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Study Of Waterlogging And Soil Salinization Problem In And Around Rawatsar Tehsil, Hanumangarh District In The Command Area Of Indira Gandhi Nahar Pariyojna (IGNP) Stage-I, Rajasthan, India

Dr. Annu Maurya

Geology Department, Govt. Dungar College, Bikaner, Rajasthan
(Affiliated with Bikaner University, Bikaner, Rajasthan)

***Abstract:** Indira Gandhi Nahar Pariyojna is the largest irrigation project in the world. It promised to green the desert but has also waterlogged vast tracts of land and more stands in danger of being turned saline through this process. A number of factors viz. large percolation losses, natural inter-dunal depressions located in the Rawatsar tehsil are used to store excess floodwaters of Ghaggar river. As the depressions are filled with water, the area around depression experiences a sudden rise in ground water level causing wide spread water logging condition. The specific areas affected by water logging are west and southwest of Baropal, southeast and southwest of Manaktheri, southeast of Rangmahal, southwest of Kalanwali Dhani. Impounding of Ghaggar flood water in natural depression is the main cause of water logging. The physiographic situation of these villages is such that villages in this belt are located at lower altitude than the depression, which creates a steep gradient and sand dunes being pervious, cause heavy seepage which results in water logging conditions in surrounding areas. The unlined canals from the saddles have further added to the problem.*

***Keywords:** IGNP, Ghaggar river, waterlogging, soil salinization.*

I. INTRODUCTION

Problems of waterlogging and soil salinization are known to have developed in irrigated agriculture since the first human civilization in Mesopotamia. The fall of this ancient civilization is attributed to both waterlogging and soil salinity (Rhoades, 1990). David Shedidan in his book "Desertification of the United States'' calls soil salinization of the irrigated lands as one of the deadliest forms of desertification (Shediden, 1981). No other region where irrigated agriculture is practiced, can be exception to this kind of desertification. It is assessed that at a global scale, 1/3rd of the irrigated land is threatened with the twin problems of waterlogging and soil salinity.

The Indira Gandhi Nahar Pariyojana occupies the north-western and far western parts of the "Thar Desert'" of Rajasthan State. It is one of the biggest projects of its kind in the world aiming at transforming desert wasteland into agriculturally productive area with the objectives of drought proofing, providing drinking water, improvement of environment, development and protection of animal wealth and increasing agricultural production. The project was conceived as a canal project for irrigating desolate land in the desert area. According to the 'Indus water Treaty', India got the exclusive right to use waters of the three rivers namely Ravi, Beas and Sutlej. The project encompasses the districts of Sri Ganganagar, Hanumangarh, Churu, Bikaner, Jaisalmer, Jodhpur and Barmer and on completion will cover Culturable Command Area (CCA) of 19.63 lac ha and irrigate 15.17 lac ha of land. The project work has been taken up in two stages i.e. Stage-I & II. The entire length of the main canal upto Mohangarh (Jaisalmer dist.) was completed in 1986. IGNP Stage-I consists of head reach of the project, comprising 204km long feeder canal originating from the Harike Barrage in Punjab, 189km long main canal (from Masitawali head to Pugal head) and 3400 km long distribution system. The Stage-I area is further subdivided into two phases- Phase 1 consists of commands irrigated by the canal systems off-take between 0 to 74 km of Main Canal and Phase-II of area served by canals originating between Km 74 and Km 189 of the Main Canal. The total CCA is 5.53 lac ha including 61 thousands ha of Kanwar Sain Lift Canal, which forms part of Phase II and serves Bikaner district for drinking water and irrigation uses. The intensity of irrigation as envisaged is 110%, Major distributions of IGNP Stage-I include Rawatsar, Naurangdesar, Anupgarh, Suratgarh and Pugal branches/ distributaries.

