinth treatment systems appear to have limited nitrification capacity (WCPH and EOA 1996).

Both water hyacinth and nutrient film treatment systems require large land areas because of shallow treatment basin depths and low reaction rates (Crites and Tchobanoglous 1998, Jewel et al., 1983). One design approach to shrink the size of ARZ systems is to grow large plants on fixed racks on the surface of shallow, activated sludge, extended-aeration treatment systems (Austin, et al., 2000). This approach is motivated by the treatment stability of aerated water hyacinth systems compared to activated sludge treatment (Austin and Tchobanoglous 1995). The higher reaction rate of low-concentration mixed liquor suspended solids (MLSS), extended-air treatment is then combined with the stability of ARZ treatment. Greater stability makes activated sludge treatment more reliable in small flow advanced treatment applications.

[1] Nutrient film treatment systems use thin films of wastewater on roots of plants growing in shallow containment without soil or other medium.

The questions arising immediately from this type of design are: What, if any, treatment role do the plants play? And does this role confer a treatment advantage? A rational design basis for combined activated sludge / ARZ treatment systems depends on this information. Because plant roots act as a fixed-film substrate (Reed, Crites, and Middlebrooks 1995), this combination will be referred to as a root zone - integrated fixed-film activated sludge (IFFAS) treatment system.

Treatment basin depth in relation to average root depth has a significant effect on treatment performance (Reed, Crites, and Middlebrooks 1995). At least a 20% penetration of the treatment water column by the root mass appears to be necessary (USEPA 2001), which sets a depth of about four feet for aerated water hyacinth treatment systems with step feed and recycle (WCPH and EOA 1996).

METHODS

Two pilot studies were performed to investigate the treatment role of plant roots in a root zone - IFFAS system. A preliminary, short-term parallel study (Study I) compared a root zone – IFFAS system to an activated sludge system that did not have a fixed-film substrate. Study II provided a one-year, parallel comparison between a root zone- IFFAS and a textile medium - IFFAS treatment system. Both studies are presented below.

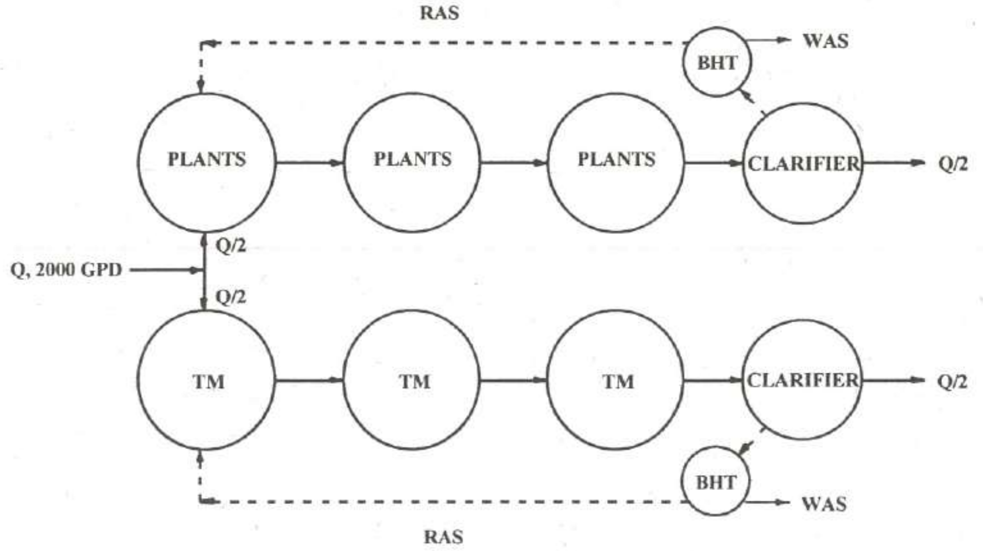
Both studies used two parallel treatment trains with three aerated reactors in series (**Figure 1**). Approximately 7.5 m^3/d (2,000 gpd) of raw domestic influent was split equally between the first reactors of each train. Metered, equal airflow was delivered to each train at approximately 1 to 2 SCFM per reactor. An equal positive dissolved oxygen profile was maintained in each treatment train. Identical, dedicated, medium-bubble, ceramic diffusers supplied air to each reactor.

