沙漠研究 7S, 85-88 (1998)
Journal of Arid Land Studies

Performance Analysis of Basin-type Solar Stills Equipped with Evaporation and Condensation Stimulators

Tomoharu YAMAGUCHI*, Makoto YOKOTA**, Yukuo ABE* and Seiji YOKOTA*

Abstract - Basic performance of double slope basin-type stills were experimentally analyzed to develop the new model for more effective solar still equipped with evaporation and condensation stimulators. The effectiveness of gathering distilled water was varied with the kinds of covering materials for still. Rigid polyester film with anti-droplet treatment was most efficient to gather the water, and inner convection fan in solar still increased the amount of distilled water about 10 % more.

Keywords: basin-solar still, covering materials, evaporation stimulator

1. Introduction

There are many ways of solar energy application in producing fresh water from brackish or sea water. The simplest and most common method is direct use of the solar energy in basin-type solar stills which act simultaneously as converters of solar energy to heat and as distillers. Our objectives of this study is to analyze the basic performance of double slope basin-type stills and to develop the new concept for basin solar still equipped with evaporation stimulator.

2. Materials and Method

2.1 Experimental apparatus

Small models of double-slope basin type solar still were conducted to the experiments. The size of the still model was 400 mm(W) × 480 mm(L) × 250 mm(H) and the horizontal floor area was 0.192 m^2. The roof slope of still was 30 deg. The roof and side-wall were laied with various materials, such as PVC(poly vinyl chloride), polyethylene and rigid polyester film. Inner surface treatments of the above covering materials were conducted, such as anti-drop film and usual droplet making film (non treatment). Both settings in presence or none of convection fan were examined. These experimental conditions were also shown in Table 1.

The water basin was set on the floor of solar still, and the bottom of basin was colored black easily to absorb the solar heat Saline water was supplied from outside mariotte's tube, which maintained constant basin-water depth. The U-troughs were set on the side walls of the still to gather condensed water.

Table 1. Experimental conditions ; covering materials and inner convective fan.

Covering materials (inner surface treatment)		Inner convective fan
Soft plastic	Polyethylene (Anti-droplet film)	Attached Non
	Polyvinyl chloride (PVC) (Anti-droplet film)	Attached Non
Rigid plastic	Polyester (Anti-droplet film)	Attached Non
	Polyester (Non, usual droplet making)	Attached Non

*Inst. of Agric.& Forest Eng., Univ. of Tsukuba, Ibaraki 305, Japan(Fax:+81-298-55-2203)
**Master's Program in Bio-systems Studies, Univ. of Tsukuba, Ibaraki 305, Japan

The setting for experimental apparatus was shown in Fig.1.

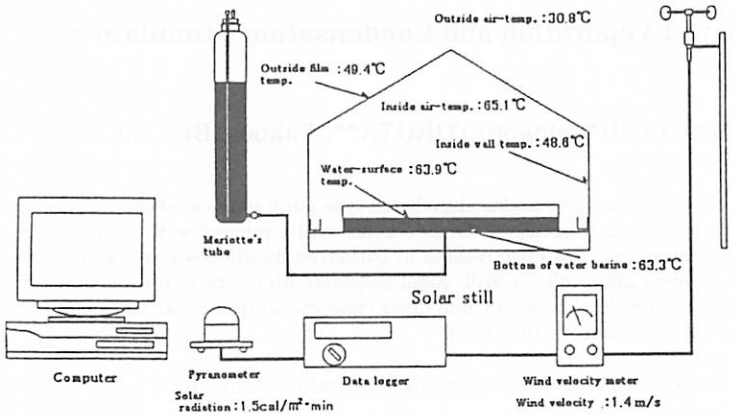


Fig.1 Experimental apparatus

2.2 Measurement

Pyranometer was used to measure the flux of total solar radiation and cup anemometer was used to measure wind velocity outside the stills. Thermocouple thermometers were set to measure the ambient air temperature inside and outside the still as well as the temperature at the surface of basin water and the inner surface of still roof and wall. The data logging system was set up using a computer. All signals concerning the environmental factors were taken every 10 min. and recorded on floppy disk in the datalogger. The average values for 1 hr. were calculated with the computer. Mass of distilled water was measured on every night.

3. Results and Discussion

3.1 Environmental temperature conditions

Acquisitions for climatic and water-output data were done since September of 1996. Fig.1 also shows one example of the measured temperature distribution inside and outside the solar still on a typical sunny day, September 12, 1996. Fig.2 and 3 show daily temperature changes in the solar stills with the anti-droplet film surface and non-treated film surface, respectively, in winter season.

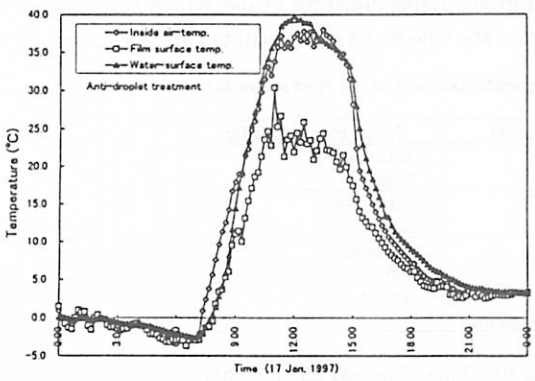


Fig.2 Daily temperature changes in the solar still.
(film surface;anti-droplet)

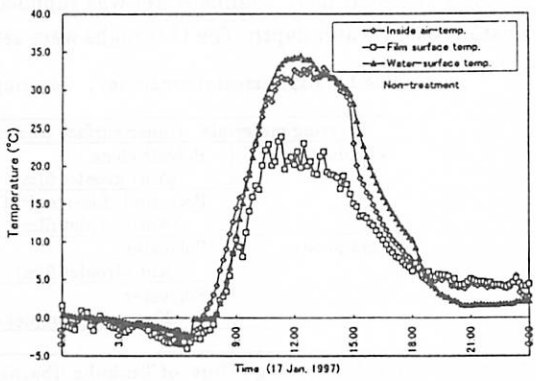


Fig.3 Daily temperature changes in the solar still.
(film surface;non-treatment)

Maximal inside air-temperatures and surface temperatures of water basin in the still with anti-droplet film were 5 to 7 ℃ higher than those in the still with non-treated film. Fig.4 shows the relationship between the daily solar radiation and temperature difference of inner air and film surface in the case of polyester covering films. This also indicates the result that higher temperature differences are created in the still of anti-droplet film rather than of non-treated films. This is due to the film-wise condensation ,which offers the transparency to solar beam and then increases the rate of heat transfer.

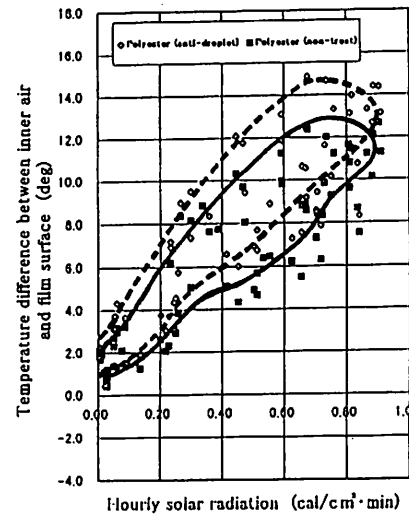


Fig. 4 Relationship between hourly solar radiation and temprature difference of inner air and film surface. (97'1/13-1/17,21,25)

3.2 Output of distilled water

The relationships between the cumulative daily solar radiation and the cumulative amounts of distilled water are shown in Fig.5 and 6, in the case of use of the inner convection fan and non of fan, respectively, when PVC and polyethylene films were used as the covering of the stills.

The PVC film stills had approximately 10 % water output more than the stills of polyethylene film. Operating the convection fan in the solar still increased the amount of gathered water about 10 %.

Fig.7 shows the summarized results for performance of water output in the solar stills with various kind of covering film. The rigid polyester film, having the inner surface treated as anti-droplet, was the most effective to gather distilled water.

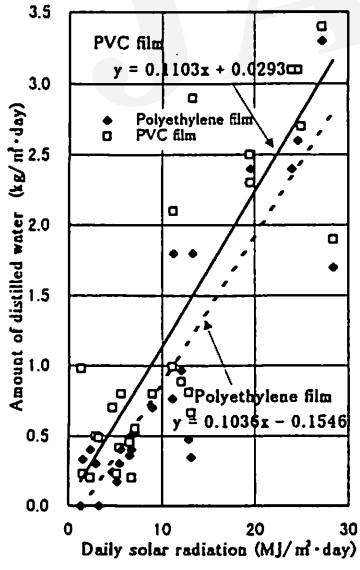


Fig.5 Radiations between daily solar radiation and amount distilled water (in case of non-fan)

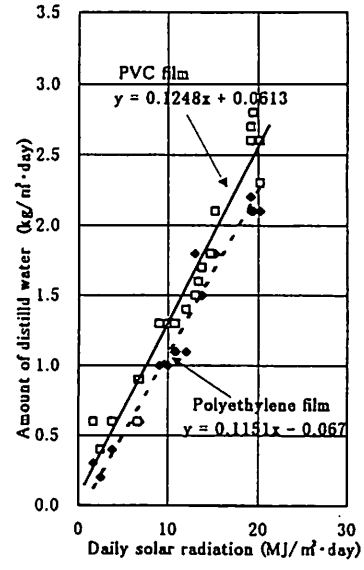


Fig.6 Relations between daily solar radiation and amount distilled water (in case of existent convective fan)

3.3 Future works

Performance of water output in the solar still has to be increased much more. Additional treatments are trying to increase the output. One is the presence of ultrasonic vibrator attached to the bottom surface of still. The ultrasonic vibrator works as evaporation stimulator. We are now gathering the data from laboratory and field experiments. Preliminary test using the device equipped with the ultrasonic vibrator in controlled environmental chamber, the ultrasonic vibrator was very effective to evaporate much water from the basin.

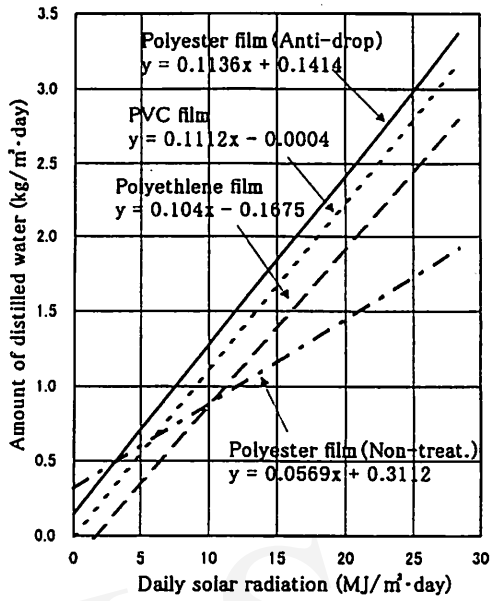


Fig.7 Amount of distilled water according to the various covering materials of still

4. Conclusion

In this study, we could have the some basic data for double slope basin-type solar stills with various kinds of covering films. It was just the first step, and further study is necessary to develop more effective solar stills with the evaporation and condensation accelerators.

References

TAWARI,G.N. et al.(1986):*Desalination*,60:191-202

ISHIKAWA,Y. and MATSUMOTO,S.(1996):*Abst. of 1996 meeting, Jap. Asso. Arid Land Studies*,7:7-8

YAMAGUCHI,T.,YOKOTA,M.,ABE,Y. and YOKOTA,S.(1997): *Abst. of 1997 meeting, Jap. Asso. Arid Land Studies*,8:4-5

沙漠研究 7S, 89-92 (1998)
Journal of Arid Land Studies

Wastewater Reuse for Revegetation and Permaculture in Arid Lands

Martin ANDA*, Goen HO, Kuruvilla MATHEW*****[1]**

Abstract - The reuse of 'greywater' or sullage, effluent from bathroom and laundry, is currently not permitted in Australia but is widely supported by the community, promoted by researchers, and improvised by up to 20% of householders. Its widespread implementation will make an enormous contribution to the sustainability of water resources. Integration with other strategies in the outdoor living environment of settlements in arid lands will derive great benefit. This paper describes five options for greywater reuse under research by the Remote Area Developments Group (RADG) at Murdoch University and case studies are given where productive use is being made for revegetation and food production strategies. Pollution control techniques and maintenace requirements are described. The case of remote Aboriginal communities is explained.

Keywords - greywater reuse, revegetation, food production.

1. Introduction

The paradigm governing wastewater management has in the past focussed on the pollutants in the wastewater and disposal as the solution. It relied on centralised water supply, sewerage and drainage systems with up to 85% of costs incurred in piping and pumping. The appropriateness of this English paradigm for Australia has been questioned (Newman & Mouritz, 1996; Beder, 1993) as has the transfer of expensive centralised systems to developing countries (Niemczynowicz, 1993) and remote Aboriginal communities (Race Discrimination Commissioner, 1994). Reuse of wastewater occurs most cost-effectively and productively with on-site (localised) or small-scale treatment systems. Thus involvement of a local community is enabled and reuse options in the local context agreed upon. In sewered areas greywater reuse can still be implemented on-site. Greywater discharged to primary systems on-site should exclude kitchen sink wastewater as it carries oils and high biochemical oxygen demand (BOD). The more concentrated blackwater (from the toilet) can still go to the sewer along with kitchen effluent. In unsewered areas the blackwater can be treated separately or dry vault (pit or composting) systems utilised. Greywater reuse can result in cost savings (to both the consumer and state water authority), reduced sewage flows in sewered areas and potable water savings of up to 38% when combined with sensible garden design. Significant impact on water and energy use requires greywater reuse to be coincidental with water-sensitive design, reduced lawn area, and growing food at home and in public open space. There is immense community support for reuse of wastewaters (WAWA, 1994). This paper will review regulatory developments, describe five methods under research by the Remote Area Developments Group (RADG), and present options for remote Aboriginal communities.

2. Current Regulation

Domestic greywater reuse, governed by state and local government health acts, is currently not allowed in any of the Australian states although it is acknowledged by the WA state authorities that 20% of householders engage in this practice in Perth (Lugg, 1994; Stone, 1996). In Queensland three options were developed for possible implementation (Department of Primary Industries, 1996). The model guidelines for domestic greywater reuse in Australia (Jeppeson, 1996) covered hand basin toilets, primary greywater systems (direct subsurface application) and secondary greywater systems (mesh, membrane or sand filtration prior to irrigation). For primary systems the guidelines have adopted the Californian approach requiring the use of a surge tank with a screen to remove lint and hair. Electrical power is therefore required for the automatic pump system and weekly inspection and clearing of the screen. The need for maintenance to these components by the householder resulted in some 80% of Californian systems being in an unsatisfactory condition (Jeppeson, 1994). The application of this approach as the solution for Australia is questionable. The updated standard AS1547-1994 guiding domestic effluent (Standards Aust./NZ, 1996) is significantly more progressive in providing design criteria for a range of treatment systems with reuse and opening the way for further innovation.

[1] * Research Associate, RADG, Institute for Environmental Science, Murdoch University, fax: (61 8 9310 4997);
** Senior Lecturer in Environmental Engineering IES, Director - RADG; *** Research Fellow IES, Manager - RADG

Treated effluent from centralised plants is used on municipal ovals, parks and golf courses in many country towns of WA (Mathew & Ho, 1993). In New South Wales treated effluent from centralised plants is allowed in urban areas (NSW Recycled Water Coordination Committee, 1993). National guidelines for the use of reclaimed water via dual reticulation have been prepared (National Health & Medical Research Council, 1996). The level of treatment recommended is secondary plus filtration and pathogen reduction, but constructed wetlands may achieve equivalent treatment with open water areas which will allow pathogenic die-off due to UV sterilisation.

3. System Characterisitcs

A greywater reuse system needs to protect public health, protect the environment, meet community aspirations and be cost-effective. Current on-site treatment systems have generally adopted the technology of the conventional activated sludge plant for large treatment systems. If removal of nutrients is required for installation of on-site units in nutrient-sensitive catchments, phosphorus (P) can be removed by alum dosing and nitrogen (N) by nitrification and denitrification in separate chambers or by intermittent aeration of a modified activated sludge set-up.

If the effluent is used for irrigation of garden plants there is the question as to why N and P should be removed. There may be an imbalance between plant requirement for the nutrients and the seasons, with a higher requirement in the warmer months than the colder months. Rather than removing the nutrients an alternative is to store the nutrients in the soil. Soils containing clay have the capacity to sorp ammonium and phosphate present in secondary effluent. Sandy soils can be amended with clay, loam or if convenient the 'red mud', bauxite-refining residue. The most progressive application of domestic greywater reuse appears to be in California. But even here the minimum prescribed depth of 430 mm for subsurface irrigation "ignore(s) the importance of aerobic bacteria and biota (found in profusion in the top few inches of garden soil) for digesting organic matter, nutrients and possible pathogens found in graywater" (Kourik, 1995).

4. Five Options Currently Under Research for Western Australia

4.1 Amended Soil Filter

Fremantle Inner City Agriculture (FINCA) developed an 800 square metre community garden and is using the greywater from two adjacent houses to irrigate it. This is part of a water-sensitive, permaculture design approach which also involves harvesting rainwater from the two houses' roofs, heavy mulching and appropriate, low water use species selection for growing food in a perennial polyculture. Design and sizing of the system was generally in accordance with Standards Australia but flow monitoring and resident behaviour to date indicates the system is over-sized.

Greywater from the two houses enters a collection tank in the park by gravity. The duty field is a variation of the 'Ecomax' principle (Bowman, 1996) comprising two laterals of 20 m x 1.2 m and 25 m x 1.2 m wide. The plastic lined trenches are filled with a mix of 85% red sand and 15% red mud (with 5% gypsum in the latter to neutralise its alkalinity). The red mud and sand are by-products of bauxite refining to alumina. P is adsorbed into this clay material and N is removed from the system by intermittent drying and wetting causing nitirification-denitrification. Pathogens are filtered and die off. The field is heavily vegetated causing significant nutrient uptake and transpiration.

4.2 Sand Filtration

The Envirotech system consists of a receival tank where settling of solids occurs, a second chamber into which the effluent flows and when this is full effluent is pumped to the top of a deep bed sand filter. Effluent is collected in the bottom and flows back to a third chamber of the tank, from where the treated effluent is pumped to the irrigation field. General practice is to chlorinate in this final chamber, although it may not be necessary for subsurface irrigation. Systems are being installed in NSW and Indonesia. A system based on Envirotech sand filtration for greywater reuse is now designed and awaiting installation at a WA residence with Health Department approval.

4.3 Wet Composting

The Dowmus vermicomposting toilet system can be upgraded to receive wastewaters - both blackwater and greywater (Cameron, 1994). In Canberra, ACT about 12 households have had trial systems installed for monitoring by Australian Capital Territory Electricity and Water (ACTEW) (Anon, 1996). Blackwater from the toilet enters a wet composting Dowmus tank and from there effluent goes to a second tank where greywater is also received. In this tank effluents are aerated around submerged volcanic rock media to achieve secondary standard treated effluent. From there the effluent goes to an irrigation storage tank in which chlorination occurs. The final effluent is mixed

with rainwater to achieve further dilution and to improve the quality of water. A wet composting research project will be established at Murdoch University in a permaculture system.

4.4 Constructed Wetlands

Tubemakers Water Treatment have recently completed construction of a combined wastewater treatment plant and constructed wetland at Mundaring, Western Australia for the Water Corporation. Mundaring had been served by septic tank systems but was in a water catchment area. The hybrid intermittently decanted extended aeration (IDEA) system consisted of two aerated tanks in series (Turner *et al*, 1996). The free water surface wetland comprised endemic emergent and submergent macrophyte zones which fostered aeration in the wetland and optimal nutrient uptake across seasonal variations. Effluent from the wetland will eventually be reused on parks and gardens in Mundaring.