There is no uniformity in the way waterlogging is defined. The widely accepted definition is the one by the National Commision on Agriculture. It defines an area as waterlogged, ‘‘When the water table rises to an extent that the soil pores in the root zone of a crop become saturated resulting in the restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon-di-oxide. The Thar desert occupies almost two-third of the total area in the north-west part of Rajasthan state. All along, it has been agriculturally unproductive. To make these lands agriculturally productive, Rajasthan Canal Project was started in 1958 and was later renamed as Indira Gandhi Nahar Paroyojna (IGNP) in 1984. One of the major negative manifestation of IGNP is rise in the water table and development of waterlogging. High temperature, presence of excessive water soluble salts in soils and high rate of evapotranspiration have caused the twin problem i.e. secondary salinization and accumulation of salts on top soils or in sub-soil horizons. According to the Indian Council of Agricultural Research (ICAR), the total salt-affected soils are spread over an area of about 5 million ha. In the country. Many attempts have been made to assess or guess the extent and distribution of salt-affected soils of India. Unfortunately, even today the extent is only superficially known. Table – 1 suggests that area under salt-affected soils vary from a mere 2 million ha. To about 24 million ha. A critical evaluation of the data on the other hand should help to arrive at a more realistic figure. As per feedback received from the NRSA, the 2 million ha. area includes the area where salt infestation could be clearly seen on remotely sensed documents and the EC of the soil is more than 30 dsm^{-1}. The most comprehensive exercise to assess the salt-affected areas in the irrigation commands seems to have been made by the Working Group (1991). Therefore, the total affected area which would include non-commanded and coastal areas, should be more than 3.3 million ha. Apparently, the area reported by Abrol et. al. (1988) includes potential areas where yield have started declining as well as areas that are in danger of turning waterlogged and saline in the near future unless preventive and remedial measures are adopted in time. Thus, one can say that the extent of salt-affected areas that have gone out of cultivation could be some where between 6 to 9 million ha. Although, the higher figure of this range still differs by about 50% from the lower figure, yet the range is quite narrow relative to the range if all the figures are taken into consideration. One of the recommendation emerging from technical sessions of the ICID Drainage Workshop held at New Delhi has very vividly highlighted the state of affairs on this issue. It says that the data on waterlogging and salinity are not adequate and there is need to update the information using latest techniques of remote sensing and GIS. Thus, the need for assessing the exact extent and distribution of waterlogged salt-affected lands and its reappraisal say after every five years should essentially be a part of the policy and programmes on land reclamation.

Since its commencement in 1963, the IGNP has been the principal source of the irrigation in the areas it covers. The canal irrigation in Rajasthan desert has a high share of 70.57% of the total net irrigated area. In 1994-95, the total net irrigated area was 1310034 ha. and the canal irrigated area was 924501 ha. according to the Deptt. of Economics and Statistics, Govt. of Rajasthan, Jaipur. Before the introduction of canal irrigation in Thar desert, absolute dependence upon uncertain rainfall and perpetual violent fluctuations in production of crops were common features and they put the agricultural activities to business of secondary importance. Various factors like the absence of natural drainage and the presence of the hard pan at shallow depth, excessive intence irrigation and a certain amount of mismanagement of the canal water have all contributed collectively in creating many adverse environmental effects. Rise in water table, seepage and waterlogging, salinization, creation of marshy lands, invasion of obnoxious weeds and some related health hazards are the major ones among them. These effects are exercising a considerable impact on the entire ecology of zone. Waterlogging and salinization are the foremost among these problems. Waterlogging is a direct consequence of the rise in water table. The water table was very low in the area before the introduction of the canal irrigation. It ranged between 40 to 51 bgl in the year 1952. Now around 10.4% of the total irrigated area by the IGNP has a water table depth between 0 to 6 m. This rise in water table is caused by excessive intense irrigation, seepage from the canal and above all by the presence of hard pan at a low depth of 0 to 20 m. When the water table rises up to 6 m bgl, the area is considered potentially sensitive area in respect of the waterlogging. The area of Stage-I of IGNP has been facing the problems of waterlogging and secondary soil salinization by the year 2000. A sizeable land areas falls under three types of, potentially sensitive, critical and waterlogged and in all the three categories the land size is increased. The water level data collected from the piezometers of IGNP area have been used to demarcate waterlogged, critical and potentially sensitive area on the basis of monitoring of water table. There was a steady rise in waterlogged, critical and potentially sensitive area up to to the year 1998. During the period 1999 to 2003, the waterlogged, critical and potentially sensitive areas have shrunken considerably. During 2003-04, there is increase in potentially sensitive area and critical area but there is decrease in waterlogged area. In year 2004-05, there is a decrease in potentially sensitive area, but an increase in critical area and waterlogged area. In the year 2005-06, there is a uniform increase in all the three categories viz. potentially sensitive area, critical area and waterlogged area.

II. RESEARCH METHOD

The climate of the study area is semi-arid to arid except southwest monsoon season during the period June to mid of September, which is followed by post monsoon period till the end of November. The winter season is from December to February and is followed by summer from March to June. The mean daily maximum temperature varies from 20.5°C during January to 42.2°C during June while mean daily minimum temperature in the district varies from 4.7°C during January to 28.1°C during July. The Normal Annual Rainfall of the district during the period 1901-2006 has been 333.27 mm. The district is a part of Thar desert and is covered by thick layer of alluvium and wind blown sand. Generally sand dunes are 4 to 5 m in height. Regional elevation of ground ranges from 100 to 300 metres above mean sea level (msl). The district has a regional slope of less than 5 m/km. Ghaggar river, locally known as Nali, is the only marked surface water drainage, which flows from NE to SW. It is an ephemeral river which sometimes gets flooded during monsoon.

