BIODATA OF Dr. S.K. KAMRA

1.	Name in full: (Surname followed by forename)	**KAMRA**, SUSHIL KUMAR
2.	Date of Birth:	30 – 12 – 1954
3.	Field of specialization	
	(i) Major discipline :	Agricultural Engineering
	(ii) Subject of specialization:	Soil and Water Conservation Engineering
	(iii) Scientific interests and capabilities :	Subsurface drainage, groundwater recharge, groundwater contamination, geo- hydrology, hydro- salinity modeling
4.	Designation:	Principal Scientist and Head
5.	Address: (a) Official:	Division of Irrigation and Drainage Engineering, Central Soil Salinity Research Institute, Karnal- 132001 (Haryana)
	Tel. No.:	0184 – 2291119, ext. 177
	Fax No.:	0184 – 2290480
	Email address:	skkamra@cssri.ernet.in;
	(b) Residential:	1587, Sector 9, Urban Estate, Karnal – 132001 (Haryana)
	Tel. No.:	0184 – 2231363; Mobile: +919416109968

6 (a) Academic career

Degree	University/Institute	Year	Distinction, if any
B. Tech. (Agril. Engg.)	Punjab Agricultural University, Ludhiana (India)	1976	University Merit Scholarship holder for 4 years, rated 3rd best student among more than 100 students
Ph.D. (Agril. Engg.)* Major: Soil & Water Engg. Minor: Mathematics	--do---	1989	OGPA: 3.82/ 4.00 (Integrated Ph.D. Programme after B. Tech.)
Post- Doctoral Research	University of Kiel, Kiel (Germany)	1995-97	Alexander von Humboldt Fellowship

*** Title of Ph.D Thesis:** Finite Element Simulation of Solute Transport in Groundwater Aquifers

6(b) Employment record

Designation	**Pay Scale**	**Nature of work**	**Organization**	**Institution**	**Period (From – to)**
Head, Division of Irrigation and Drainage Engineering	Pay Band IV (Rs#. 39000-67000) + Grade Pay of Rs. 10000/	Research Management	ICAR	Central soil Salinity Research Institute (CSSRI), Karnal, India	30.4. 2009-till date (regular); 12.6. 2007-29.4. 2009 (officiating)
Principal Scientist (Soil & Water Cons. Engg.)	Rs. 16400 - 22400	Research*	ICAR	- do-	28.7.1998-till date
Sr. Scientist (Soil & Water Cons. Engg.)	Rs. 3700 – 5700	Research	-do-	- do-	1.1.1986-28.7.1998
Scientist S-2 (Soil & Water Cons. Engg.)	Rs. 1100 – 1600	Research	-do-	- do -	01.7.1983-31.12.1985
Scientist S-1 (Soil & Water Cons. Engg.)	Rs. 700 – 1300	-do-	-do-	- do -	01.9.1977-30.6.1983

1 US $ ~ Rs. 45; *During June 2000– April 2005, I coordinated as Principal Investigator of a 5- location NATP involving considerable research management and administrative duties

6(c) Scientific Awards

(i) **National Groundwater Augmentation Award** (2011), Ministry of Water Resources (Govt. of India) for Farmers' Participatory Action Research Project (FPARP) of CSSRI on groundwater recharge for which the applicant was the team leader. It was awarded to CSSRI jointly with another institute out of 39 funded research organizations

(ii) Elected Fellow (2009), Indian National Academy of Engineering (I**NAE**)

(iii) **Rafi Ahmed Kidwai Award** (2008), Indian Council of Agricultural Research (ICAR), the highest individual award for an Indian agricultural scientist

(iv) Elected Fellow (2003), National Academy of Agricultural Sciences (**NAAS**)

(v) Awarded A**lexander von Humboldt fellowship** for 22 months (April 1995- Jan. 1997) at University of Kiel, Kiel in Germany

(vi) Selected as one of the 10 Asian Senior Professional Research Fellows for International Action Research Program on **'Groundwater Governance in Theory and Practice'** organized by International Water Management Institute (IWMI), Sri Lanka at Kansas University, Lawrence, USA (November 27- December 15, 2006)

6(d) Peer Recognition

(i) Participated as invited speaker in 'Brazilian Symposium of Salinity: Integration of Basic and Applied Research' from October 12- 15, 2010 at Fortaleza, Ceará, **Brazil** and presented **two country papers** entitled 'Status and strategies for management of salt affected soils in India' and 'Integrated drainage approaches for waterlogged saline soils of India'

(ii) Acted as **Co-coordinator**, Special Session on Drainage and **Chairman**, **Technical Sessions** III on 'Drainage and Alternate Land Management Strategies' and XIV on 'Disposal and Reuse of Drain Water and Controlled Bio- drainage' and also presented an **invited paper** 'An Overview of Subsurface Drainage Research in India' during 5th Asian Regional Conference on 'Improvement in Efficiency of Irrigation Projects through Technology Upgradation and Better Operation and Maintenance', organized by Central Water Commission, Govt. of India and ICID at New Delhi, Dec. 8- 11, 2009.

(iii) **Visiting Scientist** in the field of 'Computer simulation modeling of salt movement in agricultural soils' at Department of Bio-resource Engineering, **McGill University**, Ste-Anne- de- Bellevue, QC, **Canada,** June- August 2008.

(iv) Successfully completed as **PI** a Ministry of Water Resources (Govt. of India) funded project 'Farmers' Participatory Research on Enhancing Groundwater Recharge and Water Productivity in North West India' having a budget outlay of Rs. 50 lakh (Rs. 5 million) during 2008- 2010. Individual farmer based technologies on groundwater recharge, integrated farming based on multiple use of water and laser leveling were implemented and evaluated in **93 farmers' fields (including 52 recharge wells)** in the states of Haryana, Punjab, Uttar Pradesh and Gujarat. Based on the quality and impact of the project, it was bestowed with **National Groundwater Augmentation Award** during March 2011.

(v) Successfully completed as the **PI** of a World Bank aided **National Agricultural Technology Project (NATP)** 'Technologies for skimming and recharging fresh water in saline groundwater regions' having budget outlay of **Rs. 1.40 crore** (Rs. 14 million) during June 2000- April 2005, including organization of 4 annual workshops. CSSRI was the lead centre in Haryana and there were 4 collaborating centres in the states of Andhra Pradesh, Tamil Nadu and Gujarat. The project has paved the way for **commissioning** of large groundwater skimming and recharging projects in these four states.

(vi) Had been/ am a **reviewing referee** for International Journals (*Water Resources Research, Agricultural Water Management, J. Hydrological Processes, J. Porous Media, Environment Modelling and Software, Irrigation Science*,) as well as about a dozen national journals.

(vii) Developed a 2- dimensional numerical model and software '**DRAINSAL**' that provides decision support for environmentally safe design of sub- surface drainage systems in

waterlogged- saline soils. The model's computer code and users' manual has been sent to a number of demanding researchers in India and abroad.