Not far from the Mundaring site in Hovea, permaculture educator Ross Mars (1996) is conducting experimentation on the submergent *Triglochlin hueglii* in constructed wetlands. The aim is not only to verify treatment capability, but to use these edible species in a polyculture arrangement.

4.5 Modified aerobic treatment unit

At the sewered suburb of Palmyra, Western Australia six aged-person, state housing units were chosen for a greywater reuse trial (Bingley, 1996). Blackwater goes direct to sewer. All greywater from the six units goes to a single 'Aquarius' aerobic treatment unit. The first chamber was eliminated in this application so that biomass could be maximised in the subsequent chambers. After treatment the effluent is pumped to storage tanks located in the roof of each unit. The effluent is then gravity fed to toilet cisterns after disinfection, and excess is used for garden irrigation.

At Hamersley Street, Cottesloe, Western Australia, also a sewered suburb, a Biomax greywater reuse system was approved and installed in May 1996. Effluent is irrigated to the front and back yards via 'Dripmaster' subsurface tubing. Monitoring is currently underway to evaluate the performance with the reduced biomass as a result of greywater influent only.

5. Remote Aboriginal Communities

Unlike many of the large urban areas of Australia, remote Aboriginal communities in arid lands do not have a diverse range of water sources. Typically there are groundwater sources whose sustainability in the face of growing populations is uncertain. At Coonana, for example, water shortages have been extreme (Race Discrimination Commissioner, 1994). However, there is poor public health in some communities and any reuse proposal needs to take serious consideration of this factor. Nevertheless, wastewater reuse can lead to improved public health. Separation of greywater and blackwater enables decreased loading on treatment systems and therefore results in greater reliability and performance. Dust control is accepted as necessary to alleviate disease, e.g. trachoma, which can be achieved through revegetation. Irrigation systems to establish trees use valuable potable water, are expensive and maintenance intensive. Greywater reuse evapotranspiration systems can be designed for low-cost, durability and low maintenance with sub-surface, gravity-feed, PVC piping.

Wastewater disposal systems often account for a major maintenance cost in remote Aboriginal housing and this was often because of poor initial construction by non-Aboriginal contractors (Pholeros, Rainow & Torzillo, 1993). A holistic response for on-site systems is necessary including separation of blackwater and greywater, use of evapotranspiration instead of absorption, interconnection of houses and systems to spread peak loads, back-up pit toilets to each house to cater for system failure, overcrowding and solids reduction, productive use of treated effluent, strict supervision of below-ground construction works, and effective management and maintenance.

In WA evapotranspiration systems are now fairly common in remote communities with tight soils (McGrath, Ho & Mathew, 1991). Composting toilets have been installed at Wilson's Patch in the Goldfields and by Winun Ngari Resource Agency in the West Kimberley. Greywater reuse was recommended for Tjalku Wara in the Pilbara (Swanson, 1996) and a design was prepared by a regional permaculture practitioner. A trial greywater reuse system was approved for Frog Hollow in the East Kimberley (Kinnaird, 1997). However, most of the above principles have not been observed and the tendency has been to install deep sewerage to lagoons when funds become available rather than attempt to implement all of the principles simultaneously. On-site and community-scale systems using one or more of the above five options need to be established in remote communities for research into their appropriateness and not just their technical suitability. In most cases, however, evapotranspiration systems will be appropriate and these can be adapted for simpler greywater reuse in parallel with blackwater septic systems or dry vault toilets.

Studies were completed for wastewater reuse from lagoons at Warralong and Jigalong in the Pilbara (Mathew & Ho, 1993). There was insufficient wastewater produced for irrigation of a

football oval. Groundwater recharge was an option. The most suitable options were revegetation, orchards and vegetable gardens by subsurface or drip irrigation. If surface irrigation was proposed some form of disinfection to eliminate pathogens and enclosed storage to eliminate algae would be necessary. Reuse direct from lagoons could be subsurface from the overflow after the last lagoon or pumped from the lagoon to storage for later irrigation.

6. Conclusions

For the urban village, small country towns, or group housing a greywater reuse system utilising secondary treatment and disinfection maintained by a supplier may be most appropriate. For on-site reuse at individual houses in a low-density or remote community a primary system with large diameter subsurface irrigation 300 mm below the surface is appropriate using evapotranspiration in soils of low permeability. Filters, pumps and treatment units should be avoided as these may not be adequately maintained by the owner/occupier. Reuse from lagoons is commonly practiced in WA country towns. If nutrient removal is necessary a treatment system such as Aquarius or Ecomax with sufficient vegetation to utilise the nutrient is ideal. Research into the five methods of greywater reuse will aim to achieve regulatory approval for on-site systems in WA. Data-gathering on the long term effects of greywater on plants and soils and their nutrient uptake capacity is necessary. Regulatory authorities should approve systems which can be constructed with monitoring and inspection by local authorities. A standard code of practice on greywater reuse should be adopted. If managed correctly wastewater reuse in remote Aboriginal communities can not only result in water savings but also improved public health through dust suppression from revegetation, improved nutrition from locally grown food, and less system failures from decreased loading on treatment systems.

7. References

Anon (1996). Small-scale Systems Halve Water Use, *Waste Management and Environment*, **8**, 18 - 20.

Beder, S. (1993). Pipelines and Paradigms: The development of sewerage engineering, *Australian Civil Engineering Transactions*, **CE35**, (1), 79 - 85.

Bingley, E. B. (1996). Greywater Reuse Proposal in Relation to the Palmyra Project, *Desalination*, **106**, 371 - 375.

Bowman, M. (1996). On-site Tertiary Treatment Using Ecomax Systems, *Desalination*, **106**, 305 - 310

Cameron, D (1994), Compost Filtration: A new approach to on-site resource management, in Mathew K & Ho G (eds), *Workshop on Localised Treatment and Recycling of Domestic Wastewater*, RADG, Murdoch University.

Department of Primary Industries (1996), *Policy Options Paper - The Use of Greywater*, Brisbane.

Jeppeson, B. (1996). *Model Guidelines for Domestic Greywater Reuse for Australia*, Research Report # 107, Urban Water Research Association of Australia, Melbourne.

Kinnaird M (1997), *pers. comm.*, Environmental Health Officer, Shire of Halls Creek.

Kourik, R. (1995). Graywater for Residential Irrigation, *Landscape Architecture*, **85** (1), 30-33.

Lugg, R. (1994). Health Controls on Wastewater Reuse, in Mathew K & Ho G (eds), *Workshop on Localised Treatment and Recycling of Domestic Wastewater*, RADG, Murdoch University, Perth.

Mars R (1996), Using Submergent Macrophytes for Domestic Greywater Treatment, in Mathew & Ho (eds), *Workshop on Wetlands for Wastewater Treatment*, September 25, Murdoch University.

Mathew K & Ho G (1993), *Reuse of Wastewater at Jigalong Aboriginal Community*, RADG, Murdoch University.

McGrath D, Ho G & Mathew K (1991), The Effectiveness of Evapotranspiration Systems in Disposing of Wastewater in Remote Aboriginal Communities, *Water Science and Technology*, **23**, 1825-1833, IAWPRC, London.

National Health & Medical Research Council (1996). *Draft Guidelines for Sewerage Systems - Use of Reclaimed Water*, National Water Quality Management Strategy, Melbourne.

New South Wales Recycled Water Coordination Committee (1993). *New South Wales Guidelines for Urban and Residential Use of Reclaimed Water*, Public Works Department, Sydney.

Newman, P. W. G. and Mouritz, M. (1996). Principles and Planning Opportunities for Community Scale Systems of Water and Waste Management, *Desalination*, **106**, 339 - 354.

Niemczynowicz, J. (1993). Water Management and Ecotechnology - towards 2020, *Workshop on Sustainable Urban Water Systems and Ecotechnology*, November 18, ISTP/RADG, Murdoch University, Perth.

Pholeros, Rainow & Torzillo (1993), *Housing for Health: Towards a healthy living environment for Aboriginal Australia*, Health Habitat, Sydney.

Race Discrimination Commissioner (1994), *Water - A report on the provision of water and sanitation in remote Aboriginal & Torres Strait Islander Communities*, HREOC, AGPS, Canberra.

Standards Australia/NZ (1996). *On-site Domestic Wastewater Management*, AS/NZS 1547-Draft, Homebush/Well.

Stone, R. (1996).Water Efficiency Program for Perth, *Desalination*, **106**, 377 - 390.

Swanson T (1996), *Tjalku Wara Community: Wastewater Disposal Scheme*, Gutteridge Haskins & Davey, Perth.

Turner, N., Heaton, K. & Meney, K. (1996). Use of Innovative Wastewater Treatment Methods and Constructed Wetlands, *Wetlands for Wastewater Treatment*, in Mathew & Ho (eds), *op. cit.*

Water Authority of Western Australia (1994). *Wastewater 2040 Discussion Paper*, WAWA, Perth

沙漠研究 7S, 93-96 (1998)
Journal of Arid Land Studies

Feasibility Study for Recycling Use of Waste Water in Arid and Semi-Arid Lands

Masuo OZAKI*, Yukuo ABE**, Hiroshi KOKUBU***, Tsuyoshi UMETSU*
& Satoru TAKAHASHI****

Abstract - Development and re-vegetation of arid and semi-arid lands require fresh water resources. The sources of water in arid and semi-arid regions include sea-water, ground water, or water transported via pipelines from humid regions. In this paper, the recycling use of waste water as a possible means of obtaining purified water supply is discussed. In order to stimulate developmental activity and revitalize the local economy, it is urgently required that new water sources are explored and effectively exploited. The recycling use of waste water affords more effective utilization of water and contributes towards a hygienic social environment.

Keywords: Arid land, Water sources, Waste water treatment, Recycling use

1. Introduction

The development and re-vegetation of arid and semi-arid lands require fresh water resources. The sources of water in arid and semi-arid regions include sea-water, ground water or water transported via pipelines from humid regions. In cases where the sea-water and/or ground water is the only source of water, appropriate technology needs to be implemented for their purification.

In the present paper, recycling waste water as a possible means of obtaining purified water supply is discussed with reference to Kalgoorlie, Western Australia. The area is presently dependent on water supply that is transported over a length of 600 kilometers from the outskirts of Perth. However, in order to stimulate developmental activity and revitalize the local economy, it is urgently required that new water sources are explored and effectively exploited. Ground water is difficult to use due to its high salt content. Construction of a second pipeline for supply of fresh water is difficult, too. Drain water or waste water can be a major source of water supply. Sewage from domestic sources offers a possibility of recycling by simple treatment. Moreover, the treatment of waste water will solve several allied environmental problems.

2. Sustaining water resources and effective utilization

2.1. Sustaining water resources

Kalgoorlie is a major mining center where stock farming is another major activity. The population of this city is 30,000. The annual rainfall (about 250mm) contributes to a small part of the city's water resources. A major part of the fresh water

*Dept. of Civil Eng., Maebashi Institute of Technology, 460, Kamisadori, Maebashi 371, Japan.
Fax:+81-27-265-7302.
**Institute of Agricultural & Forest Eng., University of Tsukuba, 1-1,Tennodai, Tsukuba 305, Japan
***Dept. of Civil Design, Asia Consulting Eng. Co.,Ltd., 5-15-22, Ogikubo, Suginami, Tokyo 167, Japan.
****Dept. of Agricultural Eng., Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagaya, Tokyo 156, Japan

is transported from the outskirts of Perth. The amount of water supplied is 45,000kl/day in summer and 8,000kl/day in winter. The water supply from the pipeline is limited by the transportation ability and the amount of water available at the source reservoir. Development of new water resources is necessary for the industrial development of the region and also to increase the agricultural and pasture land productivity. Methods for development of water resources are listed below.

a) Increasing water supply through pipeline from areas surrounding the arid land.
This requires large financial investment in order to augment the capacity of the present pipeline system.

b) Purification of ground water and deriving water from the atmosphere.
Ground water purification techniques are being developed and a purification plant is operational at Ayer's Rock Resort area and a few other sites in Australia. Techniques for deriving water from vapor sources need to be developed further.

c) Recycling of urban sewage, including domestic sewage.
Treatment of industrial waste water has been widely adapted; however, recycling of domestic sewage is rarely practiced. Urban sewage mainly from domestic sources contains very few toxic elements and the salinity level is low and therefore it has a great potential for recycling.

2.2. Present status of sewage treatment in Kalgoorlie

The water utilization flow is shown in Fig.1. The volume of sewage treated is 6,300kl/day and this corresponds 14% of the volume of summer water supply or 78% of the volume of winter water supply. This percentage seems to be small in summer, but the consumption of fresh water for non-drinking use such as watering the gardens and lawns is higher compared with the winter season. The non-drinking use does not need the quality of drinkable fresh water. So, it is important that water resources having a quality of non-drinkable and industrial water are developed to meet summer requirement in this arid inland city.

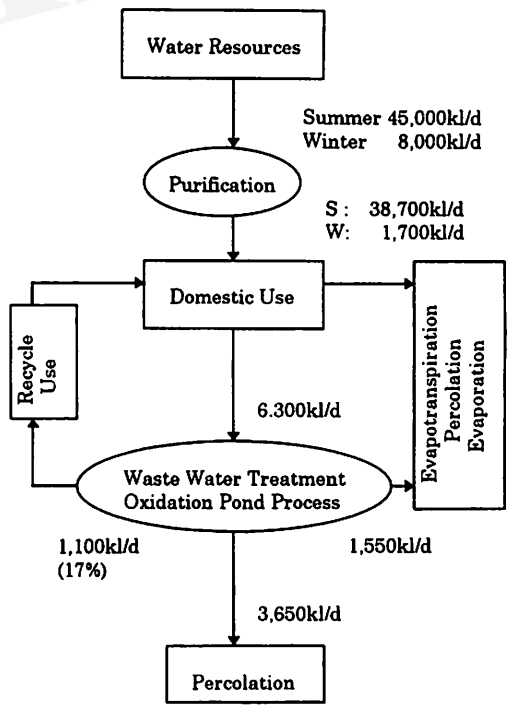


Fig.1 Flow-chart showing the water utilization

The current waste water treatment system in Kalgoorlie is the Oxidation Pond process. As there is no river in this area, the final treatment of waste water depends on evaporation and percolation. The Oxidation Pond process has

a large water surface area and much water is lost through evaporation. The water surface area of the Oxidation pond is 210,000m². The hydraulic retention time (HRT) is 40 days and the depth of water is 1.2m. The amount of evaporation from the water surface is estimated to be 1,700kl/day which is based on the decrease in water depth of 8.2 mm/ day and which constitutes 27% of the volume of sewage treatment. In this area, the drainage is inadequately developed. Therefore removal water by evaporation can be considered an effective method. However, from the viewpoint of water resources, the volume of vapor loss is equivalent to the water requirement for more than 4,000 persons. The quantity of recycling use is 1,100kl/d, 17% of the waste water. On the other hand, the volume of water percolation in 1996 was 3,650kl/d, and this causes salt accumulation in the soil. In order to efficiently use the water, the quantities of evaporation and percolation have to be reduced. Especially, we have to reduce the percolation loss, in order to prevent salinization of soil. Therefore recycling use of waste water would not only contribute towards a hygienic social environment but also in developing a stable water resource. In order to achieve this aim, we propose the introduction of the Activated Sludge Process. The Oxidation Ditch Process, which is a component of the Activated Sludge process is, considered to be more than adequate for the city's requirements.

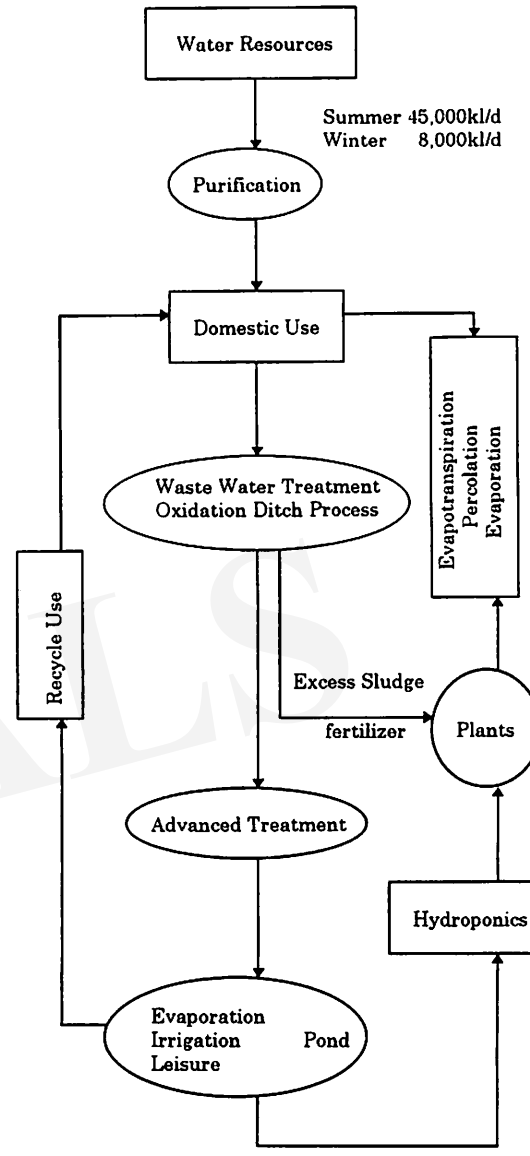


Fig. 2 Flow-chart showing water cycle recommended in this paper

2.3. Oxidation Ditch Process and recycling use

The Oxidation Ditch Process (Nakasone, 1995) has a simple structure and can be easily controlled in the Activated Sludge Process. The surplus sludge generated is low and it is possible to implement the process hygienically. Fig.2 shows a flow-chart of water cycling using the Oxidation Ditch Process. In this process, HRT in the reactor is about 24 hours even when the operation with intermittent aeration is introduced.

Photosynthesis is not required for treatment reaction, so it is possible to restrain evaporation by constructing a ditch reactor or by covering the ditch. In the case that operation with intermittent aeration is carried out for removing nitrogen, it is required to raise the amount of dissolved oxygen during aeration. Falling water as an aerating process is recommended. This system will remove not only nitrogen but also phosphorous by adding coagulating agents. However, the generation of polluted sludge cannot be avoided and some control measures need to be adopted. Since the sludge is rich in nitrogen and potassium, it can be used on farm land as a nutrient source. Post-oxidation ditch treatment using bio-film will be effective since it is not possible to lower the BOD of treated water below 10mg/l. These methods of high level purification can be considered in the future, but some of the problems can be solved by applying ground water purification. Some steps in Activated Sludge Process can be adapted for minimizing salt content, therefore it is possible to improve this to a new treatment system which combines sewage treatment with purification treatment by mixing ground water to the ditch for the purpose of increasing the volume of recycled water.

3. Conclusions

In considering the arid land development, sometimes we try to construct a new city in the center of the desert. It is not effective, and we have to try to develop the area around cities that exist in arid land (Ozaki,1995). Those cities have water resources that supply the volume of water equivalent to the requirement of domestic use. And the effluent of the waste water from the domestic use can become new water resource by the waste water treatment. The treated water supplies irrigation, industry, leisure, and non-drinking uses. Using the Activated Sludge Process, the excess sludge made from this system is supplied to farms for fertilizer. Final treatment of water that is drained from the arid area is carried out with evaporation and evapotranspiration. Introducing the recycling use of waste water, one of the water cycles shown in Fig.2 is established in the arid land. This system affords more effective utilization of water and contribute towards a hygienic social environment.