The calculated hydraulic residence time (HRT) in each train was approximately one day. No tracer studies were conducted to determine actual HRT. The working volume of each reactor was approximately 1.2 m^3 (330 gallons). Depth and diameter of each reactor were 1.1 meters (3.5 feet) and 1.2 meters (4 feet), respectively.

In Study I (September–December 1997), each train did not have a dedicated clarifier. Instead, equal doses of nitrifying biosolids were manually diverted to each train once or twice per day from an adjacent 152 m^3/d (40,000 gpd) ARZ treatment train. Study I obtained baseline data prior to installation of dedicated clarifiers in each treatment train.

For Study II (Aug. 1998–Aug. 1999), each train was outfitted with a clarifier and a biosolids holding tank, which permitted automated recycle of activated sludge (RAS). Biosolids were manually wasted as needed from each holding tank and waste volumes recorded. The MLSS in each treatment train was maintained close to 1,000 mg/L as monitored daily by a calibrated Royce TSS meter. One train had mature wetland plants on racks fixed at the water surface of each reactor. Each reactor in the other train was equipped with fringed sheets of a buoyant, synthetic textile medium (Aquamat®), chosen as roughly analogous to plant roots. The medium was anchored to reactor bottoms, extending in 1.5-inch wide fronds to the water surface. Estimated effective surface area of the Aquamat® was approximately 20 m^2 per reactor.

Figure 1 - Process Schematic for Study II. Study I did not have dedicated clarifiers, but used the same parallel treatment trains. Recycle activated sludge (RAS), waste activated sludge (WAS), biosolids holding tank (BHT), textile medium (TM), flow (Q).



The plants used in both studies had been previously evaluated to reliably produce substantial root masses 18 to 24 inches long under study conditions. Root penetration into the reactors was at least 30%. Each planted reactor had 99% surface coverage of at least three of the following genera: *Cyperus, Canna, Alocasia, Juncus, Salix, Zantendeschia,* and *Colocasia.*

Treatment performance was evaluated for COD, NH_3-N, and NO_3-N (Studies I and II). Additionally, BOD_5 and TKN-N were tested in July-August 1999 (Study II). In Study II, refrigerated, 24-hour composite samples were taken from the third reactor in each train and filtered. Grab samples were used for Study I. An in-house laboratory processed all samples except those of July-August 1999, which were sent to a certified contract laboratory. Samples were accepted if influent flows were between 3.0 and 4.5 m^3/d per train and differing no more than 10% for the previous 24 hours. The average flow difference was 0.4% (s = 3.4%).