(viii) Presented research papers in about **15 international conferences/ symposia** in India and abroad (Pakistan, The Netherlands, Slovenia, Italy, Brazil, Germany). Besides a number of short/ long- term **overseas** assignments/ working visits have been undertaken to USA, Canada, Germany, France, Switzerland and Australia.

(ix) A paper 'Effect of drain- depth on salinity control in irrigated lands of semi- arid regions' presented by the applicant in the **5th International Drainage Workshop** at Lahore, Pakistan (Feb. 8- 15, 1992) was **referred in the session report** and its contents reiterated in final general report of the workshop. The paper contributed to the **abandoning of critical watertable concept** in favour of the net downward water flux for deciding drain depth and consequent **acceptance of shallower drains in arid and semi- arid regions**.

(x) Acted as a **member of an ICAR sub- group** (1992- 93) for appraisal reporting on the extent of waterlogging and soil salinity and required mitigation measures for Stage I areas of IGNP in Rajasthan. Again during June 18- 23, 2007, coordinated as **convener** the visit of 5- member scientific team to IGNP assessing the current waterlogging and soil salinity problems in Phase I and Phase II areas of IGNP based on interaction with farmers, administrators, engineers and scientists and to suggest the remedial measures and possibilities for collaborative projects.

(xi) Facilitated as Chairman, Organizing Committee of CSSRI entrusted with the responsibility of organizing a Joint Workshop of Indo- US Agricultural Knowledge Initiative on Water Management from September 20- 22, 2006 at New Delhi, which was attended by 22 US and 50 Indian water professionals from universities, research institutes, NGOs and officials from public and private sectors.

(xii) Occasionally officiated as Project Manager, Indo- Netherlands Project on Land Drainage, operational at CSSRI from 1984- 1995. Also coordinated the drainage research activities of the Hanumangarh (Rajasthan) centre of Indo- Dutch Network Project on Drainage and Water Management at CSSRI, Karnal from 1997- 2001.

(xiii) During the past 15 years, organized as Course Director of 3 national **training programs**, summer and winter schools in the area of subsurface drainage, groundwater management and hydro- salinity modeling. In addition, also acted as a faculty member and organizer in 10 trainings/ summer or winter schools organized in the division attended by more than 300 post graduate level trainees. I also delivered lectures in about 30 trainings organized in other divisions, including by extension group in which about 750 personnel participated.

(xiv) Have been regularly working as external examiner for M.Tech/ Ph.D thesis of PAU, HAU, TNAU, IARI students; consistent reviewing referee for funding of research projects of ICAR and other agencies. After signing MOU with academic universities during the past 6 years, I am also guiding as co- Major advisor of M.Tech and Ph.D students in the discipline of Irrigation and Drainage Engineering and Geology for their research work at CSSRI.

7. Significant research achievements and impact

(i) Special Attainments

Category	Title	Year	Details	Individual/ collaborative; impact
Technologies developed	(i) Subsurface Drainage	1982-1995; 1997-2001	Introduced systematic subsurface drainage for reclamation of waterlogged saline soils, initially for Haryana and later in other states like Rajasthan under Indo-Dutch collaboration projects.	Collaborative; technology adopted till date in about 35000 ha in different canal commands of India
	(ii) Evaporation pond	1989-1997	Management of saline drainage effluent in Haryana and Punjab	Collaborative; used as a mean for disposal of saline drainage water at about 5 sites in Haryana and Rajasthan
	(iii) Computer model and Software 'DRAINSAL'	1985-1989	2- D finite element water and solute transport model for subsurface drainage systems	Individual, Software distributed to a number of users in India/ abroad
	(iv) Semi-analytical model	1998-2000	Solute dynamics in a tubewell drainage system	Collaborative; research tool
	(v) Community based groundwater skimming cum recharging system	2000-2006	Facilitates separate/ combined pumping from or recharging of two cavity tubewells installed at different depths/ groundwater quality zones in Haryana	Collaborative; paved the way for further sanctioning of recharge projects for North west India.
	(vi) Pumping cum recharging system/ recharge shaft	2000-2006	Individual farmer based pumping and recharging structures for falling/ marginally saline groundwater in Haryana	- do-
	(vii) Ground water recharge shaft and recharge cavities	2008-2010	Individual farmer based groundwater recharge wells coupled to a recharge filter at 52 sites in Haryana, Punjab, UP and Gujarat. These structures have proven highly effective in augmenting ground water, improving quality (salinity, alkalinity and fluoride) and enhancing farmers' income by saving submerged crops by recharge of excess water	Collaborative; leading to extensive demand and adoption by farmers in 4 states.

Technologies Propagation	- For reclamation of waterlogged saline soils, the manually installed subsurface drainage technology developed by the CSSRI (of which the applicant was an diligent member) during 1980s initially for Haryana has been widely adopted and replicated through mechanical installation in an area of about 35000 ha area in Rajasthan, Gujarat, Punjab, Andhra Pradesh, Karnataka and Maharashtra. This was facilitated through 2 international Indo- Dutch projects on land drainage operational at CSSRI during 1983- 2001. - The applicant successfully completed as the **PI a NATP** 'Technologies for skimming and recharging fresh water in saline groundwater regions' during 2000- 2005. CSSRI was the lead centre in Haryana and there were 4 collaborating centres in the states of Andhra Pradesh, Tamil Nadu and Gujarat. The project is paving the way for **commissioning** of large groundwater skimming and recharging projects in these states. - Individual farmer based technologies on groundwater recharge, integrated farming system, laser leveling and improved irrigation interventions have been implemented and evaluated at 93 sites in the states of Haryana, Punjab, Uttar Pradesh and Gujarat during 2008- 2010.

(ii) Externally Funded Projects

PI/Co -PI	Title	Year	Amount	Funding agency
Co- PI	Indo- Dutch Project on Land Drainage	1984- 1995	Rs. 2.5 crore	The Netherlands Govt.
Co-PI	Indo- Dutch Network Project on 'Research on the Control of Waterlogging and Salinization in Irrigated Agricultural Lands'	1996- 2002	Rs. 14.7 crore	The Netherlands Govt.
PI	NATP on 'Technologies for Skimming and Recharging Fresh Water in saline Groundwater Regions'	June 2000 – April 2005	Rs. 1.4 crore	ICAR – World Bank
PI	Farmers' Participatory Research on Enhancing Groundwater Recharge and Water Productivity in North West India	Feb. 2008- Nov. 2010	Rs. 50 *lakh*	Ministry of Water Resources (GOI)
PI	Improved irrigation, groundwater and multiple water use technologies for enhancing water productivity in North – West India'	2011- 2012	Rs. 30 lakh	Ministry of Water Resources (GOI)

Significant research achievements are presented in **Appendix I**.