The data collected through a network of 78 piezometers have been analysed for the year 2003. On the basis of data, contour maps of the waterlogged areas of the study area were prepared for the year 2003 pre and post-monsoon. The data were collected by field survey. Previous years data were collected by CAD [Command Area Development, IGNP, Bikaner, Rajasthan]. In the year 2003-04, potentially sensitive areas [water table within 1.5 to 6.0 m] were spread in 195,000 ha, critical areas [water table within 1.0 to 1.5 m] in 9,576 ha and waterlogged areas [water table within 0.0 to 1.0 m] in 207,111 ha. In the year 2003 pre and post-monsoon, Haripura, 19 AG, Kumharonwali, Gandheli and Dhannasar Kanchiyan were waterlogged areas. In 2003, lowest water level was in Rawatsar which was 0.36 m in pre-monsoon and 0.43 in post-monsoon.

III. DISCUSSION

A. NATURE OF THE PROBLEM OF THE STUDY AREA

The study area Rawatsar is a part of IGNP command area Stage-I and irrigated by Rawatsar and Naurangdesar distributaries. The problem of waterlogging and surface ponding has destroyed the natural environment of the area and has caused formation of the saline soils. The monitoring of observation wells and piezometer indicates that the water table in Rawatsar area is rising at an average rate of 0.93 m per year from the year 1952-1994. In general a rise of 0.40 m per year for the period 1952-1970, 0.66 m/ year for the period 1984-1989 and 0.41 m/year for the period 1995-2004 has been recorded in waterlogged areas. The major cause responsible for the waterlogging is the existence of hard pan of gypsum which does not allow percolation of water. In addition to that, absence of natural drainage, seepages from the main canal, unlined water courses, return seepage of irrigation water, soil texture, high water allowance and seepage from Ghaggar depressions are the other causes of waterlogging. The productivity of the waterlogged land especially crop yields declined substantially leading the farmers to quit their occupation. Water management of the waterlogged area became difficult and the hydrologi`cal conditions of the area disturbed.

B. CAUSES OF WATERLOGGING IN THE STUDY AREA

- ✓ Seepage from various sources
- ✓ Poor natural drainage as a consequence of unfavourable topography and unfavourable sub-soil geology
- ✓ Existence of hard pan at shallow depths
- ✓ Excessive and constant intense irrigation
- ✓ Excess application of water particularly in the initial years when the command was not aptly developed
- ✓ Poor on-farm management and unrealistic cropping pattern
- ✓ Hydraulic pressure of water from upper irrigated areas resulting in seepage outcrop in low areas and rainfall.

SEEPAGE FROM VARIOUS SOURCES – According to Central Water and Power Research Centre's report on IGNP, there are two main reasons of seepage from the main canal. The sidewalls of the main canal have been constructed using 25-50% of silt and 50-75% of fine to medium sand with a permeability ranging between 10^{-7} m/sec. to 10^{-5} m/sec. A possible another cause is the injured lining of the main canal.

There are five sources of seepage in the Stage-I area of IGNP including

- ✓ *SEEPAGE FROM MAIN CANAL AND BRANCHES* – WTC prescribed the norm for seepage estimation in case of lined canal is 0.30 $m^3/sec/Mm^2$ of wetted perimeter and 21.45 $m^3/sec/Mm^2$ of wetted perimeter in the case of unlines canal. Main canal and branches are fully lined.
- ✓ *SEEPAGE FROM IRRIGATED AREA AND PADDY FIELDS* – Water supply and water demand data of IGNP command area suggest that there is a marked difference between the actual field requirement and the water supplies. For example, the Gross Irrigation Requirement (GIR) = Field requirement + Conveyance loss in Anoopgarh and Suratgarh branch is 65310 ham (Kharif) and 52427 ham (Rabi) respectively while the water supply is 80577 (Kharif) and 74633 (Rabi) respectively. This excess supply of water resulted seepage problem from irrigated area. Paddy crop is grown in 1.33% of the culturable command area. Groundwater Board indicates that seepage through paddy crops ranges from 0.01 MCM to 12 MCM.
- ✓ *SEEPAGE FROM GHAGGAR DEPRESSIONS* – Water flow in Ghaggar river is available only in monsoon season but it is retained in the depressions between Suratgarh town and IGNP canals. There are 18 such depressions and they have a capacity to store 840 MCM of water collectively. A diversion canal 48.17 m long (Discharge Capacity: 240 m^3/sec) has been constructed to direct the waters of the river to these depressions. Permanently impounded water has a high rate of infiltration, therefore, a big area in lower reaches has got waterlogging problem.
- ✓ *GROUNDWATER RECHARGE FROM DIFFERENT SOURCES* - The gross amount of the groundwater recharge in the IGNP area has been computed at 962

MCM of different sources shows a distribution of groundwater recharge.