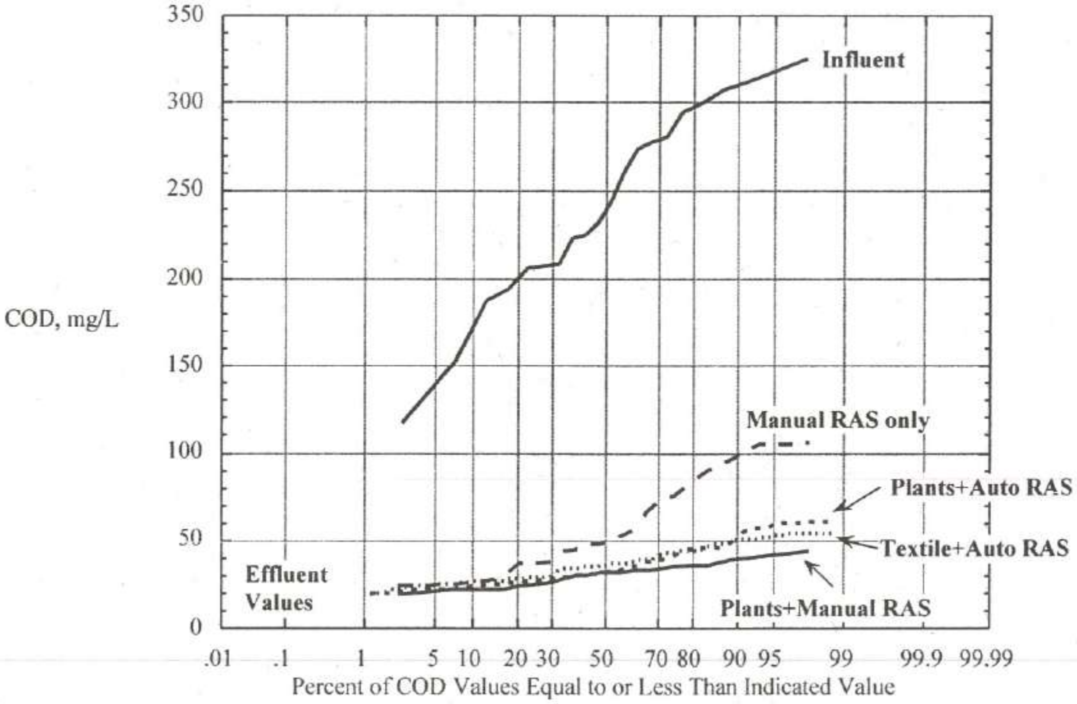
RESULTS

Study II COD treatment performance was the same in both treatment trains, but Study I COD performance was significantly better in the planted train (**Figure 2, Table1**). No difference in BOD treatment performance and stability was observed in Study II. Study II total nitrogen (TN) removal in the planted train was superior to that of the textile medium train. Seventy percent of Plants + Auto RAS effluent values were less than or equal to 10 mg/L TN, less than 20% of the Textile + Auto RAS were less than or equal to 10 mg/L (**Figure 3**). The frequency distribution

Table 1 - Treatment Summary. Mean values with standard deviation s, and sample size n.

Parameter	STUDY I Influent	STUDY I Plants + Manual RAS	STUDY I Manual RAS Only	STUDY II Influent	STUDY II Plants + Auto RAS	STUDY II Textile + Auto RAS	Unit
COD	578	31 / 95%	57 / 90%	628	34 / 95%	34 / 95%	mg/L / % removal
s	138	7 / 1%	26 4%	154	17 / 3%	17 / 3%	mg/L / %
n	29	22	22	57	25	25	
TN	-	-	-	31.1	9.8 / 68%	11.7 / 62%	mg/L / % removal
s	-	-	-	6.1	3.5 / 11%	2.6 / 8%	mg/L / %
n	-	-	-	45	12	12	
$NH_3 + NO_3$,	20.4	5.7 / 72%	14.0 / 31%	15.4	6.4 / 58%	8.8 / 43%	mg/L / % removal
s	2.6	2.8 / 14%	7.7 / 38%	6.4	3.3 / 21%	4.8 / 31%	mg/L / %
n	12	11	11	61	20	20	

Figure 2 - COD Treatment Performance. See Table 1 for mean values, standard deviations and sample size.