(iii) Summarized Achievements

Dr. S.K. Kamra has made significant contributions in developing **subsurface drainage technology** for amelioration of waterlogged saline irrigated lands in India. For areas without natural outlets, **evaporation pond technology** propagated by him can provide interim solutions for management of saline drainage effluent. These studies led to commissioning of mechanically-installed subsurface drainage projects in 7500 ha area in farmers' fields in Haryana where annual potential loss due to waterlogging and soil salinity is estimated at more than Rs. 200 *crore*. The

technology provides a net present worth of about Rs. 50000/ ha with benefit cost ratio of 1.76 and internal rate of return 20 %. Similar large scale mechanized drainage projects have been also undertaken in Rajasthan, Punjab, Maharashtra, Karnataka, Andhra Pradesh and Gujarat.

Dr. S.K. Kamra has developed a 2- dimensional water and solute transport model that can be applied for optimal drainage designs and to predict long- term salinity of drainage water for devising its environmentally safer disposal/ management options. The scope of the model was extended for pesticides during his **Alexander von Humboldt Fellowship** in Germany. For his research contributions in the area of subsurface drainage and solute transport modeling, Dr. Kamra was awarded the most prestigious **Rafi Ahmad Kidwai Award** of ICAR during 2008. He is a **Fellow** of National Academy of Agricultural Sciences (**NAAS**) and Indian National Academy of Engineering (**INAE**). During 2006, he was selected through global competition as one of the 10 Asian Senior Professional Research Fellows for IWMI's International Action Research Program on **'Groundwater Governance in Theory and Practice'** at Kansas University, Lawrence, **USA**.

Recently Dr. S.K. Kamra successfully completed as **Principal Investigator** multi- location research project on groundwater skimming (selective abstraction) and recharging of fresh water in saline groundwater regions of **Haryana, Gujarat, Andhra Pradesh and Tamil Nadu**. The impressive accomplishments of the project are paving the way for commissioning of large groundwater skimming and recharging projects in these four states. Some of the robust and improved groundwater recharge technologies of this project and improved irrigation interventions for enhancing water productivity have been implemented and evaluated at 93 farmers' fields **in the states of Haryana, Punjab, Uttar Pradesh and Gujarat** under a recent Ministry of Water Resources funded project during 2008- 2010, for which Dr. Kamra and his project team was bestowed with **National Groundwater Augmentation Award**.

(iv) International Exposure

Country	Purpose /subject title	Year	Duration	Sponsor
Germany	To participate in the kick- off workshop of **INNO-ASIA project at** Department of Geo-informatics, Friedrich Schiller University of Jena, **Germany** which aims to establish an innovative consortium network of research institutions from Germany, India, Nepal, China and Australia to work jointly on application of Geo-informatics on assessment and analysis water resources and submit bi/ multilateral projects for funding.	2011	One week (Feb. 6-11)	German Federal Ministry of Education and Research **(BMBF** *in German***)**
Brazil	To participated as invited speaker in 'Brazilian Symposium of Salinity: Integration of Basic and Applied Research' from October 12- 15, 2010 at Fortaleza, Ceará, Brazil and present two country papers.	2010	Four days (Oct. 12-15)	Organizing Committee of the symposium
Canada	**Visiting Scientist** in the field of 'Computer simulation modeling of salt movement in agricultural soils' at Department of Bioresource Engineering, **McGill University**, Ste- Anne- de- Bellevue, QC, **Canada**	2008	3 months (June-August)	McGill University, Canada

USA	Participation as a Senior Professional Research Fellow in International Action Research Program on **'Groundwater Governance in Theory and Practice'**	2006	3 weeks (Nov. 27- Dec. 15)	IWMI, Sri Lanka
Australia	International Training cum study tour on 'Natural and Enhanced Groundwater Recharge'	2004	6 weeks (August 17- Sept. 28)	NATP
Germany	Post doctoral research on 'Uncertainty Analysis of Pesticide Leaching in Heterogeneous Soils', Univ. of Kiel, Kiel	1995-1997	22 months (April 1995- Jan. 1997)	**Alexander von Humboldt Fellowship**
	(a) Presentation of a paper in 6th International Drainage Workshop, Ljubljana, **Slovenia**	1996	5 days (April 21-25)	--- do ---
	(b) Working visit to Institute of Terrestrial Ecology, Swiss Federal Institute of Technology, Schlieren (Zurich, **Switzerland**).	1996	4 days (May 28-31)	--- do ---
	(c) Presentation of a paper in International Symp. On Pesticide, Castelnuovo Fogliani- Piacenza, **Italy**	1996	3 days (Sept. 30-Oct. 2)	--- do ---
	(d) Working visit to Drainage Division, CEMAGREF, Antony Cedex, **France**	1996	5 days (Nov. 18-22)	--- do ---
	(e) Participation in Jubilee Symp. Of the International Institute for Land Reclamation and Improvement (ILRI), Wageningen, **The Netherlands**	1996.	3 days (Nov. 25-27)	--- do ---
The Netherlands	Presentation of a paper in the 15th ICID Congress at The Hague and participate in post- congress and study tour	1993	3 weeks (Sept. 3-23)	Indo- - Dutch Project
Pakistan	Presentation of a paper in 5th International Drainage Workshop, Lahore followed by post conference and study tour	1992	2 weeks (Feb. 6-20)	Indo- - Dutch Project
USA	Study tour cum training on 'Hydro Salinity Modeling', Cornell University, Ithaca (New York)	1989	4 months (March 3- July 2)	FAO (UNDP)

(v) Trainings attended in the relevant field of specialization

Title	**Duration**	**Institution**	**Year**
1. Groundwater Governance in Theory and Practice [Sponsors: IWMI]	3 weeks (Nov. 27- Dec. 15, 2006)	Kansas University, Lawrence, **USA**	2006
2. Natural and Enhanced Groundwater Recharge [NATP]	6 weeks (August 17- September 28, 2004)	Australian Centre for Groundwater Studies (CGS), University of Western Australia (Perth) and Flinders University (Adelaide),	2004

		Australia	
3. Training for Trainers course on Curriculum Development, Learning Theory and Presentation Skills [Indo-Dutch Project]	2 weeks (Dec. 3- 14, 2001)	Central Soil Salinity Research Institute, Karnal, India	2001
4. Internet with Home Page Design	1 week (Sept. 13- 17, 1999)	Centre for Information Technology, New Delhi, India	1999
5. Analysis of pumping test data [Collaborative training with Dutch consultant]	1 week (Dec. 7- 11, 1998)	Central Soil Salinity Research Institute, Karnal, India	1998
6. Groundwater Assessment and Modeling	1 week (July 13- 17, 1998)	Deptt. of Civil Engineering, Indian Institute of Technology, New Delhi	1998
7. Computer aided analysis through spread sheet programs [Collaborative training with Dutch and Egyptian consultants]	3 weeks (Feb. 8- 27, 1993)	Central Soil Salinity Research Institute, Karnal, India	1993
8. Hydro Salinity Modeling	4 months (March 3- July 2, 1989)	Deptt. of Agronomy, Cornell University, Ithaca, **USA**	1989
9. Establishment and Monitoring of Drainage Experimental Fields [Indo- Dutch Project on Land Drainage]	2 weeks (Feb. 17- March1, 1986)	Central Soil Salinity Research Institute, Karnal, India	1986
10. Drainage of Saline Soils [Summer institute]	1 month (May 17- June 15, 1982)	Central Soil Salinity Research Institute, Karnal, India	1982
11. Computer programming	10 days (Jan. 18- 28, 1981)	Hindustan Computers Ltd., New Delhi, India	1981
12. Agricultural Research and Management [ARS orientation training]	3 months (March 8- June 15, 1978)	Central Staff College for Agriculture, Hyderabad, India	1978

7. Miscellaneous:

(i) Under externally funded Indo- Dutch and NATP projects, I facilitated procurement of a large number of scientific equipment from India and abroad.