Recycling uses of waste water for irrigation water have been implemented in arid lands in the U.S.A., Israel and other countries. According to the results of this study in Kalgoorlie, we will apply this system for another arid land. For the application of this system, we have researched the natural conditions in Djbouti, Africa. The feasibility of this application has been discussed with many data obtained from the experimental farm.

References.

Nakasone, H. and Ozaki, M. (1995):Oxidation-Ditch Process Using Falling Water as Aerator, ASCE, Journal of Environmental Eng., Vol.121-2, pp.132-139

Ozaki, M., Satake, K., Kokubu, H., Abe, Y. and Ohtsuka, Y. (1995): Feasibility Study and Technological Requirements For Developments of Arid And Semi-Arid Lands In Australia, Journal of Arid Land Studies, Vol.5s, pp.291-294

沙漠研究 7S, 97-99 (1998)
Journal of Arid Land Studies

A Study of Vegetable Growing Technology in the Taklimakan Desert

Hu Yukun*

Abstract - In order to improve the living environment and satisfy the people's needs in the desert, it is necessary to determine how to best utilize the resources of local sandy soils and saline ground water to grow vegetables in the hinterland of Taklimakan Desert. After two years of experimental research, some results of vegetable growing have been obtained as follows:(1)Most vegetables can grow well in the desert and, eleven species which could tolerate the desert environment have been selected; (2)It is possible to irrigate vegetables with highly saline water (about 4.0-5.0g/l salt content), but, irrigation rates are different depending on growing seasons; (3)shelter systems, such as, sand fixation and hinderence with physical, chemical and biological technologies, should be built around the vegetable plot.

Key words:Taklimakan Desert, Saline water, Vegetable growing

1. Study purpose

The area of Taklimakan Desert which is the second biggest mobile desert in the world is 33.7 × 10^4km^2. The working conditions of oil and gas resource exploition are very arduous in the hinterland of the desert. In order to overcome lack of fresh vegetables and ensure worker health, we have used local sandy soil and water with a salinization degree (SD) of more than 4.0g/l for a vegetable growing experiment in open land of the desert since 1994.

2.Introduction to the Experiment Area

The experiment area is located among the great and compound sand ridges in the hinterland of the Taklimakan Desert (N39° 15′ 31″, E83° 16′ 42″). The soil type is dominated by sandy soil, with a texture of mainly fine sand and accounts for 50 ~ 70%. The caly particle content is only 0.3%. The organic matter content is less than 0.8 g/kg and the average salinity is 0.125%.

The mean precipitation is less than 50mm, meanwhile, the evaporation is more than 3000mm. The annual relative humidity (RH) is 45%, and is nearly zero in summer afternoons. According to meteorological observations in 1995, some data is as follows: The maximum temperature is 41.93 ℃. Sunshine time is 2661.2hrs. Frost-free growing season is 244 days. The wind seasons concentrate between March and August, and the frequency of mean wind velocity which is more than 5 m/s accounts for 18% of total wind frequency. In addition, the frequency of maximum instantaneous velocity which is more than 5 m/s in an hour is more than 60%, and the maximum instantaneous velocity is 21.78 m/s.

3. Results and Analysis

3.1 The selection of vegetable species and growing experiments

3.1.1 In order to choose the species suited to the hinterland of the desert, we engaged in growing experiments for 20 vegetable species.

* Xinjiang Inst. of Biology, Pedology and Desert Research, CAS. Urumqi, Xinjiang, China (Fax:+86-991-3835459).

Table 1. The condition of vegetable germination and it's survival rate

species	sowing date	germination date	survival rate after 10 days (%)
yubaicai pakchoi	May 25	May 30	40
spinage	June 3	June 9	57
Chinese cabbage	May 25	May 30	59
cucumber	April 26	May 2	67
eggplant	May 2	May 10	67
chilli	May 2	May 9	53
tomato	May 2	May 7	78
string bean	April 26	May 2	96
potherb mustard	May 25	June 1	74
cauliflower	May 25	May 30	70
qielian	May 25	May 30	90
wild cabbage	May 25	May 30	65
suantai	July 24	August 6	53
celery	July 23	August 2	33
garden pea	June 3	June 13	90
aquatic morning glory	August 11	August 18	82
xinglimei	April 2	April 6	67
garlic	July 24	August 6	75

The results showed that each species of vegetable seedlings comes out evenly, and can adapt to the natural conditions of the hinterland of the desert. But the difference of adaptation of species is very obviously. There are some species that have good resistance to the bad condition in the seedling stage, such as, celery, potherb mustard, wild cabbage, qielan etc..

3.1.2 Through observation of each species with the same five plants every five days during the growing season, the results showed that adaptability of each species is different. Some species are suitable for the conditions at the early and late growing stages, such as, Chinese cabbage, qielian, celery, yubacai pakchoi, potherb mustard, fragrant-flowered etc., the other species have bad adaptibility on the seedling stage, such as, tomato, eggplant, chilli, string bean, etc.. In addition, there are some species whose growth is restrained obviously at the end of growing season, such as, radish etc..

3.2 The irrigation experiment of saline water

With repeated observation of irrigation by saline water, there are some regular patterns as follows: The different irrigation rates affects the salt content of soil. While the amount of watering is small (25 kg/m^2), the salt content is mainly concentrated at the depth of 0-10 cm, the salt content is high above 30 cm, which affects the roots of seedlings and vegetables. While the amount of watering is large (50 kg/m^2), the salt content is mostly concentrated at the depth of 50-60 cm, 0-30 cm is medium, and 30-50 cm is lowest. This indicated that if the irrigation amount is large, the salt content of the soil is low, and it is beneficial to survival and growth of seedlings. At the same time, irrigation with large amount of water has the great advantage to the growth of deep root vegetables at the end of growing period because of existing desalination layer above the 50 cm. In addition, Yubaicai pakchoi is irrigated with small amount of water, the seepage depth is only 10 cm after 72 hours, and the survival rate of seedlings is 38%. If it is irrigated with large amount of water, the seepage depth is 45 cm and all seedlings are survival.

3.3 The experiment of disaster protection

Shifting sand, high temperature and dry and hot wind are chief disasters in the hinterland of the desert. Measures of physical, chemical and biological protection are adopted, which are capable of reducing the disasters and increasing the yields of the vegetables.

3.3.1 Physical protection

Vertical palings are set up around vegetable plots across the main wind direction. The height of the palings is accordance with the area of the vegetable plot. Generally, the protection range is as ten times as the height of the palings. The material of palings is mainly reeds, which can not only reduce the wind velocity, but also reduce temperature and increase humidity when it was wetted.

3.3.2 Biological protection

Biological protection belts are built up along the ridges in the low-lying land. The wind velocity is reduced obviously and temperature is changed obviously, too. For example, the temperature is reduced at noon and increased in the dawn, the daily difference in temperature is also reduced (Tab 2.)

Tab 2. The microclimate changes through building up biological protection belts

type	observation	velocity (m/s)		ground temperature (℃)					temperature
	time	20cm	150cm	0cm	5cm	10cm	15cm	20cm	(℃)
non-	14:00	3.3	4.1	50.5	31.5	27.0	8.5	28.7	31.0
protection	08:00	0.1	0.2	15.5	23.0	27.0	29.2	30.0	17.6
protection	14:00	0.7	2.0	39.5	28.5	25.5	23.0	21.5	29.6
	08:00	0.0	6.1	14.5	17.5	19.5	21.0	21.5	18.6

The survival rate of seedling is more than 70%, when the biological protection belts are built. Moreover, the growth condition is excellent. Branches and foliage are exuberant and the fruit rate is increased, meanwhile, the quality of vegetables is improved.

4. Conclusion

The vegetalbe growing is basically successful with water of SD more than 4.0 g/l in the hinterland of the Taklimakan Desert. The experiments revealed that vegetables can be produced in the open land in the hinterland of the desert, and saline water irrigation can keep vegetable growing well. Meanwhile, eleven vegetable species which are suitable for the hinterland circumustance of the desert are chosen. They are yubaicai pakchoi, tomato, qielian, chilli, eggplant, celery and so on. Vegatable plot should be irrigated with large water content (>50 kg/m^2). Spraying with small amounts of water should be avoided. In addition, the synthetic protection from desert disasters is strengthened.

Reference

Xia, X. et al (1993): Desertification and Control of Blown Sand Disasters in Xinjiang, Science Press, Beijing, China.

沙漠研究 7S, 101-103 (1998)
Journal of Arid Land Studies

Desert aquaculture - a new opportunity for world aquaculture production

Samuel APPELBAUM*

Abstract: Between 1980 and 1990, global population grew at a rate of 1.75% per annum. Of all world food producing sectors, aquaculture has been the fastest growing, reaching an annual growth rate of almost 10%, while all other sectors, including marine fisheries, remain at below 4.2% growth. At the same time, fish has been gaining a world-wide reputation as a healthy food. Demand for fish will continue to increase, but marine fish catch is stagnating or even declining, thus the gap will widen. World aquaculture has to bridge the gap and therefore requires additional opportunities: desert aquaculture is a promising one.

Key words : aquaculture, desert, food production

1. Introduction

Estimates place world population at more than 8 thousand million by 2025, increasing even further the growing demand for protein. Nine of every 10 people born live in developing countries. Aquaculture - a world protein contributor - will have to divert more of its expended energy from luxury protein products such as carnivorous fish (salmonids, bass, bream etc.) towards the development and production of cheaper herbivore species like carp, *Tilapia*, catfish, etc. These low-cost commodities, favoured by the poor, will inevitably soon have to be more intensively cultured. Statistics of annual world capture fisheries (60 million tons) indicate that stocks are being harvested near maximum yields, many species are being over fished and some are nearing extinction. Edible seafood demand is expected to climb from today's 75 tons to 115 million tons by the year 2025. Expansion in global aquaculture production from the current 15 million tons to some 55 million tons, (approx. 400% increase) will have to bridge the gap. Desert aquaculture, like prosperous off-shore aquaculture, offers new opportunities to reach world aquaculture targets. This is particularly relevant as existing inland and coastal aquaculture regions become degraded by over-intensification, and suitable aquaculture sites become rare.

2. Desert Aquaculture - a reality !

Though desert aquaculture sounds a paradox, it is nowadays a reality in Israel. In the past seven years, a few commercially operating fish farms, based on the principle of geothermal desert water, have been established in the Israeli desert. Very large quantities of this fossil, geothermal water exist in the desert ground at

*The Bengis Centre for Desert Aquaculture, Ben-Gurion University, Sede Boker Campus, 84990 Israel (Telefax: 972-7-6596810: e-mail: sappl@bgumail.bgu.ac.il)

a depth of a few hundred metres. This water is constantly warm (>30°C), accelerating fish growth, and saline, providing osmoregulatory advantages for the fish. Furthermore, the water is pollutant free, guaranteeing a high fish quality. The culture technology is based on a recirculation system which, unlike conventional systems, has small covered tanks/ponds for better control of the harsh, desert conditions. Part of the recirculating system's water is used to irrigate agricultural crops, which benefit from the dissolved minerals leaving the fish system.

3. Suitable species for Desert aquaculture

Best suited are fresh water and marine fish species that can adapt to desert aquatic conditions, i.e., high water temperatures and local water salinities; species that respond well at super high densities and grow fast with high survival rates. It is important that reproduction can be controlled. These species should certainly be accepted by the market. Examples of suitable candidates belong to the catfish family, *Claridae (Siluriformes)*, one of which is the catfish of the genus *clarias.* After the American channel catfish, these are the most important group of farmed catfish (125,000 tons annually). *Clarias* species, particularly *C. batrachus, C. fuscus and C. macrocephalus* and *C. gariepinus,* are widely cultured mainly in Asian and African countries. *Clarias gariepinus* is an excellent example of a fish suitable for desert aquaculture. It is an air breathing, fast growing fish that can be cultured at densities of over 300kg/m^3, its flesh is well accepted and has proven to be fully adaptable to desert conditions in Israel.

Other relevant fish species belong to the *Tilapias* which are tolerant to high salinity. *Tilapia* grows fast and is known and successfully marketed in many countries (world production is now over 300,000 tons p.a.).

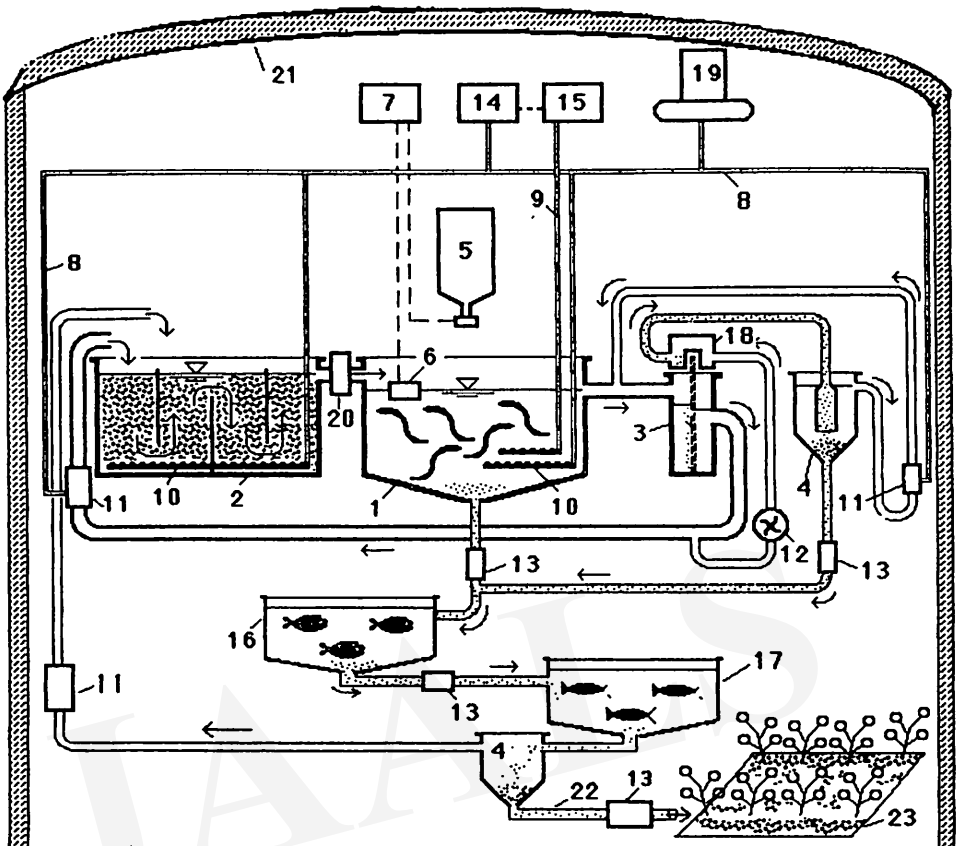
Further suitable candidates are eels, much appreciated in many countries (consumption 120,000 tons p.a.) The fact that eel can be cultured at very high densities (>100/m3) and tolerate a wide range of salinity, makes them a promising species.

4. Relevant Research

Modern intensive aquaculture must, more than ever, consider its impact on the environment. One emphasis of our research is, therefore, the development of integrated polyculture systems where different fish species are reared in the same system but in separate tanks in a chain. Water loaded with waste from one species runs to another species which is capable of utilizing it for its own growth. This maximizes the use of feed and other organic material and minimizes environmental pollution. Another research target is the technology of rearing fish without handling or use of nets, not only to reduce labour costs, but also to prevent fish injuries leading to moralities, particularly when reared at ultra high densities. In addition, we are permanently seeking new fish species, suitable for desert aquaculture.

Desert aquaculture can turn arid, barren land into fertile regions, both increasing world food production and providing alternative livelihoods for indigenous peoples.

Fig. 1. Integrated System for growing Fish in the Desert



1 - primary fish (eels or ornamental fish)
2 - biological filter
3 - rotary filter
4 - sedimentation filter
5 - feeder with electric feed meter
6 - sensor for "on-demand" feeder
7 - control unit for the feeder
8 - main air supply
9 - emergency air supply
10 - air diffusers
11 - airlifts
12 - water pump for backwashing of rotary filter
13 - sludge discharge valve
14 - control unit for emergency aeration system
15 - emergency aeration system
16 - filter feeder fish (St. Peter's Fish)
17 - omnivorous fish (catfish)
18 - backwashing device
19 - blower
20 - UV filter
21 - greenhouse
22 - irrigation to agriculture
23 - agricultural crops

References

Aiken, D., and M. Sinclair (1995) From Capture to Culture. World Aquaculture, Vol. 26(3), 21-34.

Csavas, I. (1994) World aquaculture status and outlook. Infofish International, 47-51.

Hempel, E. (1993) Constraints and possibilities for developing aquaculture. Aquaculture International. Vol. 1(1), 2-19.

Jensen, J.W. (1995) Catfish in 2005. World Aquaculture, Vol. 26(3), 42-44.

沙漠研究 7S, 105-108 (1998)
Journal of Arid Land Studies

Range Livestock in the Great Basin of North America

James A. YOUNG* and Frosty TIPTON**

Abstract - Livestock production in arid environments invokes images of tented nomads and their herds and flocks. In terms of desert technology, the nomadic herdsman is often associated with archaic uses of natural resources. As the world's human population continues to expand, demands for quality dietary protein will ensure a need for livestock production. The biomass of deserts is only directly useful to humans when processed through the internal fermentation vats of ruminant animals. Restoring desert ranges to optimal productivity is a challenge to international arid-lands scientists.

Key Words: range, restoration ecology.

1. Introduction

Livestock production from flocks and herds ranged on extensive landscapes that are too dry, rocky, or steep for crop production has been one of the standards of civilization since deepest antiquity. Desert landscapes seldom are so sufficiently productive that a livestock management system can be based year long at one specific point. The herds and their husbandry men had to move with forage availability by seasons. Transhumance livestock production systems have inherent social problems for societies of herdsmen in terms of providing fixed schools and medical services, but the basic idea of moving livestock to match forage availability is what made the utilization of desert ranges possible.

Our purpose is to describe the evolving livestock production systems of the arid portions of the temperate deserts of the Great Basin of North America and how technology interacts with these systems.

2. Nature of the Environment

The Great Basin of western North America includes the area between the Cascade-Sierra Nevada to the west and the Rocky Mountains to the east. The area currently does not have drainage to the ocean. The environment is characterized as a temperate desert (West, 1983). It is dry because the mountain wall to the west intercepts moisture from the Pacific and casts an orographic rain shadow across the basin. It is temperate because of the general high elevations. The area is not one great mountain-rimmed basin, but consists of some 200 fault-block mountain ranges that generally have their long axis running north-south. Between the mountains there are many sub-basins. Many of these basins contained lakes during portions of the Pleistocene. Some of the lakes overflowed their basins to form river systems that emptied into the great pluvial lakes Bonneville in the northeastern Great Basin and Lahontan in the northwest. Lake Bonneville rose above a mountain sill and partially drained into the Snake-Columbia

* Range scientist, USDA, Agric. Res. Serv., 920 Valley Rd., Reno, NV 89512, USA. FAX 01-702-784-1712
** Owner-manager, T-Quarter Circle Ranch, Winnemucca, NV 89445, USA.

River system. Lahontan never drained to the ocean. The Holocene brought aridity to the Great Basin and the lakes evaporated leaving behind vast accumulations of soluble salts.