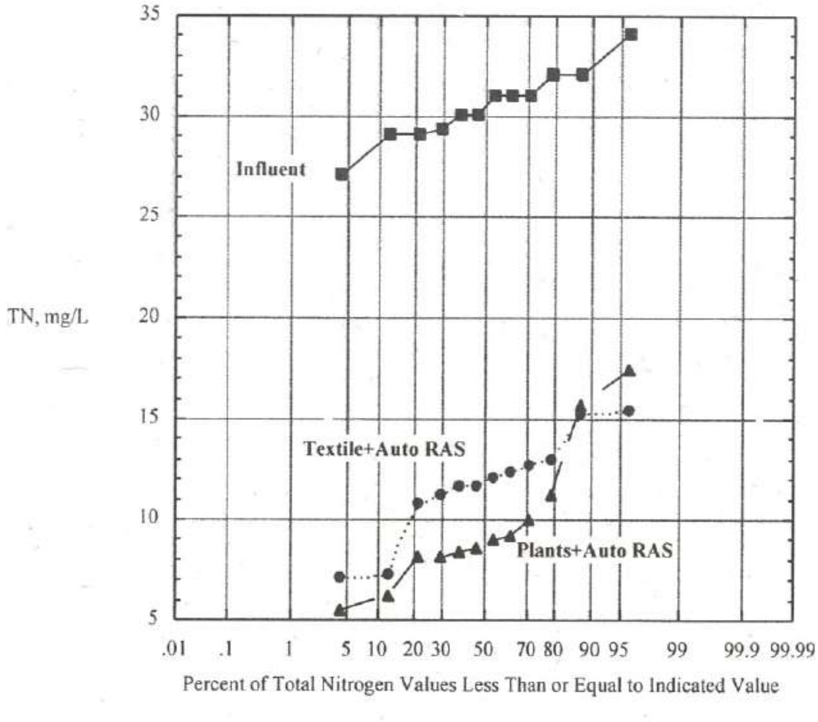


of effluent values for NH_3-N + NO_3-N [2] for Study I was similar to that of Study I COD effluent values (**Figure 4**). In Study II, treatment performance and stability for NH_3-N + NO_3-N was similar to that of TN (**Figure 4, Table 1**).

Yield (Study II) for the textile medium train was approximately 0.3 kg VSS/kg $BOD_{5\ in}$, and for the planted train less than 0.1 kg VSS/kg $BOD_{5\ in}$. Yield data collection was not part of the original experimental protocol. The yield results were obtained from biosolids waste volumes recorded in operations logs over a 29-day period after reports by the operator that he was unable to consistently reach the target MLSS concentration in the planted train. Yield calculations assumed a solids fraction of 1% with 85% VSS. Biosolids washout from the clarifiers is a confounding factor that cannot be ruled out from the yield result. Although it is likely that washout would have affected both trains equally, yield results should be regarded with caution.

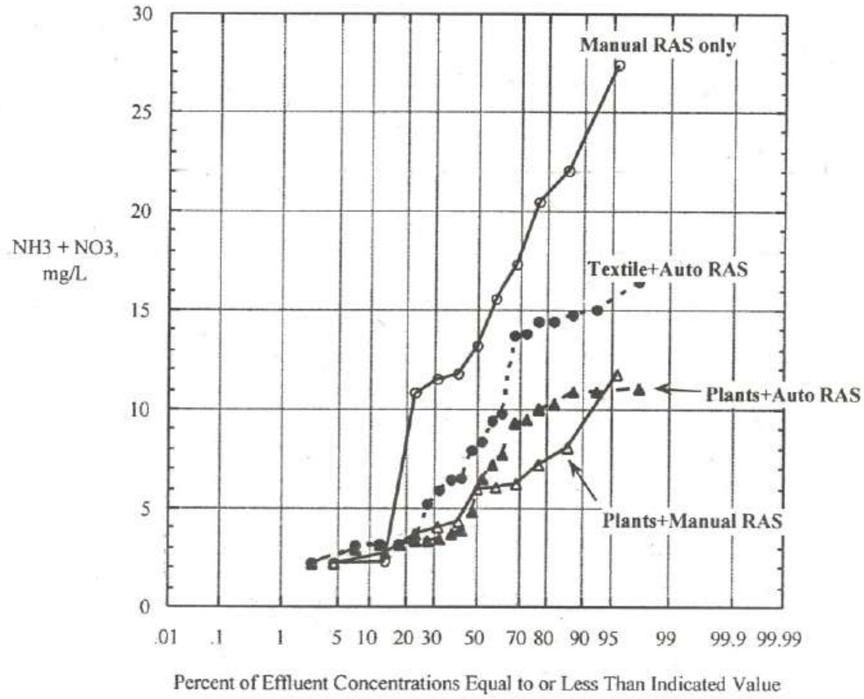
At the end of Study II plant roots and reactors were examined for build-up of biosolids. The plant roots had not accumulated biosolids, but were densely populated by snails. No significant accumulation of sludge was observed in the planted reactors.