(ii) As OIC (computer centre) from 1997- 2001 and 2007- 2009, I played a decisive role in installation of internet and LAN facilities and upgradation of computer infrastructure and institute web page.

(iii) Successfully coordinated as convener of two **Scientists'- Farmers' Stakeholder Forums** newly formulated by CSSRI in Karnal (Haryana) and Fatehgarh Sahib (Punjab) districts in collaboration with Centre for Advancement of Sustainable Agriculture (CASA), New Delhi. The Forums consist of progressive farmers, scientists (CSSRI, CASA, SAU), state department officials and farm implements industry to promote conservation agriculture interventions like laser leveling, zero tillage, residual management, groundwater recharge and crop diversification in adopted villages in these two states through regular meetings and field seminars/ visits.

(iv) Have guided/ am guiding research work of **M. Tech and Ph. D students** on following topic:

(a) Hydraulic analysis of cavity well during pumping and recharge phases (M. Tech (Irrigation and Drainage Engineering), 2005)

(b) Influence of Soil and Groundwater Salinity on Interpretation of Electrical Resistivity Surveys in the Alluvial Plains of Haryana (Ph.D (Geology)2009- till date)

(c) Simulation of Water and Salt Dynamics in Subsurface Drained land using HYDRUS (M. Tech (Irrigation and Drainage Engineering), 2011)

8. Publications

(i) Research (Journals)	27
(ii) Books	5
(iii) Book Chapters	18
(iv) Seminar/ Symposia	32
(v) Popular articles/ Bulletins/Technical Reports/ extension brochures	24
Total	**106**

Ten significant publications

1. Singh, G., Bundela, D.S., Sethi, M., Lal, K. and Kamra, S.K. 2010. Remote sensing and geographical information system for appraisal of salt affected soils in India. J. Environmental Quality, 39(1): 5- 15. [NAAS Journal Rating: 8.7]

2. Ram, J., Garg, V.K., Toky, O.P., Minhas, P.S., Tomar, O.S., Dagar, J.C. and Kamra, S.K. 2007. Bio-drainage potential of *Eucalyptus tereticornis* for reclamation of shallow water table areas in north- west India. *Agro-forestry System*, 69: 147- 165. [NAAS Journal Rating: 8.0]

3. Kamra, S.K. and Lennartz, B., 2005. Quantitative indices to characterize the extent of preferential flow in soils. *J. Environmental Modelling and Softwares*, 20(7), 903- 915. [NAAS Journal Rating: 8.5]

4. Pathak, H., Ladha, J.K., Aggarwal, P.K., Peng, S., Das, S., Singh, Yadvinder, Singh, Bijay, Kamra, S.K., Mishra, B., Sastri, A.S.R.A.S., Aggarwal. H.P., Das, D.K. and Gupta, R.K., 2003. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research*, 80: 223-234. [NAAS Journal Rating : 8.4]

5. Kamra, S.K., Lal, K., Singh, O.P. and Boonstra, J. 2002. Effect of pumping on temporal changes in groundwater quality. *Agricultural Water Management*, 56(2), 169- 178. [NAAS Journal Rating: 8.1]

6. Kamra, S.K., Lennartz, B., Van Genuchten, M.Th., Widmoser, P. 2001. Evaluating non- equilibrium solute transport in small soil columns. *J. Contaminant Hydrology*, 48 (3/4): 189- 212. [NAAS Journal Rating: 8.4]

7. Kelleners, T.J., Kamra, S.K., Jhorar, R.K. 2000. Modeling of drainage water salinity of pipe drains. *J. Hydrology*, 234: 249- 263. [NAAS Journal Rating : 8.6]

8. Kamra, S.K., Singh, Sita Ram and Rao, K.V.G.K., 1994. Effect of depth of impervious layer and adsorption on solute transport in tile-drained irrigated lands. *J. Hydrology*, 155: 251- 264. [NAAS Journal Rating: 8.6]

9. Kamra, S.K., Singh, S.R., Rao, K.V.G.K., and van Genuchten, M. Th., 1991. A semi- discrete model for water and solute movement in tile- drained soils: I. Governing equations and solution, *Water Resources Research*, 27(9): 2439-2447. [NAAS Journal Rating: 8.5]

10. Kamra, S.K., Singh, S.R., Rao, K.V.G.K., and van Genuchten, M. Th., 1991. A semi-discrete model for water and solute movement in tile-drained soils: II. Field validation and applications, *Water Resource Research*, 27(9): 2448-2456. [NAAS Journal Rating: 8.5]

Total of 10 publications: NAAS Journal Rating: 84.3

Appendix I: Brief Research contributions of Dr. S.K. Kamra

The applicant's research output of work in India during the last 30 years can be synthesized under four subgroups: (1) Subsurface drainage for reclamation of waterlogged- saline soils including evaporation pond technology for management of saline subsurface drainage effluent, (2) Numerical modeling of water and solute transport in subsurface drainage systems (3) Management of shallow groundwater systems including groundwater recharge and contamination and (4) Rainwater harvesting and conservation in alkali soils. In addition, the applicant worked on a research project entitled 'Uncertainty analysis of pesticide leaching in heterogeneous soils' during **Alexander von- Humboldt** research fellowship period of 22 months (starting April 1995) in Germany.

1. Management of shallow groundwater systems including groundwater recharge and contamination (1998-2011)

During the period from 1998 to 2002, the applicant was involved as PI in a research project dealing with evaluation of effluent salinity as a design criterion of subsurface and tubewell drainage systems. During 2000 to 2006 period, the nominee successfully completed as **Principal Investigator** a multi- location research project on groundwater skimming and recharging of fresh water in saline groundwater regions of **Haryana, Gujarat, Andhra Pradesh and Tamil Nadu**. Under the project, impressive accomplishments have been made in proposing, testing and evolving groundwater skimming (selective abstraction) or recharging of fresh water in saline groundwater regions at 5 centres in these states. Some of the **robust groundwater recharge technologies** of this project and CSSRI technologies on integrated farming system and laser leveling have been propagated at 93 sites in farmers' fields **in the states of Haryana, Punjab, Uttar Pradesh and Gujarat under a Ministry of Water Resources funded project** during March 2008- November 2010. Based on the quality and impact of the project, it was bestowed with **National Groundwater Augmentation Award** during March 2011. This has also led to **funding of another project** entitled 'Improved irrigation, groundwater and multiple water use technologies for enhancing water productivity in North – West India' by Ministry of Water Resources (GOI) for implementing these technologies at 60 sites in the states of Haryana, Punjab, Uttar Pradesh and Gujarat with a budget outlay of Rs. 30 lakh for the period 2011- 2012.