The mountains and emerging lake plains of the Great Basin became clothed during the Holocene with a vegetation dominated by woody shrubs and a perennial bunchgrass understory. The landscape characterizing plants were members of the genus Artemisia. Below the maximum level of the pluvial lakes, both the atmospheric aridity of the basin bottoms and the salt-affected soils produced a more arid environment where Artemisia gave way to the Atriplex species and associated chenopods. In the central and eastern portions of the Great Basin, dwarf conifer woodlands occurred in a belt above 1850 m in elevation. Dominated by pinyon/juniper (Pinus/Juniperus), these woodlands provided virtually the only trees in the landscape except for sparse riparian gallery forests of Populus and Salix. On the highest mountain ranges near 3000 m, sparse sub-alpine forests of 5-needle pines (Pinus) occur (Billings 1978).

At the time of contact with Europeans in the early 19th century, large concentrations of native large herbivores (primarily the American bison, Bison bison) existed only in the northeastern portion of the Great Basin. In most of the Artemisia and Atriplex communities, the primary vertebrate herbivores were species of Lepus, the jackrabbit. Jackrabbit populations are cyclic, and at their peak density they are voracious herbivores. They have the great adaptive advantage for this environment of being able to largely rely upon water obtained metabolically from their forage. Apparently, the limiting factor for many large herbivores was the availability of drinking water (McAdoo and Young 1980).

3. Livestock Production

Compared to the rest of western North America, commercial livestock production began rather late in the western Great Basin (Young and Sparks 1985). The trails used by emigrants to reach California crossed the Great Basin, but the deserts were viewed as inhospitable environments to be avoided. It was not until the last quarter of the 19th century that large numbers of longhorn cattle, derived from Spanish imports to the New World, were suddenly moved from Texas and southern California to stock the sagebrush ranges. The completion of the trans-continental railroad and population growth due to mineral discoveries sparked the growth of a livestock industry.

Several interactions of domestic livestock with the environment were immediately apparent. The dominant woody species of Artemisia were not preferred by cattle. If cattle were forced to consume the browse of Artemisia tridentata by starvation during the winter, they would die. The herbage of perennial grasses such as Pseudoreogneria spicata cured in the dry desert air and provided it was not covered by snow in the winter it could provide nutritious forage. Cattle could be moved below the snow line into the bottoms of the desert basins. In contrast to the non-preferred Artemisia tridentata, there were highly preferred low-growing shrubs or half-shrubs such as Artemisia nova, A. spinescens, Atriplex nuttallii, A. canescens, Kochia americana, and especially Krascheninnikovia

lanata growing in the lower deserts. Not only were these shrubs preferred by cattle, they provided highly nutritious diets with adequate digestible protein. In a remarkable adaptation, cattle learned to utilize the fruits of chenopod shrubs such as Atriplex confertifolia by licking them from the soil surface. The shrubs themselves are too spinescent for browsing. Combined with the browse species on winter ranges were extensive stands of the perennial grass Oryzopsis hymenoides (Achnatherum hymenoides). This grass grew in abundance in sand fields and dunes.

The limiting factor on all of the Great Basin ranges and especially on winter ranges was stock water. It has been estimated that using natural springs as the only source of stock water, only 10% of the desert winter ranges were utilizable by domestic livestock (Young 1994). Pioneer ranchers developed additional watering points by excavating natural seeps and later by sinking/drilling shallow bores that produced artesian water, or were pumped by wind powered pumps. When a large sheep industry developed in the Great Basin, it was discovered that sheep could be wintered on the desert ranges using snow as a source of moisture.

4. Reaction of Vegetation to Grazing

The general lack of precipitation in the temperate deserts during the summer confines the growing season for herbaceous plants to the early to mid-spring. If the native perennial grasses were heavily grazed every spring and the plants never given the chance to restore carbohydrate reserves, flower and set seed, they disappeared from the communities. The reduction in perennial grasses did two things: 1) it allowed abundant seedling establishment of Artemisia and other woody plants, and 2) it reduced the frequency of wildfires through lack of fuel for ignition and spread of the fire from shrub to shrub. The result was an over-abundance of non-preferred, relatively long-lived shrubs, and no available environmental potential for the re-establishment of perennial herbaceous species.

5. Sociology of Herdsmen

In the second half of the 19th century, the rangelands of the western Great Basin were settled by ranchers. The land was public domain belonging to the United States Federal government. Individual citizens could claim 128 ha of this land by meeting requirements dictated by law. To have a successful livestock operation in these temperate deserts, about 40,000 ha were required. Rarely could this be one continuous block of land because, for an integrated ranch to be successful there had to be spring-fall range in the foothills, summer range at high elevations in the mountains, and winter range in the desert basins. Most importantly, there had to be somewhere that could be irrigated for the production of forage that could be conserved for feeding to livestock during severe winters. Only about 5% of the western Great Basin was irrigable. In this environment, it requires mountain ranges above 3000 m to produce sufficient runoff to support irrigation. Considering the diversity of environments required to make a successful ranch, operations became disjunct. The most valuable environment was the irrigable land. It usually

constituted the headquarters for the livestock operation, and the only land that was privately owned. The rangeland might be distributed over a distance of several hundred kilometers. The rangeland was not privately owned, it was held in common.

The grazing of the common rangeland is an aspect the Great Basin ranges shared with tribal ranges of antiquity in Central Asia or North Africa. Arid lands are the last under-populated frontier left for humans to occupy, if they can pay the price in terms of energy requirements. The closing of common grazing areas is a product of the human population pressures encroaching on arid areas.

6. Grazing in the 21st Century

The Great Basin rangelands have been, in their infancy of exploitation, producing quality protein and fiber far in excess of the needs of the agriculturalists who husband the animals. Is this production sustainable? There is abundant scientific evidence that it is sustainable and can be made even more productive. We previously alluded to negative ecological reactions to the introduction of large herbivores to these ranges. These negative aspects are real, but they were the product of unintentional improper grazing through ignorance of the environment. We can correct these errors and restore productivity through application of technology. The bottom line on grazing arid rangelands is that domestic livestock consume coarse forage that can not be directly utilized by humans, and produce quality protein in a form directly utilizable by expanding human populations. The proper grazing of arid ranges has a place in the 21st century.

7. Conclusion

Livestock grazing on ranges has been an integral part of arid environments. The application of technology can keep such grazing a sustainable industry.

References

Billings, W. D. 1978. Alpine phytogeography across the Great Basin. Great Basin Naturalist Mem. No. 2:105-118.

McAdoo, J. K. and J. A. Young. 1980. Jackrabbits. Rangelands 2:135-138.

West, N. E. (ed.) 1983. Temperate Deserts and Semi-Deserts. Elsevier Publ. Co., Amsterdam, Netherlands.

Young, J. A. and B. A. Sparks. 1985. Cattle in the Cold Desert. Utah State University Press. Logan, UT. 253 p. (Book).

Young, J. A. 1994. Changes in plant communities in the Great Basin induced by domestic livestock grazing. pp. 113-123. in. K. T. Harper, L. L. St. Clair, K. H. Thorne, and W. M. Hess. (eds.) Natural History of the Colorado Plateau and Great Basin. Univer. Press of Colorado, Niwot, CO.

沙漠研究 7S, 109-112 (1998)
Journal of Arid Land Studies

Sustainable Ruminants Production-System Under Stress Lands In Pakistan

Dr. Raza Ali GILL * and Jalees Ahmad BHATTI **

Abstract - Growing of salt bushes on salt-affected lands and subsequent feeding to the animals, can help to attain self-sufficiency. *Atriplex amnicola* has been found to be a promising feed with a yield of about 32 tonnes/ha. The results of palatability, training and replacement of fodders with saltbush and its effect on performance have been studied. In grazing/stall feeding in combination with forages, animals maintained their body weights. Teddy goats were found to be the best users. *Atriplex* spp. can be used during the scarcity seasons. *Atriplex* leaves and soft twigs can be fed to the animals as a Total Mixed Feed.

Key Words: Saline sodic soils, *Atriplex amnicola*, palatability, acceptability, replacement.

1. Introduction

Crop and livestock are integrated in Pakistan's agriculture especially with the small farmers. Draught animals are used for cultivation and haulage while dairy animals, sheep and goats, are raised for milk and meat production by utilizing grown fodders, farm by-products, crop residues and other wastes. The monetary value of various livestock products exceeds 300 billion rupees per annum. The actual export value of livestock products in terms of foreign exchange, was about 425 million dollars during 1994-95. The share of livestock in total agricultural output is around 32 % and in national GDP is about 8 %. The growth rate of livestock sector stood at 5.6 %. Per capita availability of dietary items such as milk and meat obtained from buffaloes, cattle, goats and sheep was 121.48 and 21.38 kg, respectively (Anonymous, 1996).

Because of rising living standards, the farmer concentrates more on cash crops and attaches a low priority to growing fodder. The feeding of animals even at the present level of their population is highly inadequate, resulting into very low yields of milk, meat and fiber. The traditional concept of livestock production wherein emphasis is on numerical strength with very little emphasis on production traits is one of the limiting factors in livestock production. This results in huge livestock numbers, of which majority are uneconomical and a burden on already inadequate feed resources. Among the animals, goats/sheep have been experiencing severe nutritional deficiencies. The area under fodder production is about 2.7 million hectare in the country, producing about 58 million tonnes of fodder which is not sufficient even to meet the maintenance requirements of the existing livestock. In future the chances for increasing the forage area are remote because of preferential need for human food. A projected expanding animal population will further worsen the feed resources situation in the country and will require more than 50 % increase in the feed supply. Present day aim should be to enhance per unit productivity of livestock rather than increasing the production by increasing the number of animals.

Existing land resources are deteriorating and becoming saline sodic and water-logged at a faster rate in Pakistan. More than 6 m ha of salt-affected land is lying barren for the last 40 years and is not

* Professor and Chairman, Department of Livestock Management, Univ. of Agri., Faisalabad, Pakistan. Fax No. 92-41-647846. Phone No. 92-41- 30281- 89 Ext. 415.

** Lecturer, Department of Livestock Management, Univ. of Agri., Faisalabad, Pakistan.

producing any crop. There is a dire need of productive management of saline and water-logged soils. Over 90 billion rupees have so far been spent on engineering approach (Qureshi et al., 1996). Saline agriculture might offer an economical and sustainable solution. In the process of salt-affected soil reclamation, if certain fodder shrubs like *Atriplex* are extended to such soils, it will help meet livestock feed deficits and this in turn will increase the farmer income, effect improvement in the soil structure and sustained production from problem soils. During feed gap periods, *Atriplex* lopping (leaves and twigs) can be a potential source to supplement low quality forages to maintain animal performance.

2. Materials and Methods

Various experiments were designed and conducted on-station and on-farm to test the production potential, feeding value, acceptability of *Atriplex amnicola* and its effect on production performance of different species of animals. Feeding experiments (Training and Replacement) were conducted at the Livestock Experiment Station (LES), University of Agriculture, Faisalabad and with the farmers to determine the response of goats to different levels of *Atriplex* inclusion in the diets. The data regarding voluntary feed intake, water intake and weight gain/loss were collected and analyzed. The layout of feeding trial has been given in Table 1. Replacement experiment was conducted on Teddy goats (small-sized, early maturing and prolific breeders) to test the extent of berseem replacement with saltbush leaf hay in wheat straw based diets.

Table 1. Feeding regimens of goats in Training and Replacement rations.

Particulars		Groups		
		A	B	C
Training	Animals	16	8	8
	Week 0-4	Basal feed	Atrip.	BF
	Week 4-8	BF	BF	BF
	Week 8-12	BF	Atrip.	Atrip.
Replacement	Animals	10	10	10
	Week 1-6	BF	BF+ Atrip. (80:20)	BF+ Atrip.(60:40)

3. Results and Discussion

The production potential and chemical composition of feed ingredients including *Atriplex amnicola* are given in Table 2. It is evident that saltbush is quite comparable in terms of its protein and fiber contents. However, mineral contents are higher than those in other feedstuffs, which increase water intake resulting in decreased feed intake. Higher salt contents also reduce the palatability of *Atriplex* to some extent. .Smith and Jacobs (1978) reported a high feeding value, acceptability and efficient utilization of *Atriplex* spp. by ruminants as a crude protein supplement. In a trial to test the acceptability of *Atriplex amnicola* by different species of farm animals, it was found that camel prefers to eat saltbush (*Atriplex*) more than all other species tested, followed by goats and other animals (Fig. 1). Goats were observed to browse and utilize *Atriplex* forage better than sheep, cattle and buffaloes. In an experiment conducted by Riaz (1992) to feed Teddy goats different levels of *Atriplex* in combination with Sudex, it was observed that *Atriplex amnicola* can be fed to goats for maintenance particularly during scarcity periods without having ill effects on the health of animals. Also they performed better with some supplemental feeding.

Table 3. Production of goats fed on Training and Replacement rations.

		A	B	C
Training	Feed	0.463	0.453	0.373
	Water	0.857	1.227	1.025
	Weight	-0.151	-0.115	-0.189
Replacement	Feed	2.382	1.808	1.951
	Water	0.638	0.803	1.001
	Weight	-0.27	-0.29	-0.31

Atriplex can successfully be grown and propagated in saline sodic areas and even with brackish water. *Atriplex* may be produced as sole crop or as an intercrop with other grasses and may be grazed and harvested. Palatability and feeding value of *Atriplex* can be improved by properly using and feeding it in forms like grazing at the stage when maximum nutrients are present. It is suggested to use *Atriplex* in different combinations with conventional fodders and as a Total Mixed Ration by converting its leaves and soft twigs and other energy and protein feed sources into cakes, pellets, blocks and mash for high production objectives.

4. Conclusion

In the light of the results it could be stated that saltbush (*Atriplex* spp.) can be fed to animals in combination with appropriate feeds without any planned pre-exposure. By feeding *Atriplex* during fodder crunch periods, a substantial improvement in the performance of animals can be achieved.

Atriplex may safely be added upto 40 % of the conventional feeds and have potential to partly replace the common Rabi season (Winter) fodders for animal feeding. Total Mixed Rations can be prepared and encouraged by using *Atriplex* leaf meal with other energy, protein and premix sources and can be offered to animals in the form of cakes, pellets, crumbles and mash.

Acknowledgements

The authors gratefully acknowledge the continued interest and assistance from Dr. Ed. Barrett Lennard, Coordinator of ACIAR Project 9302 for successful implementation of the Project and are thankful to Dr. Bakht Baidar Khan, Professor Emeritus, who twice reviewed the write up of this paper.

References

Anonymous (1996): Economic Survey 1995-96. Govt. of Pakistan, Islamabad.

Attiq-ur-Rehman (1995). The potential for the use of saltbush (*Atriplex* spp.) in sheep grazing systems during summer and autumn in a Mediterranean environment. Ph.D. Thesis. Animal Group, Faculty of Agriculture, University of Western Australia.

Qureshi, R. H., S. Nawaz, J. Akhter and S. Parveen (1996). Sustainable Saline Agriculture: Pakistan experience. Fourth National Conference and Workshop 'Productive use and Rehabilitation of Saline Lands, Albany, West. Australia: 133-138.

Riaz, M. (1992). Effect of *Atriplex* feeding on growth and carcass quality of Teddy goats. M.Sc. Thesis. Department of Livestock Management, University of Agriculture, Faisalabad.

Smith, C.J. and G.A. Jacobs (1978). Skeikundige Samestelling Van Vier *Atriplex* species. Agroanimalia 10:1-5.

Wilson, A.D. (1975). The influence of water salinity on sheep performance while grazing on natural grassland and saltbush pastures. Aust. J. Agric. and Anim. Husb. 15:760-765.

Table 2. Production and nutrient composition of fodders.

Particulars	DM	CP	CF	Ash	Production(Tonnes/ha)
	-------	---%-	----------	----------	
Berseem (*Trifolium alexandrinum*)	14.68	12.15	27.73	15.19	60.00
Lucerne (*Medicago sativa*)	14.48	24.72	16.30	13.50	39.00
Maize (*Zea myze*)	23.70	08.33	29.52	09.61	28.00
Sorghum (*Sorghum bicolor*)	21.42	07.97	30.86	07.31	23.00
Oats (*Avena sativa*)	23.71	14.00	28.27	12.10	29.00
Atriplex (*Atriplex amnicola*)	36.00	14.60	21.00	19.23	32.00

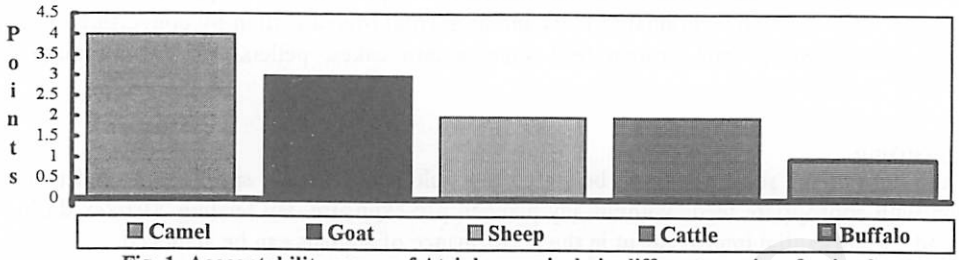


Fig. 1. Accceptability scores of Atriplex amnicola in different species of animals.

The daily feed intake of goats fed diets containing *Atriplex* in **Training** experiment varied significantly. Similarly, water intake was found to be highly significant among different groups. Water intake was higher in group B. Weight gain changes in different groups were non-significant. Weight loss in group C was the highest, whereas that in group B was the lowest (Table 3).

The results of the **Replacement** study showed that average daily feed intake of group A was maximum followed by group C. The daily feed intake in group B was slightly lower than the feed intake in group C. The feed intake in group A was higher than that in groups B and C due to its comparatively low salt contents. Most of the livestock farmers like using this feeding practice under semi-intensive livestock production system. The trend of increased water intake was observed in the groups having increasing level of *Atriplex* in the rations. This might be due to high salt content in the saltbushes, increasing the requirement of drinking water for ready excretion from the body. There was minimum variation in weight changes between the groups. The group C lost only 0.04 kg more than the group A (Table 3). The performance of goats fed on *Atriplex* based rations is comparable to those fed Basal Feed. Keeping in view the results of the present study it is envisaged that if farmers use *Atriplex* spp. with some supplements especially during scarcity periods, substantial improvement in the performance of goats can be achieved.

Increased dry matter intake was reported with increasing saltbush in the diet and intake was the highest on pure saltbush diet (1629 g/day) The highest intake on pure saltbush diet was in contrast to the expected higher intake on mixed diets (Attiq-ur-Rehman, 1995). The feed intake dropped by half and the animals lost weight rapidly when maintained on 1 % drinking salt solution (Wilson, 1975).

沙漠研究 7S, 113-116 (1998)
Journal of Arid Land Studies

Pro-active Livestock Management -- Capitalizing on Animal Behavior

Dean M. Anderson

Abstract - This paper describes a technique for modifying sheep and or goat behavior to reduce canine predation, management time and fencing requirements under mixed-species stocking. Procedures to modify behavior of individual animals are outlined. The concept involves bonding small ruminants to cattle to produce a cohesive group termed a flerd. A flerd acts as a single interdependent cohesive livestock unit under free-ranging conditions rather than as distinct flocks and herds coexisting in the same area.

Key Words: Livestock behavior, canine predation, flerds

Introduction

In 1983, the 78,000 ha (193,000 ac) Jornada Experimental Range (JER), located within the Chihuahuan Desert in southwestern New Mexico, and operated by the United States Department of Agriculture, Agriculture Research Service, expanded its range livestock research program by introducing sheep with the existing cattle. As a result of this introduction, the JER was by necessity catapulted into predator control research. Hulet et al. (1987a) found 63 (66%) aged Rambouillet-type ewes out of a range flock of 96 were lost principally to coyotes (*Canis latrans)*. From this initial loss, the JER has developed a multifaceted approach to coyote control. Turkish Akbash guard dogs in conjunction with modified sheep behavior have essentially eliminated predation caused by this wily and opportunistic canine. This paper summarizes research conducted between 1983 and 1996 to modify the behavior of small ruminants in order to enhance mixed-stocking management.