Figure 3 - Total Nitrogen Treatment Performance. See Table 1 for mean values, standard deviations and sample size.



[2] NH_3-N + NO_3-N was used as a TN surrogate parameter because the in-house laboratory was not equipped to analyze TKN. The mean difference between effluent TKN-N and NH_3-N was 1.6 mg/L (s = 1.0 mg/L, n = 12) for Plants + Auto RAS, 1.2 mg/L (s = 0.7 mg/L, n = 12) for Textile + Auto RAS. NH_3-N + NO_3-N thus appears to be a reasonable surrogate here for total nitrogen.

Figure 4 - NH_3-N + NO_3-N Treatment Performance. See Table 1 for mean values, standard deviations and sample size.



DISCUSSION

Plant roots appear to provide two principal treatment mechanisms in a root zone IFFAS treatment system. One is treatment by biofilms growing on plant roots; the other is treatment by biosolids retained on plant roots.

Virtually identical COD treatment performance and stability between the two trains in Study II (**Figure 1**) may be attributed to either fixed-films growing on plant roots and the textile medium, or to automated RAS, or to a combination of the two processes. Based on the evidence of Study II alone, it is not possible to determine quantitatively how treatment credit should be apportioned. Given the inherent instability of the activated sludge process in such a small treatment volume, it is likely that biofilms significantly influenced the overall treatment stability observed in both experimental trains.

Comparison of the COD treatment results between Studies I and II suggests that retention of biosolids in plant roots was a significant treatment mechanism. In Study I, when biosolids were dosed to the trains only once or twice per day, COD treatment performance and stability was significantly better in the planted train. This result is not surprising because of probable erratic MLSS concentrations in the unplanted train. It is surprising, however, that COD treatment removal performance in the planted train did not change between Studies I and II whether RAS was dosed once, twice, or several times per day. Were the biofilms on plant roots or the biosolids retained in plant roots the mechanism for COD treatment stability in both studies?

The results of Studies I and II total nitrogen treatment stability and performance (**Figures 3 & 4, Table 1**) provide stronger evidence in favor of the retained biosolids mechanism. Total nitrogen treatment performance and stability in the planted train did not change significantly between the two studies, but was significantly better than that observed in the textile medium + RAS train. Because influent nitrate concentrations were consistently below non-detect limits, nitrification within each treatment train is solely responsible for denitrification performance. As noted earlier, plant roots alone in aerated ARZ treatment systems tend to exhibit limited nitrification performance. It is therefore probable that nitrifying biosolids retained on plant roots were responsible for nitrification. Denitrification is also likely to have occurred in the root zone. Root masses appeared to attenuate mixing energy, probably facilitating the formation of anoxic zones that slowly exchanged volume with the bulk wastewater. Biofilms growing on plant roots and biosolids retained within plant roots would facilitate denitrification.

The apparent low yield of the planted train may be explained by retention of biosolids long enough to be consumed by snails and other grazing organisms. Despite the caveat expressed earlier regarding yield results, low yield in ARZ systems is not a new observation. Effluent VSS in aerated water hyacinth treatment systems can reach tertiary treatment standards (WCPH and EOA 1996), with a TSS accumulation in treatment basins requiring removal only every 2 to 5 years (Reed, Crites, and Middlebrooks 1995). The root zone in water hyacinth treatment systems is known to host a diverse microbial community (Brix 1993. Reed, Crites, and Middlebrooks 1995). Low effluent VSS in these systems is probably a result of grazing of bacteria by protozoa and higher invertebrates living in the root zone (Brix 1993. Crites and Tchobanoglous 1998). Although no survey of root community organisms was conducted for this study, the dense population of snails observed in the roots of planted reactors suggests that grazing contributed significantly to low yield.