(a) **Farmers' Participatory Research on Enhancing Groundwater Recharge and Water Productivity in North West India (MOWR funded, February 2008- November 2010; Budget: 50 lakh)**

The sustainability of agriculture in north- western states is threatened due to alarming decline of water table, increase in pumping cost and deterioration in groundwater quality. The groundwater decline can be deferred to some extent by enhancing artificial recharge using rain and excess canal water through surface spreading and well injection techniques. It helps in utilizing flood water that otherwise goes waste or causes damage to standing crops and also in improving groundwater quality. Well injection techniques are getting accepted due to failure or delay in arrival of natural or artificially recharged water to deeper aquifer zones with surface methods. CSSRI's efforts on enhancement of groundwater recharge and water productivity have been strengthened in a major way through a Ministry of Water Resources (GOI) funded FPARP. Innovative groundwater recharge, pond renovation, integrated farming, laser levelling technologies and irrigation interventions were implemented at 93 village sites in Haryana, Punjab, Uttar Pradesh and Gujarat during 2008- 2010. These include injection well type recharge structures installed and evaluated by CSSRI at 52 farmers' fields (32 sites in Haryana, 5 in Punjab, 3 in Uttar Pradesh and 12 in Gujarat). These are based on well injection techniques and involve passing of excess rain and canal water under gravity through a bore well to subsurface sandy zones coupled to a recharge filter consisting of layers of coarse sand, small gravel and boulders in a small brick masonry chamber. In Haryana and Punjab, these structures are successful at any low lying location where runoff gets accumulated and adversely affects the production of rice during rainy season and of wheat during any heavy winter rain.

The location of recharge sites was decided on the basis of interaction with farmers, local tubewell mechanics and NGOs. Selection of recharge structures of different designs, depths and costs (recharge shafts, recharge cavities, recharge wells, dry cavities, and abandoned wells) was based on hydro- geological investigations and quantum of potential runoff water available at specific locations. The recharge structures are based on well injection techniques and involve passing of excess rain and canal water under gravity through a bore well to subsurface sandy zones coupled to a recharge filter consisting of layers of coarse sand, small gravel and boulders in a small brick masonry chamber. These structures are successful at any low lying location where runoff gets accumulated and adversely affects the production of rice during rainy season and of wheat during any heavy winter rain. The groundwater recharge structures are simple in design keeping individual farmer's needs in mind. These systems have better chances of success and large scale adoption than the bigger and much costlier recharge schemes due to scope of maintenance of recharge filters by farmers themselves.

Depth wise soil and water samples from 35- 45 m, collected during installation of recharge structures were analyzed for soil texture (lithology) and geo- chemical parameters. The samples of runoff water being recharged were also regularly collected and analyzed for salt, nutrient and pesticide load and effect of its turbidity and sediments on clogging of recharge filters. The impact of recharge structures has been studied through recharge tests and estimation of recharge rates, geo- physical studies including correlation of aquifer resistivity with lithology, EC and RSC of groundwater, socio- economic surveys and monitoring of periodic changes in watertable depth and groundwater quality in the study areas. The recharging of water resulted in 0.6- 3.3 m and 0.3 to 3.3 m rise in water table at different sites in Haryana and Punjab during rainy seasons of 2009 and 2010 respectively. The corresponding reduction in salinity and RSC of groundwater at different sites ranged from 0.2- 2.4 and 0.1- 0.8 dS/m and 0- 6.6 and 0- 8.3 respectively during these two years.

The capital investment cost has been worked out @ Rs. 3.5 to Rs. 2.1/ m^3 recharge water for locations collecting runoff from 12- 20 ha area. The recharge structures, with intake rate of 4-6 litre/ sec, have proven highly effective in these states in augmenting groundwater, improving its quality (salinity, alkalinity and fluoride concentration) and enhancing farmers' income by saving submerged crops by recharge of excess water. The structures helped in reducing flood volumes through recharge to save

transplanted rice in the lowest 1-2 ha area at certain sites in Haryana and Punjab resulting in net saving of more than 25000/ from rice only. The payback period of 30- 45 m deep recharge structures, costing Rs. 30000- 50000, has been estimated to be 1- 2 years only. Similarly recharge through recharge wells in alluvial and rocky regions of Bharuch district of Gujarat resulted in prolonged availability and reduction in groundwater salinity and consequent 15 to 40 % increase in income from fruit (banana, papaya and mango) plantations. Further, recharge of excess canal water through recharge cavities at 3 sites in Unnao district of UP reduced fluoride concentration of groundwater from 2.0 ppm to 1.2 ppm, i.e below prescribed limit of 1.5 ppm for drinking water.

The clogging of the recharge filter has been observed to be a major constraint in the performance of recharge structures. Farmers need to be trained to clean the deposited sediments on the sand layer of recharge filter after every recharge event and replaced with new or washed sand to maintain optimal water intake. Mechanisms for farmers' involvement and marginal sharing of cost of recharge structures need to be developed. Field and lab studies are in process to devise improved designs of recharge filters, including radial and biological filters to minimize clogging problem. Thickness of upper sand layer of recharge filter has been found to be a primary factor influencing clogging, while size of gravel in the middle layer also controls effectiveness of sand as a filter.

Laser levelling is a highly effective tool to improve water productivity. Results from 6 farmers' fields in Haryana during 2009- 2010 indicate that laser levelling reduced mean irrigation water application in rice and wheat by 18.6 and 21.1 % and increased yields by 8.3 and 11.0 % respectively. This meant an additional income of Rs. 10910/ ha (Rs. 5040/ ha in rice and Rs. 5870/ ha in wheat) due to laser levelling over conventionally levelled fields. The corresponding increase in water productivity (Kg/ m^3 of applied water) are 34.6 % and 37.6 % for rice and wheat or Rs. 4.7/ m^3 for rice and Rs. 5.9/ m^3 of applied water in wheat.

(b) **NATP on Groundwater Skimming and Recharging**

The project aimed to identify, evaluate and standardize the designs and operational aspects for skimming (selective abstraction) and recharging of fresh water in saline groundwater regions of Haryana, Andhra Pradesh, Gujarat and Tamil Nadu. Central Soil Salinity Research Institute, Karnal was the lead center with co-operating centers at AICRIP (Saline Water Scheme), Bapatala (AP), Gujarat Agricultural University, Junagarh (Gujarat), Tamil Nadu Rice Research Institute, Aduthurai (TN) and Regional Research Station, TN Agricultural University, Aruppukottai.