Mixed-stocking with livestock

Casual observation of free-ranging sheep and cattle reveal sheep do not consistently stay near cattle. In fact, interactions may occur < 6% of the time during daylight hours (Hulet et al., 1992a). Furthermore, most cattle exhibit physical hostility toward canines, especially when cow-calf pairs consider themselves threatened or trapped in their presence. Therefore, our research team reasoned if we could get sheep to remain with cattle when threatened under free-ranging conditions, this might afford protection from coyotes because of intimidation or physical aggression by cattle. First we had to address the question "How do we modify sheep behavior to exhibit an uncommon behavior and consistently remain near cattle under free-ranging conditions?"

From bond to flerd Bonding behavior research began on the JER in December 1985. A flock of Rambouillet x Polypay sheep were produced that consistently remained within ≤ 20 m (66 ft) of *Bos taurus* cattle. This was accomplished by penning 45, 62 and 90 day old lambs in close confinement with heifers for 60 days to form a bond. In contrast, non-bonded sheep maintained a distance of 600 to 1,000 m (1,968 to 3,280 ft) from cattle when the bonded and non-bonded groups were observed in a 120-ha (296-ac) paddock (Anderson et al., 1987a). These bonded animals were consistently within line-of-sight to one or more cattle. The animal aggregation in which small predator-susceptible ruminants consistently remained with one or more tolerant cattle under free-ranging conditions was termed a **flerd** (**fl**ock + **herd**; Anderson et al., 1988).

Behavior of cattle with bonded and non-bonded sheep was observed in the presence of a 6-year-old female border collie trained to voice and hand signals to simulate a threatening canine (Anderson et al., 1988). Non-bonded sheep consistently bunched together and ran independently of cattle, while bonded sheep ran and consistently crowded together among the cattle until the canine threat ended. When the flerd stopped moving, cattle consistently turned to face the threatening dog.

In a 163 day (d) study, no bonded sheep were lost to coyotes, while coyotes killed non-bonded control sheep at a rate of one every five days (Hulet et al., 1987b). Bonded sheep apparently were protected from coyote predation because cattle numbers and their size intimidated the coyotes. Furthermore, observations since 1986 suggest predator protection is not compromised by formation of subgroups within a flerd as long as sheep consistently remain with cattle.

The bond appears unidirectional, i.e. the smaller ruminants' behavior is modified while cattle simply tolerate the presence of sheep. We attempted to bond 90-day-old heifers to 18-month-old ewes during 80 days of pen confinement. However, only when a single heifer was kept with the sheep would it follow the ewes, if given the opportunity to associate with other cattle, the heifer separated from the sheep and acted independently of them (Anderson et al., 1992).

Management benefits In addition to providing protection from canine predation, flerds offer other management benefits without compromising grazing/browsing benefits from mixed-species stocking. Even though sheep consistently remain near cattle under free-ranging conditions, sheep diets and cattle diets in a flerd are essentially similar to those for flocks and herds respectively (Anderson et al., 1990; Hulet et al., 1992a).

Special situations such as during parturition occur in which individual sheep may leave a flock or flerd, therefore, "sheep-proof" boundary fences are recommended. However, "sheep-proof" fencing within a property may not be required because bonded sheep consistently remain near cattle during periods of foraging and rest (Anderson et al., 1994). Fencing adequate to prevent unwanted cattle movement will prevent sheep movement if paddocks adjoining the flerd are free of cattle since bonded sheep associate with cattle, not with specific animals. This indiscriminate bonding is an advantage since flerd integrity is retained even after culling of cattle based on management decisions.

Locating animals comprising a flerd may be faster than locating separate flocks and herds. Locating bonded animals in dense brush or during periods of fog and snow requires less time because cattle are larger and are usually recognized first compared to smaller ruminants. The potential savings when needing to locate bonded animals compared to similar non-bonded animals can be substantial and has been estimated at \$0.10 hd^{-1} d^{-1} in 1992 U. S. dollars (Anderson et al., 1994).

Flerds need not be limited to sheep and cattle. We have used pen confinement to bond 5-month-old mohair kid goats (Hulet et al., 1989) and 100-day-old Spanish kids (Hulet et al., 1991) to cattle. Both breeds of goats were of mixed gender but the Spanish goats were predominantly castrated males. Our Spanish goats demonstrated minimal flocking tendencies. However, it may be possible to create a cohesive Spanish goat flerd if rigorous selection is used to eliminate individual animals that refuse to remain as cohesive members of a flerd. In contrast, mohair goats readily flocked and when confined with cattle and sheep, bonded to both cattle and sheep.

Flerd characteristics Bond strength refers to the distance of separation between predator-susceptible animals and the animal species to which they are bonded. Strong bonds have the shortest distance of separation between species. A strongly-bonded animal will act as a "bridge" for those with a weak bond or no bond because of the flocking instinct of most small ruminants. For example, we found 12 bonded sheep can control movement of 12 non-bonded sheep (Anderson et al., 1988). The optimal ratio of cattle to sheep may differ in flat vs. undulating topography because line-of-sight will vary depending on landscape. Therefore, to optimize the opportunity for a cohesive flerd, all small ruminants should be given the opportunity to bond to cattle.

Capitalizing on among-animal variation may be useful in developing flerds. Bonded wethers were found to maintain a stronger bond (shorter distance of separation) to cattle compared to bonded ewes (Anderson et al., 1996). Cattle, irrespective of physiological state, age and breeding, provide sheep equal protection from coyote predation based on 11 years of JER bonding research.

How to bond an animal

A bonded animal appears "consistently aware" of the location of the species to which it is bonded. Sheep and or goats appear to synchronously "echo" the movement of cattle as the flerd "flows" across the landscape. The bond can be produced through any reasonable method to socialize animals through close association. The mean distance between bonded small ruminants and cattle does not appear related to length of pen confinement (30 vs 60 days). Once established, the bond will endure over time even though the distance of separation between bonded sheep and cattle has been observed to increase over a three year period (Anderson et al., 1996).

Pen confinement Repeated experiments conducted since 1985 have involved confining cattle and lambs to pens for a period of uninterrupted time between 14 and 60 d. A negative aspect of this procedure is labor and feed costs during confinement, estimated to be \$0.51 $sheep^{-1}$ d^{-1} in 1992 U.S. dollars (Anderson et al., 1994). Because of high predation losses, JER lambing is carried out in a corral. This management routine can provide an opportunity to produce bonded animals. By incorporating pen bonding into ongoing management such as lambing, winter feeding or a feedlot program, the costs associated with confining sheep just to produce a bond can be eliminated.

We have successfully created bonds using rectangular and triangular pens with solid sides having mean areas ranging from 4.8 $m^2 animal^{-1}$ (52 $ft^2 animal^{-1}$) to 17.5 m^2 $animal^{-1}$ (188 $ft^2 animal^{1}$) with the ratio of cattle to small ruminants in these two size pens ranging from 1:3 to 1:1, respectively. Baled hay and a mineral block were provided in a feeder located in each pen at the end opposite the drinking water. A creep area in each pen provided a safe area where lambs could escape from cattle if they became physically abusive and an area for supplementing the growing lambs. The creep can also serve as an initial interface between cattle and the animals to be bonded by penning small ruminants in the creep during the first 24 hours and feeding hay on both sides of the creep. The following day, the small ruminants to be bonded can be released into the pen and socialization resulting from animals eating together at a common feeder can begin. An animal's location in the pen can focus attention on potential problems. Lambs penned with physically abusive heifers tend to spend twice the amount of time in the creep area compared to lambs penned with gentle, tolerant heifers (Anderson et al., 1987b).

Length of pen confinement appears to affect bond consistency. Lambs have been observed to associate with cattle within 24 hours following birth and some bonding occurs after only 7 days of uninterrupted pen confinement. However, as a rule of thumb, to produce sheep and or goats that bond to cattle, research from the JER suggests penning recently weaned small ruminants with docile, gentle cattle for a minimum of 40 to 50 consecutive days of uninterrupted confinement, this will result in a consistent bond. The procedure appears simple yet is not always successful. Following 60 d of pen confinement, a consistent cohesive bond to cattle did not develop using 60 day-old purebred Rambouillet and 1/4 Finn, 3/4 Columbia or 3/4 Targee crossbred lambs (Anderson et al., 1993).

Once a bond is created, its maturation should be fostered by initially releasing the bonded group into a small paddock in which line-of-sight among animals is consistently optimal. As the flerd matures to paddock conditions, situations such as dense brush that may limit the line-of-sight among livestock does not appear to adversely influence bond integrity. However, always provide only a single source of drinking water at any point in time, and be innovative and capitalize on animal senses when possible to bring animals together, especially in undulating topography. For example, sound can be used to help orient sheep toward cattle by placing a bell on docile cattle.

Pen confinement plus field socialization Under current JER management parturient bonded ewes are removed from the range and cattle and allowed to give birth in a corral. The ewe-lamb pairs remain in the corral for approximately 2 months during which time the lambs grow and gain strength. Following this period of corral confinement the ewe-lamb pairs are reunited with cattle. The ewes immediately re-associate with and follow the cattle as a result of having been previously bonded.

Lambs are weaned approximately 5 months after birth by removing the dams for a period of 5 days. During this 5 d separation, if lambs are evaluated for bond strength, they do not appear to have formed bonds during the previous 3 months they and their dams have followed the cattle on the range. On day 6 when the dams are returned to the flerd, though the lambs have been weaned they continued to follow their dams. The lambs raised with bonded ewes, when evaluated after 217 d with the flerd, demonstrated a bond to cattle comparable in strength and similar to pen-bonded lambs that had been weaned at 50 days of age and penned with heifers for 34 d before being placed into the flerd (Hulet et al., 1992b).

Implications It may be possible to create bonded sheep and or goats by combining short periods (3 to 7 d based on unpublished data) of socialization in pens with extended (proposed several weeks) periods of confinement in a paddock that provides optimum line-of-sight opportunities among animals. Because JER sheep bunch together when threatened, once these sheep have become socialized to cattle, it may be possible to shorten the period of small paddock confinement by periodically using a threatening canine to force the sheep to return to the cattle when they are observed to have separated. Unpublished research conducted on the JER indicates a threatening canine used to "dog" sheep that have separated from cattle may be a valuable tool to foster bond formation. One aspect of current animal behavior research on the JER is focused on how to produce bonded animals in the shortest possible time.

Conclusions

Several management costs including predation losses from coyotes, labor and fencing can be reduced when raising small ruminants with cattle. This is accomplished by modifying the individual behaviors of sheep and goats that will ultimately alter their group behavior. Molding behavior to create flerds by socializing sheep and goats to cattle requires the keen eye and consistent innovative input of a pro-active manager. Flexibility is essential when operating a mixed-species livestock operation, especially when one of the multifaceted approaches involves manipulating animal behavior.

References

Anderson, D. M., Hulet, C. V., Smith, J. N., Shupe, W. L. and Murray, L. W. (1987a). Applied Animal Behavior Science, 19:31- 40.

Anderson, D. M., Hulet, C. V., Smith, J. N., Shupe, W. L. and Murray, L. W. (1987b). Applied Animal Behavior Science, 19:27-30.

Anderson, D. M., Hulet, C. V., Shupe, W. L., Smith, J. N. and Murray, L. W. (1988). Applied Animal Behavior Science, 21:251-257.

Anderson, D. M., Hulet, C. V., Hamadeh, S. K., Smith, J. N. and Murray, L. W. (1990). Applied Animal Behavior Science, 26:231-242.

Anderson, D. M., Hulet, C. V., Smith J. N., Shupe, W; L. and Murray, L. W. (1992). Applied Animal Behavior Science, 34:181-188.

Anderson, D. M., Walker, J., Havstad, K. M., Murray, L. W. (1993). In: Proceedings 46th Annual Meeting Society For Range Management, Denver, CO (Abstract), pp. 70-71.

Anderson, D. M., Havstad, K. M., Shupe, W; L., Libeau, R., Smith, J, N. and Murray, L. W. (1994). Small Ruminant Research, 14:1-8.

Anderson, D. M., Estell, R. E., Havstad, K. M., Shupe, W. L., Libeau, R. and Murray, L. W. (1996). Applied Animal Behavior Science, 47:201-209.

Hulet, C. V., Shupe, W. L. and Howard, V. W. Jr. (1987a). Rangelands, 9:102-105.

Hulet, C. V., Anderson, D. M., Smith, J. N. and Shupe, W. L. (1987b). Applied Animal Behavior Science, 19:19-25.

Hulet, C. V., Anderson, D. M., Smith, J. N., Shupe, W. L., Taylor, C. A., Jr. and Murray, L. W. (1989). Applied Animal Behavior Science, 22:261-267.

Hulet, C. V., Anderson, D. M., Smith, J. N., Shupe, W. L. and Murray, L. W. (1991). Applied Animal Behavior Science, 30:97-103.

Hulet, C. V., Anderson, D. M., Nakamatsu, V. B., Murray, L. W. Pieper, R. D. (1992a). Sheep Research Journal, 8:11-18.

Hulet, C. V., Anderson, D. M., Shupe W. L. and Murray, L. W. (1992b). Sheep Research Journal, 8:69- 72.

New Technologies for Sustainable Production in Arid Areas

Poster Papers

沙漠研究 7S, 117-120 (1998)
Journal of Arid Land Studies

Water Management for Sustainable Forest Systems in Arid Land -CO_2 Reduction and Solar Energy Utilization-

Kiyotaka TAHARA[1], Toshinori KOJIMA[1] and Atsushi INABA[2]

Abstract - Afforestation of deserts is thought to be one of the most promising measures against the CO_2 problem. We first discuss the amount of biomass energy produced from a poplar forest, which originally needs 600 mm annual precipitation, under the condition that primary production is proportional to the 3/2 power of the precipitation. Second, we discussed the energy for the desalinization of brackish water. The effect of CO_2 reduction when the short amount of water was supplied by gathering rainwater from some to the rest of an area is also evaluated. The necessity of introduction of solar PV cells for the water management is also discussed.

Key Words: forest, CO2, precipitation

1. Introduction

Recently, global warming is noted as one of the most important global environmental problems. Global warming is mainly caused by the increase of atmospheric CO_2 concentration. CO_2 emissions are primarily from fossil fuel combustion. It is essential to develop highly-efficient energy utilization processes and substitute energy sources as a countermeasure against CO_2 problem. Biomass energy production by plantation is one of the most promising alternatives to conventional energy from fossil fuel. The vast majority of the CO_2 released from the conversion of biomass is merely CO_2 that has been recently sequestered from the atmosphere by plant growth - the carbon contained in biomass both above and below the ground. In contrast, large amount of CO_2 released by fossil fuel conversion is from long term storage. Biomass energy production by plantation would thus result in relatively large net reduction of atmospheric carbon emissions. On the other hand, desertification that is caused by deforestation and inappropriate irrigation is also noted as one of the most important global environmental problems. Furthermore, afforestation of deserts is thought to be one of the most promising measures against the CO_2 problem. In our previous study, the problem of energy for water production was focused in the course of the afforestation of deserts (Matsumura and Kojima, 1991). Here, the concepts of just afforestation and energy plantation should be distinguished, as electricity is produced sustainably by energy plantation to substitute electricity from fossil while CO_2 is just once absorbed by the afforestation. On the other hand, the produced electricity by energy plantation should be transported to some area of energy consumers. Thus, the combination of afforestation and energy plantation should be considered for the optimum utilization of desert for combating CO_2 problem.

In the present study, we discuss the way of energy supply for the water management to sustain a poplar forest in arid region; gathering water and desalinization from brackish water with salt content

[1] Department of Industrial Chemistry, Seikei Univ., Musashino-shi Tokyo 180, Japan
[2] National Institute for Resources and Environment, Tsukuba-shi Ibaraki 305, Japan
(Fax: +81-422-37-3871 or +81-298-58-8412, E-mail: tahara@nire.go.jp)

comparable to sea water. First of all, the possibility of sustainable forest management only by using biomass energy is evaluated. The necessity of introduction of solar PV cells for the water management is also discussed.

2. Assumption for the present evaluation

Table 1 summarizes the required amount of various energy forms for plantation; establishment, fertilizers, pesticides, equipment, harvesting and hauling (Turhollow and Perlack, 1991). Primary production (annual growth) was assumed to be equal to 960 g-dry·m^{-2} (in case of annual precipitation : 600 mm), and to be changed by annual precipitation. It was also assumed that sustainable and sufficient poplar forest management requires the precipitation of 600mm. For the case of annual precipitation larger than 600 mm, no evaluation was conducted in the present study. In case of that less than 600 mm, we assumed that the primary production was proportional to 3/2 power of annual precipitation (or amount of water supply).

$$Pp = (X/600)^{3/2} \times 960 \quad \cdots(1)$$

(Pp : primary production [g-dry·m^{-2}], X : annual precipitation [mm·yr^{-1}]

Heating value of harvested poplar was assumed to be 4,500 kcal·kg-dry^{-1}. In the present study, all of the primary production was assumed to be converted into electricity with the conversion efficiency of 22%, while the efficiency from coal is 39%. CO_2 emissions per kWh of coal fired power plant and PV cell power plant were 0.916 kg-CO_2·kWh^{-1} and 0.153 kg-CO_2·kWh^{-1} (Tahara *et al.*, 1997). Required energy for desalinization by RO (Reverse Osmosis), excepting plant construction energy, was assumed to be 5.35 kWh·m^{-3} (Kinjo, 1996).

Table 1 Annual energy inputs for hybrid poplar forestry system

	Diesel oil	Natural gas [GJ·ha^{-1}·yr^{-1}]	Electricity
Establishment	0.14		
Fertilizers	0.24	2.81	0.28
Pesticides	0.29	0.10	0.02
Equipment	0.17		
Harvesting	7.31		
Hauling	2.40		
Total Energy	10.55	2.91	0.30

3. Results and Discussion

3.1 CO_2 emissions from poplar afforestation in energy plantation system CO_2 emissions were calculated by "NIRE-LCA ver.2", LCA (Life Cycle Assessment) software developed at the National Institute for Resources and Environment using a bottom-up approach (Kobayashi *et al.*,1994, Kobayashi *et al.*,1995). The calculated total CO_2 emission from energy plantation system of poplar forest was 961.7 kg-CO_2·ha^{-1}·yr^{-1}.

3.2 Base case: without water management Decrease in annual precipitation causes decrease in primary production. CO_2 reduction effect by substitution for coal fired power plant by the present energy plantation was calculated. The results of the effect vs. annual precipitation are shown in Fig.1. The effect was proportional to the 3/2 power of the precipitation as it is proportional to the primary production.

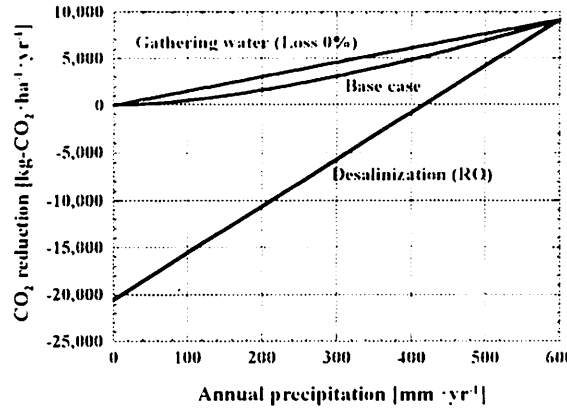


Fig.1 Effect of water management on CO_2 reduction

3.3 With water production by desalinization with RO Here, the amount of water equivalent to the shortage of natural precipitation from 600 mm is assumed to be supplied from desalinization by RO. Electricity for desalinization is firstly supplied from biomass power plants, and then, is provided from coal fired power plants if any shortage. If any surplus, the produced electricity from biomass is substituted for the coal fired power plants. CO_2 reduction was negative in case with annual precipitation less than 420 mm precipitation. These results are also shown in Fig.1.