Retention of biosolids appears to confer operational stability by retarding washout of biosolids from treatment reactors. In the author's experience, biosolids management in small, activated sludge treatment systems is a science and art requiring skills learned with difficulty. Treatment performance and stability is easily compromised by biosolids washout in small, activated sludge treatment systems. Small, activated sludge treatment systems often do not receive sufficient operational attention or skill to adequately manage biosolids and are therefore not recommend by the EPA (EPA 2000). Study I unintentionally simulated poor biosolids management, but treatment performance was subsequently shown not to have suffered as a result. There was no significant difference in the planted train treatment performance and stability between Study I with sporadic biosolids recycle and Study II with automated biosolids recycle.

CONCLUSIONS

As reported in the ARZ treatment literature, plant roots impact treatment by providing a large surface area for biofilm formation and by hosting a community of organisms that consume microbial biomass. These treatment mechanisms were probably significant in the studies reported here. When an ARZ system is combined with extended-aeration, activated sludge treatment in shallow reactors, another treatment mechanism emerges; retention of biosolids on plant roots.

Retention of biosolids was a significant mechanism in the studies presented here. Without further studies, it is not possible to determine quantitatively how to apportion treatment credit between biofilms and retained biosolids.

Total nitrogen treatment performance and stability appears to be significantly enhanced by retention of biosolids on plant roots.

From this study one would conclude that here is no difference in COD or BOD treatment performance or stability between root zone IFFAS and textile medium IFFAS treatment systems.

Retention of biosolids on plant roots appears to lower yield and confers resistance to biosolids washout, but these results require further investigation to quantify.

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Annexure-XX

LIST OF DOCTORS IN DIFFERENT BLOCKS

Block Name: Pachperwa

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. M. Alam	M.B.B.S.	Dysentry	30
2	Dr. Zubin Ahmad	B.D.M.S.	Cholera	10
3	Dr. Dinesh	B.D.M.S.	Chicken Pox	5
4	Dr. Deepak Kumar	M.B.B.S.	Blue Baby Syndrome	3
5	Dr. A.H. Ansari	M.B.B.S.	Jaundice	25
6	Dr. Nawab Ahmad	B.D.M.S.	Asthama	30
	TOTAL			**103**

Block Name: Tulsipur

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. Babban	B.D.M.S.	Diorrhea	20
2	Dr. Owais Ahmad	B.D.M.S.	Cholera	10
3	Dr. Md. Siddiqui	B.D.M.S.	Chicken Pox	3
4	Dr. M.F. Khan	M.B.B.S.	Blue Baby Syndrome	1
5	Dr. Yunus Azam	M.B.B.S.	Jaundice	10
6	Dr. O.P. Siddiqui	M.B.B.S.	Diorrhea	11
7	Dr. Zubin	M.B.B.S.	Skin Irritation	10
8	Dr. Narul Hassan	B.D.M.S.	Asthama	30
	TOTAL			**95**

Block Name: Rehra Bazar

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. F. S. Siddiqui	B.D.M.S.	Cholera	30
2	Dr. M. Ahmad	B.D.M.S.	Chicken Pox	15
3	Dr. A K. Bhat	B.D.M.S.	Chicken Pox	12
4	Dr. A. Khan	M.B.B.S.	Blue Baby Syndrome	4
5	Dr. Ali	M.B.B.S.	Blue Baby Syndrome	5
6	Dr. P. Singh	M.B.B.S.	Diorrhea	10
7	Dr. Chandra	M.B.B.S.	Skin Irritation	5