During project period (2000- 2006), notable contributions were made in evolving groundwater skimming and recharging technologies at logically selected sites in these four states. A valuable repository of hydro-geological information has been synthesized for benchmark sites in these states.

(i) At Karnal center (Haryana), a groundwater skimming cum recharge system has been standardized that permits separate or combined pumping from or recharging (with filtered surface runoff) of two cavity tubewells installed at 7 and 40 m depth in different groundwater quality zones. It facilitates increased availability of good water in upper cavity and improves groundwater quality of deeper cavity for possible irrigation use. The system works on a community/ group of farmers basis and is to be located at a downstream site where excess runoff is available for recharge.

(ii) The impact of the system was evaluated through a series of pumping cum recovery and recharging tests, periodical observations on groundwater levels and quality through a network of observation wells. Recharge rates under filter bed and through injection in two cavities were estimated using water from a nearby and a distant tubewell. The recharge rates of 2 to 3 l/sec

through shallow cavity were low at about one quarter of the pumping rates while of deep cavity was very low at less than one l/sec.

(iii) The results were also analyzed to estimate aquifer parameters including resistance of clay layer, area of influence of cavity wells. Based on a number of time- drawdown and distance- drawdown approaches, the estimated value of hydraulic conductivity (K) ranged between 21-27 m/day during pumping, 21.2 m/day during recovery and 18.4 m/day during the recharge phases. The corresponding values of specific storage coefficient Ss were estimated at 0.005 to 0.0096, 0.00385 and 0.005 to 0.008 m^{-1} during pumping, recovery and recharge phases respectively. The thickness of aquifer was estimated as 9.25 m, radius of cavity as 8.0-9.0 m and radius of influence of cavity tubewell in the study area as 150 m. The estimated depth of cavity at 0.65–0.85 times its radius indicated that cavities in the area are not necessarily of hemi- spherical shape. Synthesis of results indicated that the distance- draw down approach incorporates the effect of a larger groundwater system and the resulting estimated parameters consequently are more representative of actual field conditions.

(iv) The improvement in groundwater quality in the area was evaluated through periodic resistivity surveys and quantifying the area under different apparent resistivity zones. Kamra et al. (2005) report general improvement in the groundwater regime of area due to combined effect of the natural and imposed recharge interventions. The farmers have started directing excess runoff to cavity tubewells through reflex valves without filtration.

(v) At another site, a **pumping cum recharging structure and** a **recharge shaft** have been designed. These are individual farmer based systems suitable for falling/ marginally saline groundwater regions. The pumping cum recharge structure facilitates groundwater recharge of a tubewell through gravel packed bore hole using rainfall or excess canal water after passing through a double chamber recharge filter. The recharge shaft serves the sole purpose of groundwater recharge and is to be located close to any operational or abandoned tubewell. It consists of a gravel- packed filled borehole to carry filtered recharge water to favourable aquifer zones.

(vi) Hydraulic evaluation and socio- economic analysis of these structures indicate better chances of success of individual farmer based recharge interventions and considerable scope for incorporation of inexpensive recharge filters in the existing or abandoned cavity/ strainer tubewells. Pilot studies on pressurized well injection, clogging and alternate designs of recharge filters are recommended.

(vii) In addition, radial collector well and multiple filter point systems for skimming of fresh water floating over saline groundwater have been evolved for sandy coastal regions **Andhra Pradesh and Tamil Nadu** while groundwater recharge through farm and percolation ponds have been proposed and evaluated for rocky regions of **Gujarat and Tamil Nadu.**

All these studies were conducted in farmers' fields with active participation of farmers. Four annual workshops were organized at different centers to evaluate the progress and transferring the results and hydrological know how to farmers. The nominee has been actively involved with group activities aimed at popularizing the hydrological issues, in particular rainwater harvesting and groundwater recharge, amongst farmers and school children. The project paved the way for commissioning of mega groundwater skimming projects in coastal sandy regions of Andhra Pradesh and Tamil Nadu and artificial recharge projects in Haryana, Gujarat and Tamil Nadu.

(c) **Evaluation of Effluent Salinity as a Design Criteria of Tubewell Drainage System**

The objective of the study was to predict pumped water quality from available information on hydro- geo-chemical characteristics of the area including depth wise salinity in the soil and groundwater.

(i) To compile the data base for water and salt transport models in tubewell drainage systems, long term pumping and recovery tests of up to 72 hours duration were conducted at 5 sites distributed over 3000 ha area in Gohana block of Haryana. The effect of pumping and recovery on temporal changes in drawdown and pumped water quality was studied in three fully penetrating wells of 30 m depth and two of 60 m depth developed by reverse rotary technique. A comprehensive database on hydraulic, lithological and geophysical parameters of logs of 5 tubewells and the chemical properties including heavy metals of soil, groundwater and the pumped water was complied.

(ii) Depth wise samples of soil and groundwater collected during drilling of wells and piezometers and of pumped water quality at different times during pumping tests were analyzed for EC, pH, ionic composition and a number of heavy metals. Groundwater in the project area is characterized by moderately to seriously high EC, SAR, pH and RSC, as well as serious contamination with heavy metals in particular As, Pb, Cd and Ni. The results emphasize careful monitoring of groundwater in the area not only conventional quality parameters but also for heavy metal contaminants. Linear correlation was worked out between above chemical properties, concentration of heavy metals and geo- physical parameters of self potential and apparent resistivity. Multiple correlation analysis indicated spontaneous potential (SP) to be highly correlated with salinity, resistance and texture.

(iii) The time- drawdown/ recovery data of pumping tests for boreholes and piezometers at 5, 10 and 20 m lateral distance was analyzed by Theis Jacob method using software code SATEM (Selected Aquifer Test Evaluation Methods) of ILRI. 3- D saturated flow model, MODFLOW (PMWIN)) was applied to estimate long term effluent salinity of tubewells in the study area.

(iv) To characterize the lateral and depth wise salinity distribution in the project area, geo-resistivity survey was conducted. 250 electric soundings at a grid spacing of 300 x 300 m using Wenner configuration were performed to prepare iso- resistivity and related water quality maps up to 60 m depth zone below ground level. At every third site, Schlumberger test was conducted to characterize surface 1.5 m deep unsaturated zone supplemented by soil sampling. In addition, EM 38 soil salinity surveys at the same grid were conducted to compare its results with soil samples and resistivity results.

(v) A semi- analytical model based on complex velocity potential and stream function approach was applied to derive spatial distribution of concentration around a pumping well based on time series data of concentration of well or one or more observation wells. The model was applied to time series data on concentration of pumped water at five test wells to derive concentration distribution at different radial distances from the well.

(vi) A solute mass/ water balance approach was applied to estimate pumped water quality of a well based on vertical profiles of solute concentration and flow contribution from different sections of screened areas in the aquifer. The concentration of any chemical constituent in pumped water was taken as a flow and concentration weighted integration of inputs to the well from different sections. The relative flow components from corresponding sections were estimated from distribution of hydraulic conductivity (K) of various screened sections of the aquifer derived from particle size distribution of collected soil samples and corresponding K values

reported in literature. The model gives a constant simulated value which was found to be close to the observed temporal values of EC and a number of heavy metals in pumped water in an average sense for Gohana region.