- ✓ *ABSENCE OF NATURAL DRAINAGE SYSTEM* – One of the most important factor that causes waterlogging in the IGNP area is an absence of any natural drainage system. There is virtually no effective river in the area hence no surface drainage is possible. The river Ghaggar originating from the Shivalik hills, flows only for 3 kms in the western part of the Hanumangarh district. During its spring time in monsoon it however, inundates a 7 km wide strip in Ganganagar district. Many researches indicate that there existed a river system in the area in the past geological ages. Researches have also tried to trace the palaeochannels of the extinct river and have tried to study the evolution of present geomorphological and geological conditions. In the study area around Rawatsar is a complete absence of any natural drainage system in this area. Palaeochannels in north of Hanumangarh, north of Rawatsar and between Ajitpura and Birkali village have been traced out.
- ✓ *PRESENCE OF HARD PAN* – Presently, the aquifer system in the IGNP Stage-I area is made up of a complex arrangement of layers of sand and clays. It has frequent lenses of silt, clay and kankar and occasional gravel horizons. The Quaternary ones are consist of recent and sub-recent aeolian sand deposits and alluvium. There are brownish and yellow sands, gravel and partly consolidated kankar. The Tertiary ones have limestone, gypsiferous and bentonitic clays, shales, chalk, marl and ferruginous, argillaceous and gritty sandstone. Presence of a hard pan is a hydrological barrier that does not allow the percolated water to infiltrate deeper. The hard pan is not continuous on a regional basis and hence it becomes difficult to design any uniform and broadly applicable remedial device. A block diagram of Masitawali Head, Rawatsar and Jhakhranwali manifests the layer wise arrangement with sand as upper most layer followed by clay and kankar immediately. These details show evidently that the infiltrated water is blocked underneath and is not allowed to move further. The presence of impervious layers accompanied by absence of surface drainage outlet is a major factor in rise of the water table and subsequent waterlogging.
- ✓ *SOIL RELATED CAUSES* - Soils of the arid region are generally sandy and considered infertile. The soils of the IGNP area form a part of vast former flood-plains mixed with sandy aeolian deposits of Ghaggar, Saraswati, Chautang, Sutlej and Eastern branches of Indus. All of them eventually drained at some period in the past into the Rann of Kachchh. During the Pleistocene time, the western Rajasthan became gradually drier. Two dominant soil formations present in the area are flood-plains and aeolian deposits. At some places, desert plain soils and lateritic crusts are also found. The flood plain soils are highly stratified, deep, calcareous and generally associated with the problems of salinity and alkalinity. Aeolian soils are overlying the flood plains and other extensive areas of medium to high dunes and influential flats which occupy much of the southern and western part of the project area. In the interdunal planes, occasional kankar or gypsiferous soils are present in the sub-soil within 1.5 m of the soil surface at places.

  The Agriculture Department conducted a detailed survey in the study area around Rawatsar in 1968. It stated that most of the soils are deep and light in texture except in Aranywali-Rampura association where they are of heavier texture. These heavier textured soils are found in the low-lying areas. Lime in powdered form is common in occurrence. Soils have moderately rapid permeability except in Rampura and Mirzawali series. This survey divided the soils of the study area into four irrigability classes viz. class-I, class-II, class-III and class-IV. Waterlogging has occurred more intensely in the class-I areas because this soil class is well-drained and has higher permeability.
- ✓ *HIGH WATER ALLOWANCE* – Excess application of water particularly during the initial years when the command area was not fully developed and constant excessive intense irrigation are two of the important causes of waterlogging. It is clearly evident now that in early years, availability of water was much higher than the actual requirements. Besides this, canal water meant for Stage-II was used in Stage-I area. For example, in 1994-95, the allotted water was 4156.17 Mm^3 to irrigate 5.25 lac ha. land but it drew 5562.88 Mm^3 a 26% higher share. High water allowances have always more available on surface. The water allowance of the IGNP is currently 5.23 cusec/thousand acres. It has been recommended constantly by various governmental and non-governmental agencies to reduce it to 3 cusec/thousand acres. The share of Stage-I is 3.38 MAF and would be 2.262 MAF. Water allowance is reduced to 3.5 cusec/thousand acres. The current Kharif and Rabi Deltas are 2.5' and 1.71' which are 42.85% and 36.80% more than required. This high delta is three times more effective in contributing to waterlogging than total seepage losses. Rawatsar distributary's water capacity is 630 cusec and it has remained same despite the acute waterlogging in the area. If water allowance is reduced, waterlogging can be significantly controlled.
- ✓ *GRADIENT FLOW OF WATER FROM THE UPPER IRRIGATED AREAS TO LOW LYING AREAS* – The IGNP has been designed in such a manner that it flows down from higher altitude areas to lower altitude areas. That is why the first stage of the project did not require lift system support for much of its flow. The entire main canal and the feeder (IGF) have no lift systems. This design has prompted all the surface water to flow downwards. It is assumable that if the higher altitude areas get waterlogged due to hydraulic pressure of water, the infiltrated sub-surface water might flow downwards as well. This assumption can be supported by studying the rise of water table. In the Anoopgarh area, a safe area in regard of waterlogging, currently the average water level in the area is 10.45 m. It was 12.3 m only a year earlier and 12.76 m in 1998-99. Period of 1998-2001 has witnessed a decline in water levels throughout the IGNP area except Anoopgarh. Gradient flow of infiltrated water from the upper Suratgarh and Hanumangarh may well ba a cause being this exceptional rise. The average altitude in