3.4 With water management: gathering water

It was assumed that short amount of water was supplied by gathered rainwater to some fraction of total area and in the other area, no water was supplied; the water was gathered by banks and then it was stored. The results are shown in Fig.1. The effect in CO_2 reduction was straightforward to the precipitation. It is clearly observed that the enhancement effect in CO_2 reduction is enlarged with annual precipitation, attains maximum around middle precipitation area, and then decrease to zero at 600 mm.

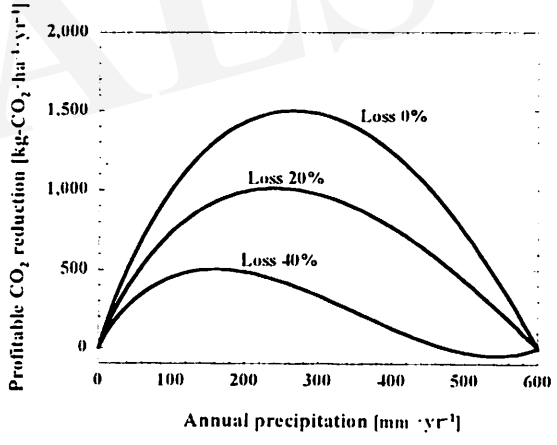


Fig.2 Improvement effect in CO_2 reduction by water gathering

In spite of the above results, naturally, it is difficult to gather 100% of the rainwater. It is necessary to consider some water loss in the gathering water. In addition, some energy for gathering water is essential, though it was not taken into account in the present analysis. The differences in the CO_2 reduction effect (profitable CO_2 reduction) between for the base case, and for

20, and 40 % of water loss in the water gathering are shown in Fig.2 with the results of the difference for 0% water loss. In case of 0%, loss the maximum enhancement effect was found at 270 mm of annual precipitation. The difference for loss 20% was of course less than that for the case of 0% but the tendency was same as that for 0%. But the difference for the case of 40%, there was a range of annual precipitation between 480-600 mm where negative effect of water gathering was demonstrated. These results indicate that it is necessary to be careful whether water should be gathered or not, site by site.

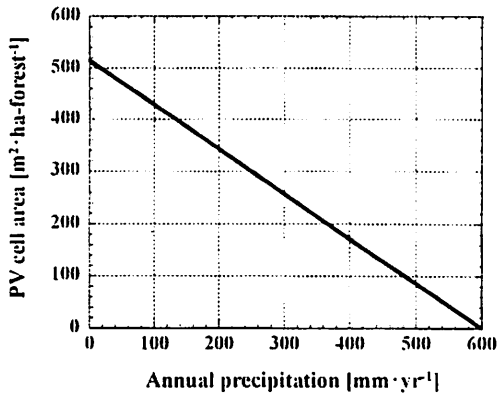


Fig.3 PV cell area

3.5 Water production using electricity from PV It was assumed that short amount of water was supplied from desalinization using electricity from PV power plant of 62.5 $kWh \cdot m^{-2}$. In the present case, construction energy of PV cell was considered, however it was negligibly small. The calculated PV cell area was shown in Fig.3. In the largest case, i.e., no rain water case, PV cell area was 5% of the forest area at most.

4. Conclusion

When electricity from biomass power plants is supplied for desalinization, it was found that the CO_2 reduction was negative in the area with precipitation less than 420 mm. Sustainable forest system needs annual precipitation more than 420 mm. In case of gathering water, the maximum enhancement effect compared to the base case was found at 270 mm of annual precipitation, without water loss in the course of the catchment. But for the case of 40% of water loss, there was a range of annual precipitation between 480-600 mm where negative effect by water gathering was demonstrated. These results indicate that it is necessary to be careful whether water should be gathered or not, site by site. In the case of desalinization by RO using electricity from PV power plant, PV cell size was 5% of forest size at most, i.e., in no rain water case. PV power plant was demonstrated to have large effect to substitute electricity from fossil fuel fired plant, though its transportation is difficult.

References

Kinjo Y. (1996). Nihon Kaisui Gakaishi, 50, 4: 273-279.
Kobayashi, M., A. Inaba and T. Nakayama (1994). J. of the Japan Institute of Energy, 73, (12): 1057-1079.
Kobayashi, M., A. Inaba and T. Nakayama (1995). J. of the Japan Institute of Energy, 74, (1): 46-52.
Matsumura K. and T. Kojima (1991): Journal of Arid land studied, 1: 17-26.
Tahara K., T. Kojima and A. Inaba (1997). Kagaku Kougaku Ronbunshu, 23, 1: 88-94.
Turhollow A. F. and R. D. Perlack (1991). Biomass and Bioenergy, 1, 3:129-135.

沙漠研究 7S, 121-124 (1998)
Journal of Arid Land Studies

Development of a Roof Type Solar Membrane Distillator for Desert Afforestation

Sumito KOMIYAMA*, Kyo MATSUYAMA*,
Norihiko MIYAHARA* and Kazuo MURASE*

Abstract A new roof type solar membrane distillator for desert afforestation has been developed and analyzed experimentally and numerically. Results show that the optimal parameter for stable runnings is the operational condition of the upward feed method. Even thought sea water is supplied into the distillator under a feed rate flowing down in a rectangular cavity by gravity, the amount of distillate could be stably produced as we expected by simulation. So this method is independent of the setting situations.

Key Words: Membrane Distillator, PTFE Membrane, Desert Afforestation

1. INTRODUCTION

Drought areas where the annual precipitation is less than 500~600mm occupy 1/3 of the land in the world and have been extending every year by unusual weather and enviromental destructions .e.g. too much deforestation.

We have been developing a variety of roof type solar distillators[1)-6)] for our conception of The Inland Marine Oasis Solar System, in which the distillators are located at a seaside or a lakeside and the distillate is used to afforest the desert areas. This type has several merits; it is easy to construct the compact design, to hybridize the distillator with a solar cell or a green house, to make a multi-effect distiller, and to set it up.

In this study, a roof type solar membrane distillator was developed with PTFE(Poly-Tetra-Fluoro-Ethylene)membrane. The characteristics of the distillator were experimentally and numerically analyzed. The optimal parameters of design and operation are cleared on the basis of the analytical data.

2. EXPERIMENT

Fig.1 is a schematic diagram of a flow sheet for a roof type solar membrane distillator. This module comprises four accumulated flat plates(1m in length, 0.3m in width)in Fig.2. A solar collector is made of Al(thickness 2mm) , a PTFE membrane sheet(NITTO-DENKO Co.Ltd., NTF-520 0.85 μ m in thickness, 80% void fraction). two types of polyethlene meshs (porosity 0.4, 0.5 thickness 0.3, 5.0mm), and a acrylic radiator for observation (thickness 3.0㎜). Ion exchange water, as a substitute for sea water, was fed to either undertube (upward feed case in Fig.2) or overtube(downward feed case), so that the evaporate water that was heated up by infrared lamps passes through the membrane, diffuses in a spacer from a membrane to a radiator, then the vapor condensates on the radiator. The power

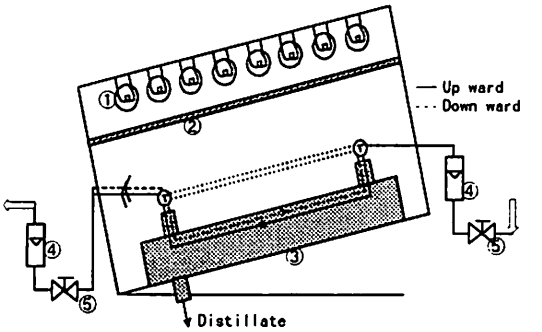


Fig. 1 Experimental apparatus

* Dept. of Appl. Chem. Chuo Univ., Tokyo 112, Japan(FAX: 81-3-3817-1895)
e-mail: hmurase @.chem.chuo-u.ac.jp

of 24 infrared lamps is adjusted by volt-sliders and the heating intensity is measured by pyrometer (Model MS-42). The temperature distributions of the collector and distilled water are measured at 11 positions along the distance from the underedge x by using copper-constantan thermocouples. For the purpose of evaluating distillator characteristic, temperature profiles, flow rates of feed and distilled water are recorded both in case of downward and upward feed rate at each power of lumps, feed, and slope of the still.

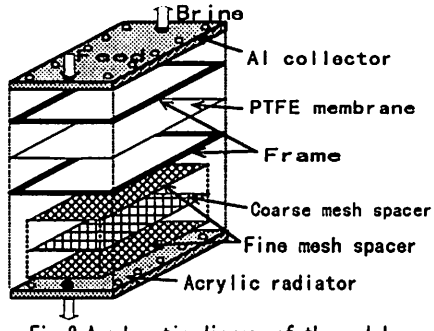


Fig. 2 A schematic diagram of the module

3. SIMULATION MODEL

In order to simulate the performance of this module at steady states, the heat and mass balances for these parts namely, a solar collector, evaporate distillate, flow and the radiator was constructed as follows.

Collector $$0 = \alpha_P I_0 L - h_{PA}(T_P - T_A) - \sigma\varepsilon F\left(T_P^4 - T_{sky}^4\right) - U_{PS}(T_P - T_S) \quad \cdots (1)$$

Evaporate $$\rho CW \cdot dT_S/dX = U_{PS}(T_P - T_S) - R_S D - \sigma\varepsilon F\left(T_P^4 - T_D^4\right) - (k/z)(T_S - B - T_D) \quad \cdots (2)$$

Distillate $$\rho CD \cdot dT_D/dX = -U_{DB}(T_D - T_B) + R_D D + \sigma\varepsilon F\left(T_S^4 - T_D^4\right) + (k/z)(T_S - B - T_D) \quad \cdots (3)$$

Radiator $$0 = U_{DB}(T_D - T_B) - h_{BA}(T_B - T_A) \quad \cdots (4)$$

$$D = \frac{\Gamma}{A}\frac{1}{\left(\delta/\delta^{3.6} + Z\right)}\frac{(P_S - P_D)}{P_{BM}}, \quad A = \frac{RT}{\pi} \quad \cdots (5)$$

B.C. I) Downward feed

a) $dT_P/dX = dT_B/dX = 0$ at X=0 $\cdots (6)$

b) $T_S = T_{SI} = const.$, $W_I = F$, $dT_P/dX = dT_D/dX = dT_B/dX = 0$ at X=L $\cdots (7)$

II) Upward feed

a) $T_S = T_{SI} = const.$, $W_I = F$, $dT_P/dX = dT_B/dX = 0$ at X=0 $\cdots (8)$

b) $dT_P/dX = dT_D/dX = dT_B/dX = 0$ at X=L $\cdots (9)$

These mathematical equations are simultaneously calculated by F.E.M. (Finite Element Method)

4. RESULTS AND DISCUSION

4.1 Temperature profiles

Fig.3-a,b show the temperature distributions of a collector and a radiator comparing experimental and simulation data in case of a)upward feed and b)downward feed. Each parameter

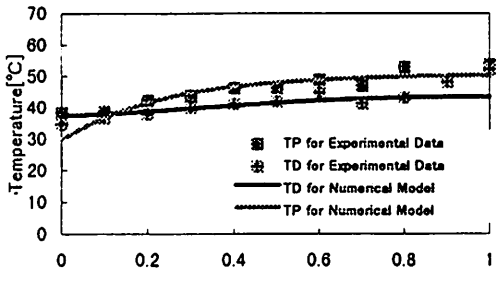


Fig.3-(a) Temperature Distribution in case of Upward Feed at 600W/m^2

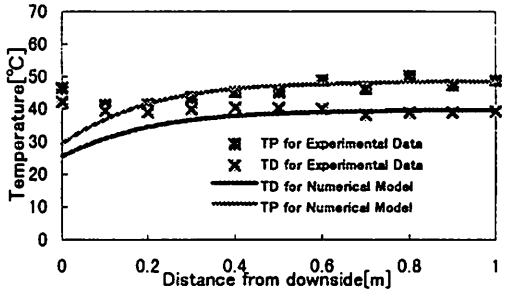


Fig.3-(b) Temperature Distribution in case of Downward Feed at 600W/m^2

in simulation, especially head transfer coefficient(U_{PS},U_{DB},h_{PA},h_{BA}), was determined by fitting one of experimental data with calculation. Heat flux is generally transfered from collector to radiator but the reverse tendency occurred near at the inlet of feed. Temperature difference between collector and radiator in Fig.3-a got smaller in comparison with Fig.3-b.

4.2 VERIFICATION OF SIMULATION

Productivity of distilated water depends on this temperature difference. Effects of feed rate on the productivity with experimental and calculation data are shown in Fig.4-a,b at solar intensity I=600W/m^2. Fig.4-a indicated the underestimation of the simulated productivity but on the other operation in Fig.4-b, productivity of all experiment data were lower than one under the identical simulation condition. The value of feed(14 kg/h·m) means the flow rate of flowing down through the cavity between parallel plates under the identical conditions of the experiment. Good performances are expected on the range of feed less than 14 kg/h·m because productivity increase according to the decreasing feed. But the minimum feed rate in case of down feed is about 2.5kg/h·m.

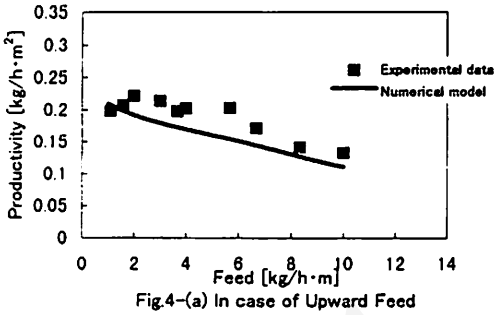


Fig.4-(a) In case of Upward Feed at I=600W/m^2

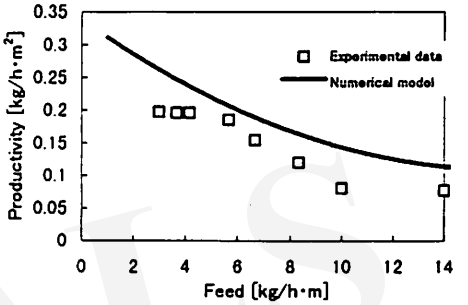


Fig.4-(b) In case of Downward Feed at I=600W/m^2

Fig.4-b, however, shows that sea water on this range of feed will not be fully saturated in the cavity between collector and membrane. In the case for downward feed it's very difficult to control the flow rate on this range for reasons of keeping the mass balance between inlet and outlet flow rate.

3.FEED CONTROL

As the distillator was set up on the more inclined condition, the flow rate of feed by gravity is naturally larger only in the case for downward feed. Accordingly, the minimum feed rate for producing distillate is shifted to the higher flow rate as the larger inclination setting. Otherwise, the upward feed operation makes the feed supplied stably to the distillate in spite of the several setting of inclination because of flowing upagainst gravity.

4.EVALUATION OF PRODUCTIVITY

Fig.5-a,b show the effect of feed and solar intensity on the estimated productivity in both case.

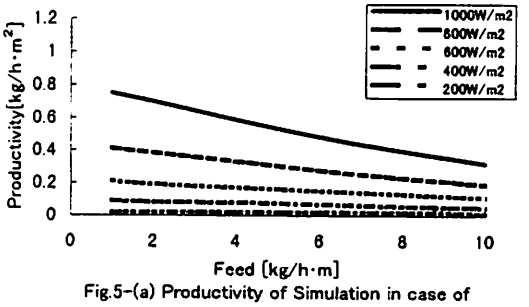


Fig.5-(a) Productivity of Simulation in case of Upward Feed

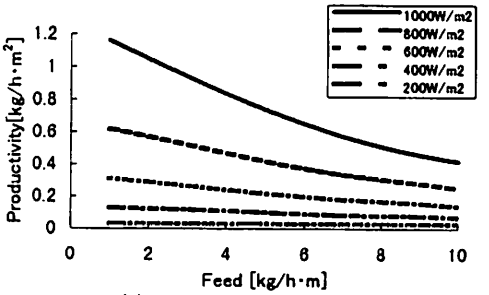


Fig.5-(b) Productivity of Simulation in case of Downward Feed

The results indicated the performance in downward feed is better compared to the upward feed, for identical feed saturation. The condition of downward feed identifies with the cocurrent flow of evaporate ,so that two parts have same temperature gradient and the larger temperature difference between the collector and the radiator contributes to lager productivity.

Fig.6 shows the effect of the feed direction(upward and downward) on the experimental productivities. Solid lines present in the case for upward feed and broken lines in the case for downward feed. The remarkable difference could be seen at the highest solar intensity. Otherwise, productivities in both cases almost show the same values. But in the case for downward feed, the flow rate at the outlet sea water must be choked in order to keep this feed rate so that the inner pressure in module would be higher and higher according to decrease the feed. For the practical use, the heat transfer area of distillator will be necessary for more than 2 m^2. Downward feed operation results in impractical condition at the low flow rate of sea water.

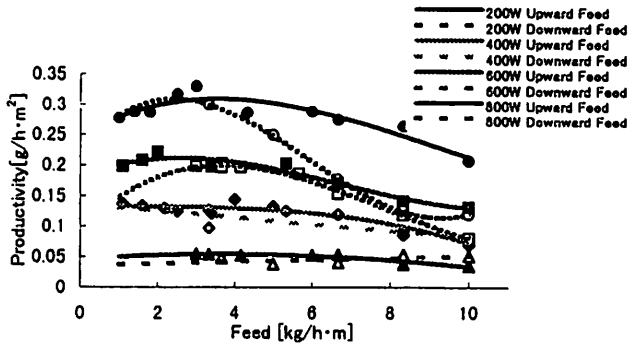


Fig.6 Productivity of Experimental Data

CONCLUSION

A new roof type solar membrane distillator was developed and the static characteristics were experimentally and numerically analyzed. The following results were obtained.

1) The calculated productivity of distillate in the case for a downward feed had a good agreement with the experimental data.
2) The amount of distillate in the case for upward feed was stably produced in spite of the several setting conditions with the flow rate of feed and the angle of the inclined distillator.
3) The counter current operation with the feed and distillate flow was not expected to have the higher efficiency owing to the insufficiency of feed.

NOMENCLATURE

B= rise of boiling point [℃]
C= specific heat [kcal/kg·℃]
D= flow rate of distilate [kg/h·m]
F= geometrical factor [-]
h= heat transfer coefficient [kcal/m·hr]
I= intensity of solar radiation [kcal/m^2·hr]
L= length of plate [m]
U= overall heat transfer coefficient [kcal/m^2·hr.·℃]
W= flow rate of brine [kg/h·m]
U= velocity [m/hr]
α = absorptivity of plate [-]
δ = thickness of membrane [m]
ε = porosity [-]
π = total pressure [Pa]
ρ = density [/m^3]
σ = stefan-boltzman constant [kcal/m^2·hr.·$℃^4$]

REFERENCE

1)Krumi.Y, *et al.*(1995):J. Arid Land Studies,5S,
2)Toyama, S., *et al.* (1991) : "Memoirs of the Faculty of Engineering , Nagoya Univ.",43, No1
3)Toyama, S., *et al.* (1992) : Bull. Soc. Sea Water Sci., Japan, 46: 3(*in Japanese*)
4)Salah. H., *et al.* (1989) : Desalination,71: 347
5)Murase. K., *et al.* (1989) : Desalination,73: 111
6)Toyama, S. *et al.* (1985) : Kagaku Kougaku Ronbunshu, 11 : 567,13 : 249(*in Japanese*)

沙漠研究 7S, 125-128 (1998)
Journal of Arid Land Studies

Solar Powered Reverse Osmosis Desalination

Don HARRISON* and *Goen HO**

Abstract - A compact, solar powered reverse osmosis desalination unit has been developed that would not only provide fresh drinking water from brackish water, but do so with little attention or maintenance. Reverse Osmosis is the leading technology for brackish water desalination, but it is prone to fouling, and failures of the technology are common. The development methodology has been driven by the need to reduce the risks of fouling. Accordingly, low recovery ratios are used at reasonably low pressures. The energy recovery system, a key component, not only makes the low recovery ratio regime economic in terms of energy use, but also facilitates fully automatic start-up and shut-down as well as self-regulation during fluctuating insolation levels. Three units were produced with recovery ratios of 12%, 16% and 25%. The preferred model, the 16% recovery production unit produces 620mL per minute of fresh water from brackish feed in sunny winter conditions in Perth.