(vii) To improve upon the simulations, modular 3D finite difference groundwater flow model (MODFLOW) was applied to the distance draw down data of 5 test sites using hydraulic parameters estimated separately. There was good match between the observed and simulated results indicating the validity of estimated hydraulic parameters and modeling approach. s

(viii) An empirical approach was applied to estimate the safe yield and spacing of skimming wells in the area. For a test site with horizontal hydraulic conductivity of 10 m/day, groundwater salinity varying from 4 dS/m in upper 3- 37 m depth zone to 35 dS/m below till 52m depth, skimming wells of 3- 4 litre/ sec discharge and 0.15- 0.40 penetration ratio can be installed at 50 m spacing under isotropic conditions. Anisotropy significantly influences the design of skimming wells in in aquifers with increasing salinity with depth.

2. Subsurface Drainage (1983- 1995)

Since 1983, the applicant has been diligently involved in CSSRI's efforts to develop a techno- economic and environmentally viable **subsurface drainage technology** for amelioration of waterlogged saline irrigated lands in arid and semi- arid regions of India. Research output from a number of drainage pilot studies varying in size from 10 to 75 ha in Haryana, most notable at **Sampla** (Distt. Rohtak), have resulted in standardization of this technology for soils of Haryana, Punjab and Rajasthan. At most of these sites, the watertable fluctuated between about 1.5 m from ground level during summer to near the surface during monsoon. The initial salinity of groundwater at most sites was more than 10 dS/m, being as high as 40 dS/m in extreme cases. In the earlier installations, cement clay tiles were used for laterals and cement concrete pipes for the collectors. However, after 1986, pvc rigid and corrugated pipes are being increasingly used as sub- surface drains. Either graded natural gravel or pvc (synthetic) netting (60-75 mesh size) have been used as envelope at these sites. The average salinity of root zone at all the sites has been considerably reduced resulting in good production of a number of crops in hitherto barren highly saline lands. At Sampla, the installation of drainage system in initially barren soils enabled cultivation and production of about 2 t/ha of coarse cereal grains or seed cotton in k*harif* and more than 4 t/ha of wheat or barley and 2.0 t/her of mustard in *rabi* season.

For inland areas without a natural outlet, research efforts made by the applicant from 1989 onwards at the farm of **Central Institute for Research on Buffaloes (CIRB), Hisar**, have resulted in the introduction of evaporation pond technology for management of saline drainage effluent. This was the first effort in India on evaluating the scope of evaporation ponds for storage and possible evaporation of saline effluent of subsurface drainage system in arid regions of India. A number of similar projects on evaporation ponds have been executed since late 1990s by a number of agencies in the states of Haryana and Rajasthan. At current prices, the cost of providing the subsurface drainage system has been estimated to be about Rs 40000/ per hectare without a pond and Rs. 50000/ ha with an evaporation pond. The operational cost of the drainage system is mainly due to pumping of the drainage effluent.

(i) For the inland waterlogged- saline soils, subsurface drains of 65 to 80 m spacing and 1.5 to 1.8 m depth can provide adequate watertable and salinity control for potential crop production. For arid regions of Haryana and Rajasthan, drain spacing up to 100m could be tried.

(ii) In areas with suitable outlets, rainwater leaching through drainage during rainy season is adequate to maintain favourable salt balance of drained fields. The quality of drainage effluent improves after one or two years to levels for possible use in irrigation. After reclamation leaching, the watertable rise during non- rainy season due to suspension of drainage has no adverse effects.

(iii) In inland areas without an outlet, evaporation ponds with surface area of about 5 % of the drainage area offer an interim solution for managing saline drainage effluent. The quality of pond water deteriorates with time and seepage losses can be significant during initial years in ponds constructed in sandy substratum. Peripheral drains provided on the sides of the pond restrict groundwater contamination to surrounding areas while measures like provision of drain lines below pond bed or use of some sort of lining need to be tested. There could be long-term problems of evaporation ponds which may be viewed to provide a temporary and partial remedy.

(iv) Reuse of drainage water for irrigation of salt tolerant crops is an option to handle large volumes of saline drainage effluent in Haryana. Drainage waters of about 10 dS/m salinity can be recycled for irrigation of crops like barley, wheat and mustard in the winter season. Long- term effects of saline water irrigation on root zone salinity and groundwater contamination need constant monitoring and surveillance.

Small scale studies of CSSRI facilitated commissioning of large scale mechanically- installed subsurface drainage projects in farmers' fields in Haryana and Rajasthan as well as the inception of an Indo- Dutch Network Drainage Project at CSSRI to extend drainage technology to four affected states of Rajasthan, Gujarat, Andhra Pradesh and Karnataka.

3. Mathematical Modeling (1985- 1997)

The applicant has contributed adequately to the research conducted at CSSRI on the development and application of mathematical models to supplement field drainage research. The applicant has been principally involved in the development and validation of a two- dimensional finite element model '**DRAINSAL**' of water and solute transport in subsurface drained soils. The model provides long- term predictions of the desalinization of a tile- drained soil and of the associated changes in salt loads of drainage effluent and groundwater quality. The model considers steady state water movement in the unsaturated and saturated zones, and includes the effect of convective transport, dispersion and linear adsorption. The inputs to the program consist of information on finite element discretization of the flow domain and types of boundary conditions and information related to drainage system (depth, spacing and radius of drains), aquifer (porosity, hydraulic conductivity, depth to impervious layer and groundwater salinity), soil (water retention and unsaturated hydraulic conductivity functions and initial salinity), inflow parameters (rainfall, quantity and quality of irrigation water, evapo- transpiration) and adsorption.

The model was calibrated and validated against field results of the Sampla subsurface drainage system. It was calibrated with observed data of two years and 10 year predictions on salt concentration in soil, groundwater and drainage effluent were made. Salient results on model applications indicate that

(i) Sub-surface drains of about 75 m spacing and 1.5 to 1.8 m depth are reasonably effective in amelioration of sandy loam saline soils of Haryana State. The drainage effluent is much saline during the initial years of reclamation in drains wider and deeper than these limits, especially if installed at depths $\geq$ 2.5 m.

(ii) The salt concentration in the soil, groundwater and drainage water are significantly influenced by aquifer stratification, depth of impervious layer and adsorption. The adsorbing solutes are retarded for a longer period in the groundwater than in the soil profile of tile- drained lands.

(iii) Notwithstanding the steady water flow assumption, the model can provide reliable estimates of the salt load of drainage effluent. It can also be modified to predict the losses of nutrient and trace elements to the drains.