the Hanumangarh area is above, whereas it is around 165 m in Suratgarh and 155 m in Anoopgarh. Baropal neaeby the study area is an interesting example in this regard. It is one of the area that is worst affected by waterlogging. 176-180 m is relatively lower to its adjoining areas.

- *POOR ON FARM MANAGEMENT AND UNREALISTIC CROPPING PATTERNS* – The entire Rajasthan state in general and the area covered by IGNP in particular has very poor rural literacy rates. This poor literacy results in farmers inability to understand the problem in proper aspect. They have less knowledge of pesticides and banned chemicals. In case of waterlogged areas, farmers have shown particular ignorance in selection of crops. They have constantly tried to yield crops with higher water demands. Constant flood irrigation has made the problem worse and there has been completely ignorance based reluctance in applying bio-drainage.
- *RAINFALL AND AVAILABILITY OF WATER* – Rainfall and availability of water in the canal system are two significant factors that affect the degree of waterlogging on a land. Decline in water table and the status of waterlogging in the IGNP area in general and the study area in particular are result of scanty rainfall and poor availability of water in the canal system. The average annual rainfall in the Rawatsar system area is only 322 mm.

IV. IMPACTS OF WATERLOGGING

Waterlogging and surface ponding (a severe state of waterlogging when rise in water level continues even after reaching the ground level and the water rises above surface) has destroyed the natural environment of the region and has caused formation of saline soils. In eventual course, the affected land has become absolutely unfit for agriculture. The total affected area is very small but the impact on the concerned people has been very adverse. The farmers have been forced to leave crop production for their survival and to replace it by pasture and livestock formations. These replacements make the land unfit for resuming crop production and eventually result in loss of employment and livelihood. This is particularly devastating for low capital and small land holders who have no real alternates in employment.

- *DECLINE IN PRODUCTIVITY* – The productivity of the waterlogged lands specially crop yields declines substancially when the water table rise up to 1.5 m. It obviously results in drop of income by agriculture. The returns are even lesser than the cost put in by the farmers. To maintain production levels, farmers try to put in more cost but the returns keep declining. Finally, they opt rice production in the Kharif and continue with wheat or gram in the Rabi. Rice requires more water and the Rabi crops are dependent upon a minimum layer of only 0.20 m of unsaturated soil,. Therefore, salinity level increase and eventually yields of both Kharif and Rabi witness further decrease.
- *SHIFT OF EMPLOYMENT* – Loss of crop productivity has lead the farmers to quit their occupation in agriculture. There has been seen a shift to other occupations like animal husbandry and agriculture labouring. Small landholders find it difficult to keep ownerships of their land and because agriculture is the only field of their specialization, however they are forced to work under humiliation and exploitation as waged farm labours.
- *IMPACTS ON HEALTH* – The Department of Health does not treat the health impacts of waterlogging. Neither IGNP have any Health Impacts Monitoring Unit nor Command Area Development (CAD) and the Health Department. Farmers are totally unaware of the health problems of their actions and the particular implications threatned by some specific problem like surface ponding. It is indicated by some agencies that ‘‘the irrigated areas of IGNP offer good environments for the wider distribution of the malaria vectors.
- *RISE IN GROUNDWATER LEVELS* – Because of typical sub-surface composition and high percolation rates of the soils, there have been accumulation of infiltrated water in the IGNP area. Absence of proper natural drainage, presence of hydrological barrier, low permeability layer at shallow depth and seepage losses have risen the water table alarmingly in the Stage-I area where many places are acutely affected.
- *REGIONAL SALT BALANCE* – Originally, the water of the Indus River System was of good quality but it has been salinized up to high degree. Salinization is a problem specific to the water table rise areas where groundwater accumulates on surface and arises the possibility of salt deposition. These deposition in longer course can affect the crop productivity of the soil significantly.
- *DRAINAGE PROBLEMS* – Various studies in the IGNP Stage-I area indicate that potential or actual drainage conditions in the IGNP Project are related to two groups of factors : firstly, the way the irrigation system is operated at both canal and field levels, and secondly, the natural features in the soil and underlying layers down to atleast 50 m. Some waterlogging in Stage-I is a result of circumstances such as the greater availability of water and the special case of the Ghaggar Depressions. Although the current extent of waterlogging is small (though increasing) compared with the total area, the effects on individual stakeholders and villagers have been devastating. To avoid such problems in the future, very conservative limits should be adopted in the initial planning and in deciding which land is irrigable.