8	Dr. N. Pratap	B.D.M.S.	Asthama	10
	TOTAL			91

Block Name: Gainsari

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. M. Abbas	B.D.M.S.	Diorrhea	25
2	Dr. H. Ali	M.B.B.S.	Diorrhea	15
3	Dr. R. P. Singh	M.B.B.S.	Chicken Pox	10
4	Dr. Deepak	B.D.M.S.	Blue Baby Syndrome	1
5	Dr.K. Gupta	M.B.B.S.	Diorrhea	10
6	Dr. B. K. Pandey	B.D.M.S.	Asthama	25
	TOTAL			86

Block Name: Utraula

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. Nisar	M.B.B.S.	Jaundice	10
2	Dr. Fuzul Haque	M.B.B.S.	Jaundice	5
3	Dr. Javed	M.B.B.S.	Skin Irritation	1
4	Dr. Tiggo	M.B.B.S.	Blue Baby Syndrome	3
5	Dr. Malik Hamid	M.B.B.S.	Dysentry	15
6	Dr. Om Prakash	B.D.M.S.	Cholera	10
7	Dr. Sunaullah	B.D.M.S.	Chicken Pox	20
8	Dr. Kharinisa	M.B.B.S.	Blue Baby Syndrome	3
9	Dr. A.H. Ansari	M.B.B.S.	Jaundice	25
10	Dr. Nawab Ahmad	B.D.M.S.	Asthama	30
	TOTAL			103

Block Name: Gaindas Buzurg

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. Ravi Pratap	M.B.B.S.	Chicken Pox	20
2	Dr. Pramod	B.D.M.S.	Jaundice	15
3	Dr. Biswas	B.D.M.S.	Chicken Pox	5
4	Dr. P. Singh	M.B.B.S.	Blue Baby Syndrome	4
5	Dr. Ashok Singh	M.B.B.S.	Jaundice	20
6	Dr. N.K. Pandey	B.D.M.S.	Asthama	30

	TOTAL	94

Block Name: Balrampur

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. Ashok Singh	M.B.B.S.	Blue Baby Syndrome	6
2	Dr. Afzal Khurana	M.B.B.S.	Chicken Pox	7
3	Dr. M.F. Yadav	M.B.B.S.	Chicken Pox	5
4	Dr. Shakti	M.B.B.S.	Asthama	4
5	Dr. G.K. Singh	M.B.B.S.	Skin Irritation	8
6	Dr. A. K. Rana	M.B.B.S.	Dysentry	30
7	Dr. Nawab Ali	B.D.M.S.	Cholera	7
8	Dr. S. Siddiqui	B.D.M.S.	Chicken Pox	5
9	Dr. K. Singh	M.B.B.S.	Blue Baby Syndrome	3
10	Dr. R.P. Singh	M.B.B.S.	Jaundice	13
11	Dr. Nawab Ahmad	B.D.M.S.	Asthama	10
	TOTAL			**98**

Block Name: Haraya Satgrharwa

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. M. Aslam	M.B.B.S.	Diorrhea	17
2	Dr. Rasool Ahmad	B.D.M.S.	Cholera	9
3	Dr. Raghav	B.D.M.S.	Chicken Pox	8
4	Dr. K.P. Singh	M.B.B.S.	Blue Baby Syndrome	2
5	Dr. R. H. Ansari	M.B.B.S.	Jaundice	15
6	Dr. Nabi	B.D.M.S.	Asthama	20
	TOTAL			**71**

Block Name: Shri Gutt Ganj

S.No	Doctor's Name	Qualification	Disease	Number of Patients
1	Dr. Mohd. Ahmad	M.B.B.S.	Asthama	23
2	Dr. Nawab Arzoo	B.D.M.S.	Jaundice	15
3	Dr. Prakash	B.D.M.S.	Skin Irritation	5
4	Dr. Rajeev Kumar	M.B.B.S.	Blue Baby Syndrome	3
5	Dr. Rahman	M.B.B.S.	Jaundice	10
6	Dr.Alimgaer	B.D.M.S.	Asthama	25
	TOTAL			**81**