The model has been applied to analyze drainage design criterion for salinity control, to estimate the volume and salinity of drainage effluent and to provide decision support for its disposal or reuse under alternate drainage designs. The published field and model results have contributed to **the abandoning of critical watertable concept in favour of the concept of net downward water flux for deciding drain depth and consequent acceptance of shallower drains in arid and semi- arid regions.** These aspects presented by the applicant during the 5th International Drainage Workshop were specifically referred in the technical session's report and further reiterated in the final general report of the workshop held at Lahore from February 8- 15, 1992.

The scope of the model was extended for reactive solutes, including pesticides, during applicant's stay in Germany as an Alexander von Humboldt fellow (April 1995- January 1997). Based on stochastic analysis of results of lab and field studies on pesticide leaching in soils and subsurface drainage systems, quantitative indices have been derived and proposed to characterize the extent of preferential flow in soils. In addition, uncharacteristic preferential flow mechanisms involving water and solute movement along interface of soil horizons to field drains were identified and reported for clayey soils of north Germany.

4. Rainwater Harvesting and Conservation in Alkali Soils (1978- 1984)

Alkali soils, characterized by very low infiltration rates, produce considerable amount of runoff during the monsoon and provide excellent opportunity for rainwater harvesting. The applicant was actively involved with two field experiments relating to rainwater management in alkali soils:

(i) The first study aimed to develop a rainwater harvesting system for utilization of alkali lands as grasslands without addition of amendments and in absence of any irrigation source except rainfall. Alkali plots (20m x 50m) were divided into two compartments: rainwater was harvested in the upper compartment while alkali- tolerant Karnal grass and Para grass were grown in the lower compartment. The 4- year study indicated that a water harvesting compartment at least twice as large as the grassed compartment can provide sufficient rainwater for getting good yields of grasses and partially reclaiming the land.

(ii) The hydrological response (rainfall- runoff relationships) of alkali soil to different land- use treatments (trees and grasses) was studied in four geometrically identical highly alkali watersheds of 0.5 ha each. The results indicated that growing of tree species like *Acacia nilotica* and alkali tolerant grasses like Karnal grass (*Diplachne fusca*) can reduce the runoff volume in barren alkali catchment from over 80 % to about 45 % and the corresponding peak runoff rates can also be reduced to almost half.

APENDIX II : List of Publications of Dr. S.K. Kamra

Journal Papers

1. Singh, G., Bundela, D.S., Sethi, M., Lal, K. and Kamra, S.K. 2010. Remote sensing and geographical information system for appraisal of salt affected soils in India. J. Environmental Quality, 39 (1): 5- 15 [NAAS Journal Rating: 8.7]

2. Ram, J, Garg, V.K., Toky, O.P., Minhas, P.S., Tomar, O.S., Dagar, J.C. and Kamra, S.K. 2007. Bio-drainage potential of *Eucalyptus tereticornis* for reclamation of shallow water table areas in north- west India. *Agro-forestry System*, 69: 147- 165. [NAAS Journal ID: A062; Rating: 8.0]

3. Pandey, H., Singh, J. and Kamra, S.K. 2006. Comparison of aquifer parameters estimation techniques. *J. Water Management*, 14(2): 69- 74. [NAAS Journal ID: J317; Rating: 4.0]

4. Kamra, S.K. and Lennartz, B., 2005. Quantitative indices to characterize the extent of preferential flow in soils. *J. Environmental Modelling and Software*, 20(7), 903- 915. [NAAS Journal ID: E052; Rating: 8.5]

5. Pathak, H., Ladha, J.K., Aggarwal, P.K., Peng, S., Das, S., Singh, Yadvinder, Singh, Bijay, Kamra, S.K., Mishra, B., Sastri, A.S.R.A.S., Aggarwal. H.P., Das, D.K. and Gupta, R.K., 2003. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research*, 80: 223-234. [NAAS Journal ID: F012; Rating: 8.4]

6. Kamra, S.K., Lal, K., Singh, O.P. and Boonstra, J. 2002. Effect of pumping on temporal changes in groundwater quality. *Agricultural Water Management*, 56(2), 169- 178. [NAAS Journal ID: A055; Rating: 8.1]

7. Kaledhonkar, M.J., Kamra, S.K., Sharma, D.P. 2002. Estimating the volume of subsurface drainage water under different crops. *J. The Institution of Engineers (India)*, 83: 44- 48.

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11. Lennartz, B. and Kamra, S.K., 1998. Temporal variability of solute transport under vadose zone conditions. *J. Hydrological Processes*, 12: 1939- 1949. [NAAS Journal ID: J159; Rating: 5.0]

12. Lennartz, B., Kamra, S.K., Meyer- Windel, S., 1997. Field scale variability of solute transport parameters and related soil properties. *J. Hydrology and Earth System Sciences*, European Geophysical Union, 4: 801- 811.

13. Rao, K.V.G.K. Rao, Kamra, S.K. and Sharma, D.P. 1996. Drainage of waterlogged saline soils of India. *J. Water Management*, 4: 31- 37. [NAAS Journal ID: J317; Rating: 4.0]

14. Kaledhonkar, M.J., Kamra, S.K., Yadav, R.K. and Tiwari, K.N. 1996. Probabilities of historic droughts for south western Orissa in India. *J. Indian Water Resources Society*, 2 (4), 19- 24.

15. Kamra, S.K., Rao, K.V.G.K., Singh, Sita Ram, 1995. Modeling solute transport in sub- surface drained soil-aquifer system of irrigated lands. *J. Irrigation and Drainage System*, 9: 189- 204. [NAAS Journal ID: I154; Rating: 3.0]

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Books

1. Singh, G.B., Kamra, S.K., Sharma, P.C., Kaledhonkar, M.J. and Gautam, R.K., 2007. CSSRI- Annual Report 2006-2007, Central Soil Salinity Research Institute, Karnal- 132001, India, 128 p.

2. Singh, Gurbachan, Sharma, P.C., Ambast, S.K., Kamra, S.K. and Khosla, B.K (Ed.s). 2006. CSSRI: A Journey to Excellence (1969- 2006). Central Soil Salinity Research Institute, Karnal- 132001, India, 156 p.

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4. Tyagi, N.K., Kamra, S.K., Minhas, P.S., and Singh, N.T.(Eds.), 1993. Sustainable Irrigation in Saline Environment, National Workshop on Sustainable Irrigation, Central Soil Salinity Research Institute, Karnal, India, Feb. 17- 19, 229 p.

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2. Kamra, S.K. and Minhas, S.K. 2009. Skimming and recharge technologies for areas underlain with saline groundwater. In: Sustainable Management of water Resources: Emerging Science and Technology Issues in South Asia (Ed. Menon, M.G.K. and Sharma, V.P.), Indian National Science Academy, New Delhi, 254- 265 pp.

3. Kamra, S.K. 2009. Engineering interventions for management of marginally saline groundwaters. In: Bio- Nano- Geo- Sciences: The Future Challenge (Ed. Srivastava, A. and Roy,I), Ane Books Pvt. Ltd., New Delhi, 123- 131 pp.

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