Photo 1: Formation of soil salinity and degradation of plants in waterlogged area in Luni- ki-Dhani

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Photo 2: Degradation of plants due to salinity of water in Luna-ki-Dhani

Photo 3: Impact of waterlogging in Rawatsar town

V. REMEDIAL MEASURES FOR WATERLOGGING

The present study area consists low-lying topography therefore, acute problem of waterlogging has been observed due to absence of adequate natural surface drainage in the region. The reclamation of the waterlogged land is possible only through some artificial drainage systems which can help to drain out the standing water on the surface of the land and there by decreasing the size of waterlogged bodies in the study area. Govt. of Rajasthan has recorded several drainage methods in the study area with partial amount of success. All the artificial drainage systems adopted by Groundwater Department to solve the waterlogging problem is described as under:

SURFACE DRAINS – Surface drainage removes excess water from the soil surface to prevent damage to crops and avoid ponding of water on the land surface (ASAE 1979). It is suitable where water accumulates over the land surface due to rainfall and runoff, adversely affecting the crop. It involves excavation of open drains to evacuate the accumulated water. Under monsoon climate, surface waterlogging is common and hence, surface drainage has a considerable relevance in India. A network of open reaches with bed levels of 0.5-1.5 m bgl are constructed in this type of drainage scheme where erosive soils of the area would require surface drains with flat side slopes with stability. Surface drain system has some limitations as loss of land and maintenance requirements are the two main problems in this scheme. In addition to that, these drains have a limitation in form of annual desilting and clearing of weeds. The requirement of a slope for the flow of water is another constraint in this system particularly in the areas where is no natural slope or drainage present.

RAWATSAR DRAIN – The most effective and currently in operation, remedy effort attempted in the study area is Rawatsar Drain Project (Table – 1). This pilot project of reclamation of waste-lands of waterlogged area has been implemented through financial assistance of Department of Land Resources, Government of India through DRDA, Hanumangarh. The work of construction of drains, pumping of water and monitoring of system have been under taken by Irrigation Division of Rawatsar. After construction of the Rawatsar Main Drain and pumping stations, the project is now being operated under the scheme of watershed known as Rawatsar Drainage 'A', 'B' and 'C' from 15 to 30 km. Though the Rawatsar Drain Project has succeeded in excluding the ponded water out of the affected area, there are a few factors to be considered seriously. First the project has yet been helped by other factors like a low rainfall in last few years and poor availability of water in courses. It has yet not been exposed to average or heavy rainfall. Besides this because it is an open drain, some vital health related considerations should be cared seriously. The population along the drain use this excluded salinized and highly disease-prone water for drinking. There have been no attempts at any stage to improve the quality of this water. No purification plant or method is being employed, moreover, this water is drained into the IGMN and thus reused into the agriculture system.

S.No	Name of Chak	Reclaimed area (in Bigha)
1.	9 RWM	432.80
2.	11 KWD	597.00
3.	12 KWD	697.45
4.	13 KWD (A)	446.95
5.	13 KWD (B)	405.05
6.	15 KWD	644.90
7.	16 KWD	918.90
8.	½ APM	468.00
9.	6 KWM	481.00
10.	2 NGM	541.00
11.	15 DWD	180.45
12.	17 DWD	591.45
13.	18 DWD	517.70
14.	19 DWD	353.45
15.	21/22 DWD	502.50
16.	23 DWD	117.50
17.	24 DWD	609.50
18.	25 DWD	543.00
19.	27 DWD	447.00
20.	28 DWD	427.50
21.	30 DWD	286.00
22.	8 AM	250.00
23.	10 AM	140.00
24.	11 AM	252.00
25.	DORD 91.500 (I)	364.60