Key Words: Desalination, Brackish Water, Reverse Osmosis, Solar Power, Remote Area

1. Introduction

This paper describes testing of a production model solar powered desalination unit which produces over 40 L/hour from a 120W peak array. The unit has only one cylinder with an internal valving system and a large diameter single membrane. A valve was developed which was integral with the piston head and automatically switched at the end of each stroke. A large, single cylinder machine allowed the cylinder to be set vertically in front of the motor/gearbox. Mounting of the membrane module vertically, and a large diameter, short module facilitated a compact design.

2. Summary of Results of System Testing

2.1. Pump Tests

The efficiency of the pumps developed remains an estimate only at this stage. To determine the efficiency, it is necessary to remove the energy recovery hydraulic lines and record the ratio of electrical energy input to hydraulic energy output of the pump. Unfortunately, to test this, it is necessary to run the crank end of the cylinder dry. The shaft seal and piston head valve are intolerant of dry running, so tests have been brief. Over the test periods, the pumps have performed at about 50% efficiency, which is a satisfactory performance. Higher pressures are likely to produce higher efficiencies.

Pump slip, that is leakage past the main pump seal and valves, was assessed at 2% which was a great improvement on previous prototypes. This effectively gives the 16% recovery model an actual recovery ratio of 14%.

Modelling suggested that pump efficiency was more important than energy recovery efficiency. Accordingly, only one pump seal is used, with the cup facing the wet end of the pump. Any leakage past the seal on its suction stroke tends to recycle waste water and overstate the actual pumped recovery ratio. In early prototypes, this slip was rated at 9% but subsequent development brought this down to negligible levels.

The leakage through the piston head valve occurs mostly at the change-over between energy recovery and exhaust strokes. This affects both the volume of water and the eventual pressure of the water which is used for energy recovery. Hydraulic energy is therefore lost quickly with higher leakage. Figure 1 shows the effects of these slip values on the performance of the Mark IV prototype, the penultimate model. The actual production models have slips that have been engineered down to low levels in comparison.

* * Senior Project Officer, Energy Technology and Environment Branch, Western Power; ** Assoc Prof, Director - Institute for Environmental Science, Murdoch University, Murdoch WA 6150, Australia (Fax: +61-8-9310 4997).

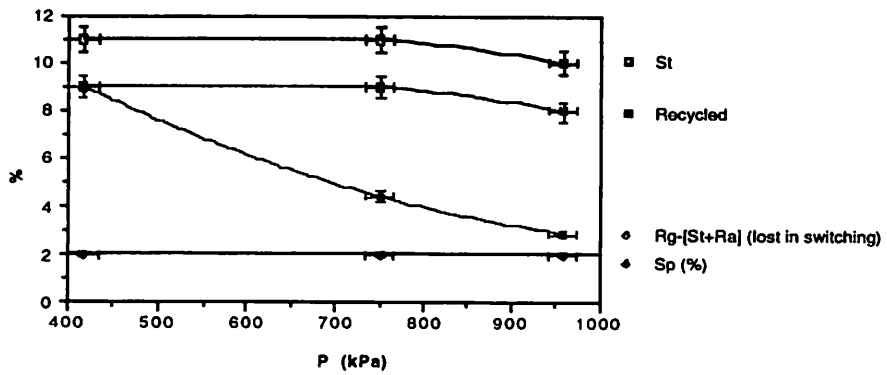


Figure 1. The slip parameters of the Mark IV prototype plotted against operating pressure. S_t is the total slip, recycled water is that which bypasses the main seal on its suction stroke, lost in switching refers to the losses in the piston head valve and S_p is the pump slip for the 25% recovery model.

The relationship between the geometric recovery ratio, the actual recovery ratio and the percentage of flow lost in switching is shown in Figure 2.

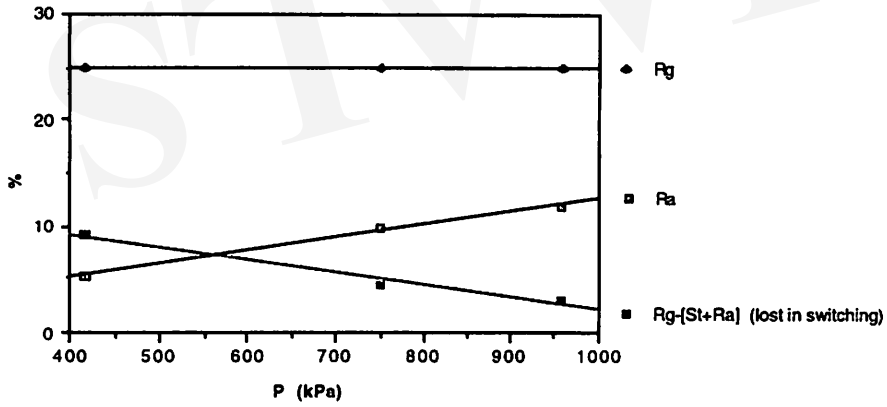


Figure 2. The geometric recovery ratio R_g, the actual recovery ratio R_a and the percentage of flow lost in switching are plotted against operating pressure for the 25% recovery model.

The difference between the geometric recovery ratio and the actual recovery ratio for the production models is now 7% for the 12% recovery model, and 1.5% for the 16% and 25% recovery models across a range of operating pressures.

2.2. Membrane Tests

Over the course of the project, a number of membrane combinations were tried and the results are summarised in Figure 3. The membrane permeation constant (k) is the flux rate per kPa operating pressure of that particular membrane. The first two digits in the product number refer to the width (25 being 2.5 inches) while the second two are the length in inches (40 being 40 inches long).

The Desal 5 is a high flux selective membrane more suited to softening than desalination, having only 60% or so rejection of monovalent salts like sodium chloride. It may, however, find a place in the treatment of low salinity water where only minor reductions are required to meet NH&MRC Guidelines. The Desal 5 is also a suitable filter for colours and microbial pathogens.

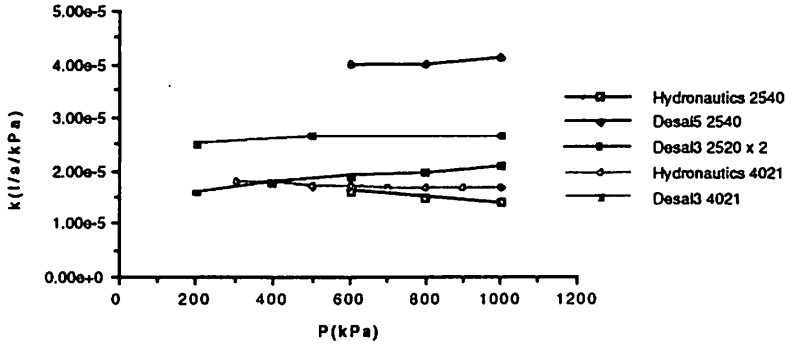


Figure 3. The membrane permeation constants of different membrane combinations.

The salt rejection ratios calculated at 1000 kPa operating pressure for the different concentrations are shown in Figure 4. The effective permeate concentration is plotted against feed concentration for the two pressures in Figure 5.

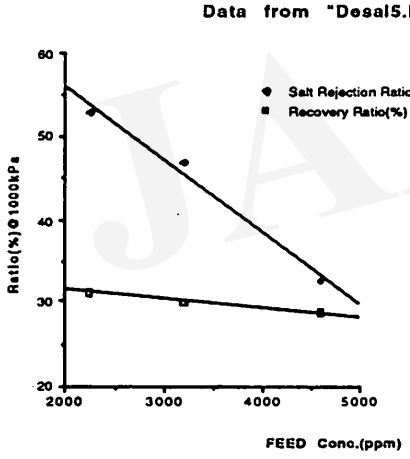


Figure 4. Salt rejection and recovery ratios plotted against feed concentrations at 1000kPa for Desal 5 membrane.

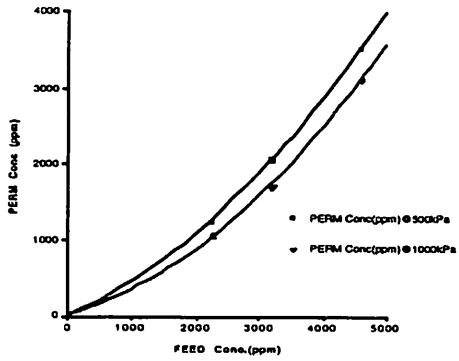


Figure 5. The permeate concentration plotted against feed concentration at 500 and 1000kPa for the Desal 5 membrane.

Overall, the Desal 3 4021 had the highest flux rates consistent with high salt rejection requirements. It should be noted though, that these are the initial flux rates and they decline to lower levels rapidly, experimentally by 25% or more before settling down to a slower rate of decline. There is also a 10% variation allowed for by the manufacturers between individual membranes.

We have based all our predictions on a k value of 2.0×10^{-5} for the Desal 3.

3. Conclusion

The project aims have been met in that a commercially viable production model of the solar powered desalination unit has been manufactured and tested. The single cylinder design is compact, simple in design and more competitive for commercial production. Reliability seems satisfactory, and long-term testing is being undertaken.

4. Acknowledgement

The financial support of MERIWA for conducting the research is gratefully acknowledged. Venco Products Pty. Ltd. is our commercial partner in the research project. The assistance of Messrs. Geoff Hill and Bernie Brix is greatly appreciated. Mr. Sören Scheid assists in editing this paper.

5. Reference

Harrison, D. and Ho. G. (1996) MERIWA Report No. 172 'Solar Powered Desalination for Remote Areas', MERIWA, Perth

沙漠研究 7S, 129-132 (1998)
Journal of Arid Land Studies

Bacteriological Water Testing in Remote Localities

T. GAWTHORNE *, K.MATHEW**, R. GIBBS***, J. PILLAI ****,
G.E.HO***** and M. ANDA******[1]

Abstract - The Remote Area Developments Group (RADG) has developed a portable, bacteriological water supply test kit for remote communities which do not have their water tested on a regular basis by the Water Corporation. The Colisure P/A test for total coliforms has been selected from a range of methods that were trialled and evaluated. It can be used in remote Aboriginal communities by the Envirnmental Health Worker or the clinic Health Worker after a small amount of training supported by an RADG video and booklet. Absence of coliforms may not mean an absence of Salmonella. Research is underway on hydrogen sulphide paper strips as a portable test method to accompany the Colisure P/A test. During 1996/97 RADG conducted field trials with 30 remote Aboriginal communities across WA to determine the appropriateness and level of acceptance of the two methods. Parallel testing will be conducted by the Water Corporation and Path Centre to determine their reliability alongside laboratory-tested samples.

Keywords - water testing, remote localities, bacteriological.

1. Background

The importance of clean water has long been recognised and yet it is still a problem for many countries and communities around the world. The practice recommended by the World Health Organisation for monitoring the microbiological quality of water is to test for total coliforms and thermotolerant coliforms which are usually present in contaminated water (WHO 1993). It is assumed that these coliforms are present whenever faecal contamination has occurred and therefore there is the possibility of pathogen transmission.

Routine testing of bacteriological quality of water is a public health requirement and the National Guidelines for Drinking Water Quality in Australia recommend frequent sampling, at least once a month and preferably once a fortnight (NHMRC 1995). Despite the acceptance of these guidelines the majority of remote Aboriginal communities in Western Australia do not at present have any form of water testing.

2. Current Testing Procedure

Bacteriological testing is presently available only to 48 out of the 250 Aboriginal communities in Western Australia. The Water Corporation or any other agency responsible for testing, collect a sample from the water tank or immediately after the tank once a month and transport the sample to the testing laboratory located at Queen Elizabeth II Medical Centre in Perth. Chartering an aircraft is necessary to transport the samples from the remote location to a place where it can be loaded into a commercial flight because the sample must arrive at the laboratory within 24 hours to give a valid result.

The current procedure for analysis of water samples from remote areas detailed above has various drawbacks.

- Large numbers of small communities which do not get funding do not get their water tested.
- It is difficult to guarantee that samples arrive within the prescribed time period. If samples are delayed another sample must be collected.
- The sample collecting exercise is very costly. Therefore all communities will not get the water tested and frequent sampling is not possible.
- The inspectors who visit the community often do not have sufficient time to carry out other tasks such as routine maintenance, checking of facilities etc. because aircraft must leave promptly to ensure delivery within 24 hours.
- The system has very little flexibility. Only one sample is collected immediately after the tank and this will not pick up any pollution that may occur in the distribution system.

[1] * Research Assistant, ** Research Fellow - RADG, *** Research Fellow, **** Postgraduate Researcher - RADG, *****
Director - RADG, ****** Research Associate - RADG, Murdoch University, Murdoch WA 6150, fax: (61 8 9310 4997)

- It takes 5 - 6 days to analyse a sample and get the result to an inspector using the current system. Thus if contamination is discovered there will be an inevitable delay between any remedial action can be taken.

3. Research Findings

To improve the present situation research by RADG has been focussed on the development and adaptation of portable water testing kits for use in remote Aboriginal communities. These have the advantage of being faster, cheaper and able to be used by trained Aboriginal personnel.

Turner and Mathew (1991) compared the available test kits namely Colilert, Del Agua, Millipore one-use unit and Millipore dipslide for their applicability for use in remote Aboriginal communities. They recommended the Colilert presence/absence test as it is a one step test that is easy to use and easily interpreted and was found to be as sensitive and reliable as the methods used by the State Health Laboratories of Western Australia. Other studies elsewhere have also concluded that the Colilert is equal in performance to the standard methods employed for the determination of total coliforms in water (Edberg *et al.* 1989, Covert *et al.* 1992, Clark and El-Shaarawi 1993).

At this stage of the study it was found that an additional portable test is available called Colisure. The Colisure is a most probable number (MPN) test that is very similar to the Colilert and is dispensed in either a five tube MPN (20 ml in each tube) or a 100 ml P/A. After incubation for 24 hours at 30°C a colour change from yellow to red indicates the presence of one or more coliform organisms and the presence of E. coli is identified by fluorescence under a long-wave UV lamp.

The reliability and sensitivity of the Colisure P/A for the differentiation of total Coliforms and E. coli from water was compared to that of the Colilert and the methods employed by the State Health Laboratories of Western Australia. It was found that both Colisure P/A and Colilert P/A were as reliable and sensitive for the differentiation of total Coliforms and E.coli from water as the methods used by the State Health Laboratories (Gawthorne *et al.* 1994). The advantage for both Colisure and Colilert is their substrate specificity. The Colilert and Colisure are derived from technology originally designed to identify microbes on the basis of their constituent enzymes (Edberg *et al.* 1988). The nutrient portion of the test simultaneously becomes the indicator portion of the procedure.

The enzymic reactions have the advantage of being specific to the bacteria possessing the enzymes for growth which produce the colour change and are more rapid than the traditional culturing methods (Feng and Hartman 1982). So both methods are technically feasible and the selection is to be decided by its adaptability to remote communities.

4. Suitability for Remote Localities

The test to be recommended to remote localities should be simple to operate and interpret. The present tests have simple procedures and few steps to be carried out. The sample is poured into the bottle containing the reagent and a colour change indicates the presence of indicator bacteria. This is an important consideration as the people most likely to use the tests will have minimal training in bacterial analysis.

Another criteria is that the avenues for contamination should be minimal. The tests can be operated in the open air in high winds with a low risk of contamination as these have a "one-step operation" of pouring the water sample into the sterile bottle containing the reagent.

The Colilert and the Colisure require much less time to process the sample (24 hours) compared to the Path Centre (68 hours). This is a direct result of the specificity of the enzyme reactions the Colisure and the Colilert are based on. If the travelling time of the sample to the laboratory and the time taken to send the results back to the community is taken into account the Colilert and Colisure are nearly five times faster in analysing community water than the current procedures.

Unlike Colilert, the Colisure P/A test has the reagent pre-dispensed in a sterile 100 mL bottle. This aspect of Colisure P/A was seen as an advantage due to the reduced avenues for contamination over Colilert P/A. So the Colisure P/A test was selected to be used in remote communities.

5. Pilot Project at Communities

After the nomination of the most appropriate test, the next aim of the project was to promote the use of the kit for testing waters in remote localities. This was to be done through training Aboriginal Health and Environmental Health workers in the operation of the kit and by raising awareness of water testing and diseases in the communities. For this purpose, training materials needed to be produced, that could be used to help instruct people relatively untrained in bacterial

analysis. The chosen format for the training materials was a video with an explanatory brochure. These could be used to introduce the concept of faecal pollution and the link with disease in addition to detailing the process of water testing.

Following the above purpose a video and brochure were produced with the aim of teaching Aboriginal Health and Environmental Health workers how to use the Colisure P/A. The video was filmed in Coonana Aboriginal Community, east of Kalgoorlie and the people of the community were pleased with the finished product. The brochure was written in such a manner that people with little formal education as well as those more experienced would be able to understand and learn from the information presented.

Training to test water with the on site kit was done using video, brochure and practical exercises in three communities; Burringurrah near Carnarvon, Cosmo Newberry near Laverton and Jigalong near Newman. Firstly background information about germ theory was reviewed and then the concept of faecal indicators and the Colisure were introduced. The video was then shown followed by a look at the relevant section of the brochure and simulation where the students have to identify the contaminated sample by using the Colisure.

At all the three communities the incubator and test facility were made available for three months. The training materials and the format were suitable for teaching the operation of the on site test kit. But due to the absence of operators from the community, tests could not be conducted regularly all the time. Three months was a very short time to make definite conclusions. An agreement between the community and service provider is necessary on operational and training matters for completing the project successfully.

The trial period to implement the test in a community is for a minimum of 12 months or preferably two years to ensure that the testing becomes the responsibility of the community. A minimum of two people, the principal operator, and an assistant operator were trained in the communities to make sure the test is continued even if the principal operator was absent. The coordinator received the reports regularly and RADG members visited the community once in three months to make sure the system was working properly. After the trial period the project is now implemented in 15 communities where the water is expected to be tested every fortnight and the results monitored regularly by the project group.

6. Proposal for a New Method

Another method that is under research by the RADG is the hydrogen sulphide paper strip method which has been developed by Manja *et al.* (1982) to test the bacterial quality of drinking water, especially in cases of emergency. This method is based on the detection of hydrogen sulphide producing bacteria which are often associated with faecal matter. Although the method does not directly detect any specific bacteria a good correlation was obtained with the results from this test and with the standard tests for detecting coliforms in drinking water (Castillo *et al.*, 1994; Grant and Ziel, 1996). The main advantage of this method is that it is much cheaper, an on-site testing procedure that does not require any technical support at site, a simple method that can be conducted by any person after a small amount of training, and a procedure which is efficient at room temperature within 20 - 44°C. The Colisure chemicals have a short shelf life and have to be stored in a refrigerator until use whereas the H_2S bottles are stable at room temperature. The Colisure chemicals are costly compared to the H_2S medium which could be prepared in any laboratory.