26.	DORD 91.500 (II)	758.90
27.	DORD 91.500 (III)	313.45
28.	DORD 999L	617.40
29.	1 NGM	350.00
	TOTAL	13255.45

Table 1: Chakwise details of the area reclaimed by the Rawatsar Drain Project (Irrigation Division, Rawatsar)

HORIZONTAL SUBSURFACE DRAINAGE SYSTEMS (SSD) – Horizontal subsurfacedrainage involves the removal of water from below the surface, primarily from the crop root zone. The drainage system comprises a network of perforated pipes installed below the ground surface. Besides water table control, this type of drainage system controls soil salinity by leaching out the concentrated and harmful salt solutions from the root zone of the soil. This is a proven technology for saline land reclamation and has considerable relevance in India where excess soil salinity is a major constraint in agricultural production in the irrigation command areas. In the study area, horizontal subsurface drainage systems have recently been installed in Dabli Kalan, Chak 9 DBLK and 12 DBLK area. The drainage system has been successfully used in the study area and reclaimed the land for good quality agriculture.

VERTICAL SUBSURFACE DRAINAGE SYSTEM – Vertical subsurface drainage involves pumping out groundwater through tube wells or dug wells. While in the unirrigated areas outside the command of a canal irrigation projects, this is considered as an irrigation endeavour, in the canal irrigated areas this is a mechanism to promote conjunctive use of water that helps in checking the gradual rise of water table and development of soil salinity. The groundwater wing of CAD after conducting pre-feasibility studies has prepared a pilot project ‘‘Groundwater management and salinity protection through vertical drainage in IGNP Stage-I’’, in June. Six tubewells and five shallow skimming wells have been constructed under this project at villages Masitawali and Lunio Ki Dhani respectively. In the study area, to arrest the rise of water table, two type areas have been selected for pilot studies through vertical drainage. First area is north-northwest of Masitawali Head in between the IGNP and Naurangdesar distributary covering an area of about 600 ha. Second area situated north of Lunio ki Dhani along the Indira Gandhi Main Canal covers an area of about 33 ha.

The area selected for pilot studies has a depth to water of less than 2 m bgl. A major part of the area between the villages Dabli Kalan, Dabli Khurd and Masitawali Head on left the left bank of the main canal and also near Lunio ki Dhani on the right bank of the main canal has already turned into marshy land and secondary salinization is evident on the surface. The waterlogged area near Lunio ki Dhani is located near Indira Gandhi Main Canal and forms an inland drainage in a closed basin. The area around Lunio ki Dhani is generally flat but near the village it forms a depression without any outlet and this is the most critical area, facing the problem of waterlogging, high water table and soil salinity.

- ✓ *Vertical Drainage Through Wells* – The 5 shallow skimming wells of 5x3 m diameter at a spacing of 125.00 m in a single row were constructed in Chak MSTN and Lunio ki Dhani in the year 1992. The wells were constructed above the hydrological barrier layer and within the permeable horizon without infiltration galleries. The drained water i.e. 40,000 g/d of EC value 8000 µs at 25° C. The water samples are being collected periodically to monitor the quality of drained water, canal water and blended water. The wells were put in operation on 2nd March 1993 and within a span at five months the gradual rise at the rate of 0.80 m/yhas not only been arrested but water level has been further lowered down to 1.00 m bgl.
- ✓ *Vertical Drainage Through Tubewells* – To demonstrate vertical drainage through tubewells, a battery of 6 tubewells were constructed by the ring of Groundwater Department. The tubewells are being operated on 50 experimental basis sporadically with the help of generating set 50 KVA, stationed at Masitawali Head. The average depth of tubewells ranges from 20.00 to 34.00 m bgl. Casing pipe is lowered to a depth of 12.00 to 22.00 m of 250 mm inner diameter. The discharge of each tubewell is 30 m/h and the quality of groundwater is fresh. The pumped water from the tubewell is being blended with the water in the main canal in a pre-determined ratio judiciously.

BIO-DRAINAGE – Bio-drainage is the removal of groundwater by plants through evapotranspiration, which depends upon the plant species, plantation density, depth to water table and climate. Since many plants thrive well in saline root zone environment, it is believed that they may extract salt solutions and reduce subsoil salinity. However, whether the plant roots extract only the water, leaving the salts behind or whether it draws saline water and stores the salts in the plant is not well known. Some of the plants are trimmed from time to time and the cut portions are used as fodder or fuel wood. If the plants had drawn saline water, then trimming would remove some of the salts from a saline land, which would be a cheaper alternative for salt removal from the soil.

Raadsma (1974) has reported the ability of plants to supplement the drainage effect of conventional drainage systems in reclaiming polders in the Netherlands. Weeds of a certain species were sown over the area to be reclaimed from waterlogging, besides providing shallow trenches. Anonymous (1988) has indicated high transpiration by deep-rooted plants and abstraction of a part of rainfall as interception by the plant foliage, besides the salt tolerant nature of certain plant species. Certain plants could draw groundwater from as deep as 20 m due to their deep root system. Chhabra and Thakur (1998) have reported from a 4-year lysimeter study that under non saline condition (groundwater salinity 0.4 *dSI*m), the transpiration rate gradually increased from I" to 4thyear at each of the three water table depth of 1, 1.5 and 2 m in the lysirneter. They observed that bio-drainage was highest when groundwater salinity was lowest and that the eucalyptus trees bio-drained 2022; 2830,3021 and 2475 rnm of water in 1'\ 2nd,)'d and 4thyear at a groundwater salinity of 12 dSm·'. Cramer et al. (1999) have, however, reported that *Casuarina glauca* could extract groundwater more than *Eucalyptus camaldulensis* planted at similar densities. They used naturally occurring isotope signatures of soil water, groundwater and sap flow measurement to determine tree water sources. Heuperman (1999) during a 14-year study of non-irrigated eucalyptus growing On a medium textured soil found a distinct local impact on the water table underneath the plantation, about 7 years after establishment. A study on irrigated eucalyptus revealed that after 4 years of planting, the trees started to influence the water table. When 5-year old, the trees had created a groundwater extraction scenario, with the water table being deeper than the underlying piezometric pressures. Chaudhry et al. (2000) studied 6-year old eucalyptus plants in a 4-ha area in Pakistan and reported a deeper water table in the area under the plantation and a reduced groundwater table depth in the regions away from the plantation also. Heuperman & Kapoor (2003) observed the average annual rate of transpiration as 3446 mm from a 25-ha plantation *(Eucalyptus camaldulensis, Acacia nilotica, Prosopis cineraria, Ziziphus spp,)* in the Indira Gandhi Nahar Project (IGNP) in Rajasthan during a 6-year (1991-1997) study. The water removal rate was estimated as equivalent to a vertical drainage network with 500 m well spacing with a 33 *m3/hr* pumping rate. He estimated that a forest cover of 1,77,000 ha « 10% of the total irrigable area in IGNP) would be able to transpire the estimated annual ground water recharge of 2.6 billon cubic meters.

Bio-drainage definitely helped in reducing the waterlogged areas by lowering the water table in the study area. Proposal to plant 30,000 seedings along the road and canal side as being planned by CADA can help in the lowering of the water table by 15 to 20 cm/year. Further increase in the number of plantations will help in the maintenance of the eco-system. Construction of drainage ponds in affected areas can lower the water table and mitigate saline conditions caused due to capillary action. It is estimated that one ha. drainage pond can remove 0.02 MCM of water annually and can protect 20 ha. of land. Bio-drainage with eucalyptus species was also attempted along small stretches of the canals. The experiences were good only along certain patches where the plants survived but failed due to continuous water stagnation. The bio-plantations may be used in certain waterlogged wastelands with suitable species and management practices. It has very limited success for controlling waterlogging of the agricultural lands.

VI. CONCLUSION

- ✓ Agricultural potential in Rawatsar block is high with respect to ground water quality. Water having EC< 4000 mmhos occurs in major part of the district which can be used for growing semi tolerant to salt tolerant crops.
- ✓ In some areas, fresh water cushions have been developed due to seepage of canal water accumulated over impervious formation. Therefore attempt has to be made to locate those points where maximum thickness can be ascertained and ground water can be exploited judiciously.
- ✓ Anti water logging measures should be taken to avoid further water logging in the areas around natural depressions.
- ✓ It is strongly advocated that a massive ground water development programme may be launched especially in the Ghaggar flood plain area where the quality of ground water is suitable for irrigation.
- ✓ Saline ground water available in the district can be used for agriculture by blending with canal water or using in lean period. Batteries of tubewells tapping saline water can be constructed along Pilibanga branch for use in conjunction with fresh canal water.
- ✓ Modern agricultural management techniques have to be adopted for effective and optimum utilization of the water resources. Maintaining irrigation through minimum pumping hours as per minimum requirement of water by the crop and also selecting most suitable cost effective cropping pattern can achieve this.
- ✓ High water requirement crops need to be discouraged. Proper agriculture extension services should be provided to the farmers so that they can go for alternate low water requirement economical crops.
- ✓ Implementation of further ground water development programme in the area must be under competent technical supervision to avoid well failures and saline water ingress.
- ✓ Sewage reclamation should be an important part of the development of irrigation sector. It is required to avoid contamination of water resources. This source of irrigation water is highly reliable, albeit only for non-edible crops.

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