There is a lack of correlation between the presence of coliforms and pathogens such as Salmonella particularly in the tropics and the subtropics tropics (Jimenez *et al.*, 1989; Townsend, 1992). Also 30% of the reported cases from the Aboriginal communities were in the absence of coliforms (Peterson and Schorsch, 1980). Therefore testing drinking water for the presence of Salmonella is an absolute necessity. So far there is no easy testing procedure for Salmonella. The standard test is a many step procedure that takes 3 - 4 days to obtain the end result and the testing kits such as the Colisure and the Colilert do not test for Salmonella. The identification of the presence of Salmonella sp. from the H_2S positive bottles (Castillo *et al.*, 1994; Manja *et al.* 1982) and further research in this laboratory (Gawthorne *et al.* 1996) confirmed that the H_2S bottles could also detect the presence of Salmonella in drinking water. This method has thus the added advantage of detecting the presence of both coliforms and Salmonella sp.

7. Conclusions and Recommendations

- The Colisure P/A test is recommended for the regular testing of coliform organisms in water for remote communities in preference to the Colilert test.
- The Colisure P/A test for coliform organism has to be implemented in communities and the programme should be evaluated for at least two years in 30 communities.
- The H_2S method has to be further tested in the laboratory for comparison with the standard methods of coliforms and Salmonella and if found suitable could be supplied to the 30 communities.
- The Colisure P/A test for coliform is to be used as the first step for the Salmonella test in the field and the results should be evaluated for two years in at least 30 communities.

8. Acknowledgements

We wish to tank the Health Department of Western Australia and ATSIC for their cooperation and financial support for the project. The Public Health Research and Development Committee of National Health and Medical Research Council has accepted the further research as one of their projects. We acknowledge the support of NH&MRC.

9. References

Castillo, G., Duarte, R., Ruiz, Z., Marucic, M.T., Honorato, B., Mercado, R., Coloma, V., Lorca, V., Martins, M.T. and Dutka, B.J. (1994) Evaluation of disinfected and untreated drinking water supplied in Chile by the H2S paper strip test. *Water Research*. 28, 1765-1770.

Clark, J.A. and El-Shaarawi, A.H. (1993), Evaluation of commercial presence-absencetest kits for detection of total coliforms, Escherichia coli, and other indicator bacteria, *Applied and Environmental Microbiology*, 59: 380-388.

Covert, T.C., Rice, E.W., Johnson, S.A., Berman, D., Johnson, C.H. and Mason, P.J. (1992), Comparing defined-substrate coliform tests for the detection of Escherichia coli in water, *Journal of the American Water Works Association*, 84: 98-104.

Edberg, S.C., Allen, M.J., Smith, D.B., and The National Collaborative Study (1988), National field evaluation of a defined substrate method for the simultaneous enumeration of total coliforms and Escherichia coli from drinking water: comparison with the standard multiple tube method, *Applied and Environmental Microbiology*, 54: 1595-1601.

Edberg, S.C., Allen M.J., Smith, D.B., and The National Collaborative Study, (1989), National field evaluation of a defined substrate method for the simultaneous detection of total coliforms and Escherichia coli from drinking water: comparison with presence-Absence techniques, *Applied and Environmental Microbiology*, 55: 1003-1008.

Feng, P.C.S. and Hartman, P.A. (1982), Fluorogenic assays for immediate confirmation of Escherichia coli, *Applied and Environmental Microbiology*, 43: 1320-1329.

Gawthorne, T., Mathew, K., Gibbs, R and Ho, G. (1994) "On-site bacteriological test for portable water". *National Conference on Technology Transfer in Remote Communities*, Murdoch University. pp. 44-51.

Gawthorne,T., Gibbs R.A., Mathew, K. and Ho G.E.(1996). H2S papers as presumptive tests for Salmonella contamination in tropical drinking water. *Water Science and Technology*, 34(7-8): 187 - 194

Grant, M.A. and Ziel, C.A. (1996). Evaluation of a simple screening test for faecal pollution in water. *Journal of Water SRT- Aqua.*,45(1): 13-18.

Jimenez, L., Munoz, I., Toranzos, T. and Hazen T.C. (1989). Survival and activity of Salmonella typhimurium and Escherichia coli in tropical freshwater. *Journal of Applied Bacteriology*. 67, 621-69.

Kromoredjo,P. and Fujioka, R.S.(1991). Evaluating three simple methods to assess the microbial quality of drinking water in Indonesia. *Environmental Technology and Water Quality*, .6: 259-270.

Manja, K.S., Maurya, M.S. and Rao, K.M . (1982). A simple field test for the detection of faecal pollution in drinking water. *Bulletin of the World Health Organisation*. 60, 797-801.

NHMRC (National Health and Medical Research Council) (1995), Guidelines for Drinking Water Quality in Australia, Canberra Publishing and Printing, Canberra.

Peterson, D.J. and Schorsch, I. (1980). The microbiological surveillance of drinking water in Western Australia. *WA Health Surveyor*. 2 (June), 7-11.

Townsend, S.A. (1992). The relationships between Salmonellas and faecal indicator bacteria concentrations in two pools in the Australia wet/dry tropics. *Journal of Applied Bacteriology*. 73, 182-188.

Turner, N. and Mathew, K.(1991), *The Testing of Bacteriological Water Quality in Remote Areas of Western Australia*, Murdoch University, Murdoch.

WHO (1993). Volume 3. Drinking water quality control in small-community supplied, In: *Guidelines for Drinking Water Quality*. WHO, Geneva.

沙漠研究 7S, 133-136 (1998)
Journal of Arid Land Studies

Studies on the Changes of Soil Physical Properties by Adding Water Holding Polymers

Shingo YABASHI*, Andreas HAMACHER*, Jun LIU*,Yukuo ABE**, Satoru TAKAHASHI***

Abstract - Water holding polymer is a high water absorptive substance and is one of the new materials. The study was conducted to determine characteristics of soil physical properties caused by adding water holding polymers. In this paper, the following subjects were studied: 1) Effects on the pF- moisture characteristics of the soils. 2) Effects on the permeability of soils. 3) Effects on the compaction of soils.

Key Words: Polymer, pF-moisture, Permeability, Compaction of soil

1. Introduction

Water holding polymers are a high water absorptive substances and are new materials which recieved recently much attention in many different fields, including horticulture and agriculture. Because of the excellent water absorbability and water retentivity of polymers, they can be used for soil amendmend matters. Recently, polymers have been actively introduced for the greening of sand dunes, deserts, road slopes without irrigation facilities and others. The behavior of water holding polymers in the soil, including, their weight and their some hundred times better water absorbability and expansive volume, has influence on the structure of the original soil and has, no doubt, great influence on different soil physical properties. However, it is still not obvious, if this phenomenon can be used for the improvement of problem soils or not.

2. Specific characteristic of water holding polymer

Water holding polymers have first been developed in the U.S.A. Now in Japan, water holding polymers are produced by more than ten companies and are used in various processes. They are divided mainly into the following three classes, such as starch system, allulose system and synthetic polymer system. The color is mostly white or light yellow and the appearence is a granule or a powder. The particle size ranges from 150 μm to 2800 μm. The bulk density ranges from 0.4 to 1.2, but is in most cases under 0.8. Hydrogen ion concentration (pH) is nearly neutral in the range of 6.0 ~ 8.0, but there are exception with an alkalinity of 9.0.

The water content is mostly under 7.0 and usually dry. The absorptive magnifying power of water is generally large in a wide range of 150 ~ 1000 ml/g. Moreover, there is no evidence of simultant and allergy, with no problem in the safety.

Table 1 Characteristic properties of water holding polymer

Characteristic properties / Name of polymer	Main ingredient	Color	Appearance	Particle size(μm)	pH	Absorptive magnifying power of water (ml/g)	Water content at pF 2.5 (%)	Water content at pF 4.0 (%)
A	Polyacrylic acid	white	granule	1000~3000	7.0	173.4	2710	849
B	Isobutylenemaleic (acid) anhydride	white	granule	1000~3000 (platy)	8.5~9.0	177.4	9464	2471
C	Polyacrylic acid	white	powder	40~84	7.0~8.0	341.2	3606	2065
D	Polyvinyl alcohol	light yellow	powder	180~290	6.0~7.0	188.8	7607	1407

* Chiba University, Faculty of Horticulture(FAX. 0081-47-363-1497)
** University of Tsukuba, Faculty of Agriculture and Forest Engineering
*** Tokyo University of Agriculture, Faculty of Agriculture

3. Method

The addition rate of water holding polymers in the soil was decided on mass ratio 0.1%, 0.5% and 1.0% taking account of its very large absorptive magnifying power of water. The soil samples were all dried and, after crushing, the fine-grained soil was sieved to 840 μm. Water holding polymers were mixed into the soil samples and homogenized as far as possible. Characteristics properties of water holding polymers of the experiments of this paper are shown in Table 1.

4. Experiments

4.1. Experiment 1

In this experiment, the high water retention value (pF 2.5 ~ 4.0) of the soil containing the water holding polymer was measured and compared with the original soil, using the centrifuging method.

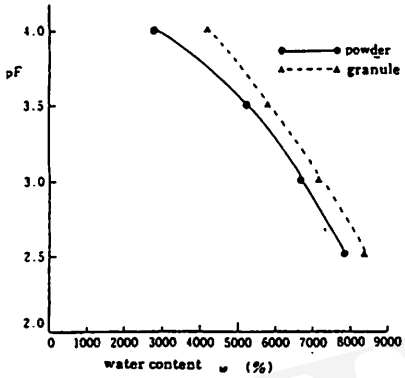


Fig.1 Moisture characteristics of water holding polymer

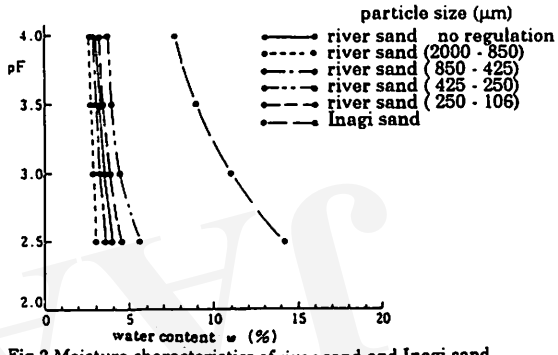


Fig.2 Moisture characteristics of river sand and Inagi sand

Change of water retention of soil samples containing water holding polymers are based on pF-soil moisture characteristics:

(1) Sample soil and experimental method: In this experiment, sample soils like river sand, Inagi sand, decomposed granite, Kanuma soil, Akadama soil and other horticultural soils in dry condition have been used. Because of the irreversibility in the difference of wet and dry condition, both fresh and dried soil have been used for the Kuroboku and the Kanto loam soil.

(2) Result and considerations: In this experiment, only three figures out of a total amount of eleven have been selected and discussed. Figure 1 shows moisture characteristics of powder and granule water holding polymer. Figure 2 shows moisture characteristics of river sand and Inagi sand.
Figure 3 shows moisture characteristics of river sand and Inagi sand by adding powder water holding polymer.

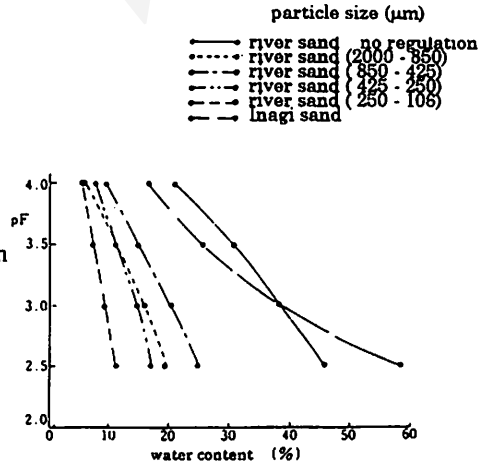


Fig.3 Moisture characteristics of river sand and Inagi sand by adding powder water holding polymer

The results obtained can be summarized as follows:

1.The water retention of water holding polymer, obtained by the pF-moisture curve, was very large in comparison with that of soils.
2.With a few exceptions, the water retention of sand was roughly in inverse proportion to the grain size.
3.Increase in the water retention of sand by adding water holding polymer was very large, and powder substances was superior in this effect to granular one.
4.Generally, fine particle soils showed less effect on the water rentention than coarse particle soils.
5. There was a large difference in water retention with Kuroboku soil and Kanto loam between fresh soil and air dried soils.
6. The effect of water holding substances to the organic soils was small.

4.2. Experiment 2

Four kinds of water holding substances, their addition rate and combination of materials, were investigated using granular substances (A and B), powder substances (C and D), sand, Kanto loam and Kuroboku soil.

Change of permeability of soil samples containing water holding polymers:

(1) Sample soil and experimental method: Sample soils, river sand, Kanto loam soil and Kuroboku soil were used in dry condition. In this section, river sand was divided after washing and drying into four grain sizes, 850 ~ 250 μm , 425 ~ 250 μm, 250 ~ 106 μm and 850 ~ 106 μm. The hydraulic conductivity of sample soils was measured by the falling head permeability test, according to the JIS method.

(2) Result and considerations: Figure 4 shows relationship of the adding rate and hydraulic conductivity of water holding polymers in the case of river sand with the grain size 850 ~ 250 μ m and 425 ~ 250 μ m. Figure 5 shows the adding rate and hydraulic conductivity of water holding polymers.

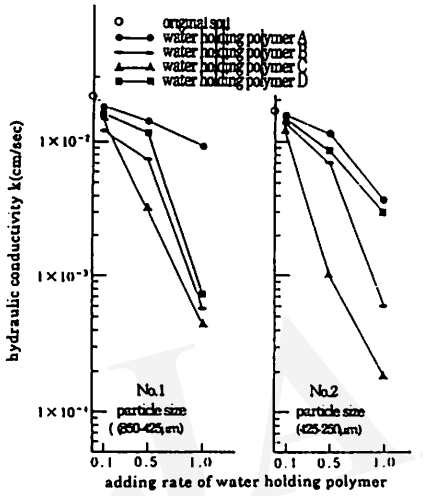


Fig.4 Adding rate and hydraulic conductivity of water holding polymer

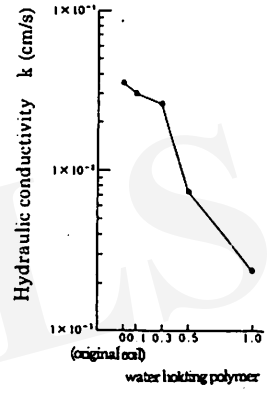


Fig.5 Adding rate and hydraulic conductivity of water holding polymer (water holding polymer: B)

The results obtained can be summarized as follows:

1.Permeability of water holding substances in the glass tube was very small.

2.Permeability of the soils containing water holding substances became smaller with increase in the addition rate.

3.When the sands were changed from coarse particles to fine particles, the permeability became smaller.

4.Generally, permeability of sands containing the water holding substance C was the smallest.

5.When a few centimeter deep layer of well swollen water holding substances was made in the sand, the permeability bacame smaller. In particular, permeability of sand with the gelatinized substance D was the smallest.

6.When the sand containing water holding substances was saturated with water, the liquid phase in the three phases became larger with increase in the addition rate. Water retained in the swollen substances, however made permeability low.

4.3. Experiment 3

In this experiment, the effects on compaction of soils of four kinds of water holding substan- ces (WHS), their addition rate and combination of materials were investigated, using granular substances A and B, powder substances C and D, and three kinds of sand.

Characteristic of compaction of river sand containing water holding polymers:

(1) Sample soil and experimental method: As sample soil, river sand was used after washing and drying and divided into two grain sizes, 850 ~ 425 μ m and under 2000 μ m. A

compaction test was carried out according to the wetting process of the JIS method.

(2) Results and considerations:

Figure 6 shows the compaction curve of mixed soil with water holding polymer A under 2000 μ m particle size.

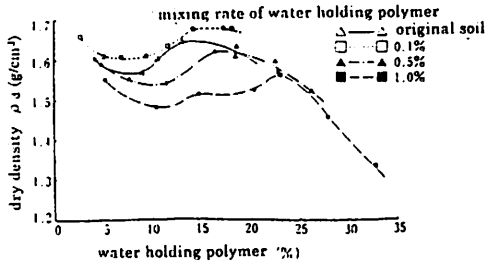


Fig. 6 Compaction curve of mixed soil with water holding polymer A (under 2000 μm particle size)

The results obtained can be summarized as follows:

1.Compaction curve of sand gave relatively flat lines.

2.In comparison of compaction curve of the two kinds of sand, the shape of curves of the sand with a grain size 850 ~ 425 μ m was flatter than that of the sand with a grain size under 2000 μ m.

3.On the characteristic of compaction of sands with contained WHS, the sand with the grain size 850 ~ 425 μ m were more diverse than the sand with a grain size under 2000 μ m and gave a complicated curve shapes.

4.Genarally, dry density (ρ_d) of soil mixed with WHS became smaller with increase in addition rate.

5.The characteristic of compaction of the mixed soil with 0.1% WHS was more complicated than the soil with 0.5% and 1.0% WHS.

6.When the water content of the mixed soil with 0.5% and 1.% WHS exceeded 20%, a sharp drop in the dry density (ρ_d) was observed.

5. Conclusion

On the basis of the above mentioned results and considerations of the experiments, the conclusion of this study can be summarized as follows:

Effects which water holding polymers give to physical properties of mixed soils, like water retentivity, permeability and the characteristic of compaction, are generally strong.

Consequently, we anticipate a practical application of water holding polymers for soil improvement.

References

1) Society of High Polymer (1986): Polymer Science; Kodansha, Tokyo (in Japanese)

2)Takeuchi, Y. et. al. (1983): Studies on the greening of dry land by the use of water holding polymer (No.1), Research on Sand Dune 30 (2), pp. 42-49 (in Japanese)

3)Toyama, M. (1985): Greening and water holding polymer; Road and Nature 47, pp.36-40 (in Japanese)

4) Toyama, M. (1985): Use of water holding polymer to the agricultural field (1), Agriculture and Horticulture 61 (8), pp. 63-68 (in Japanese)

沙漠研究 7S, 137-140 (1998)
Journal of Arid Land Studies

Hardness of Seeds and Germination Dynamics of Fabaceae Arid Species.

K. N. TODERICH*, K. IDZIKOWSKA**, H. R. HALILOV***

Abstract. The effects of various treatments of Astragalus (Fabaceae) seeds before sowing, and the dynamics germination and seedling growth are shown. The morphology of seeds, structure of seed coat and morphological characteristics of embryo and endosperm for hardness of seeds of Fabaceae asiatic species are established. It is suggested that the hardness of seeds of Fabaceae is conditioned by well developed palisade tissue and thick cuticule layer on the epidermal cells of seed coat. The germinating ability of seeds in the field condition have been increased 8-10 times more than control. The practical recommendation on use of mechanical and chemical methods of seeds treatment of desert wild species of Fabaceae are supposed.

Key words: seed coat, embryo, palisade tissue, seeds, hardness, acid sulfuric, Fabaceae.

1. Introduction.

In absence of purposeful ecological policies in Central Asia countries and due to extensive resource consuming economics in the second half of 20th century, degradation of the ecosystems over a vast territory has occurred. Economic activity transforms natural desert vegetation cover and results in formation of unstable anthropogenic modifications of the plant communities, simplification of their structure, decrease of their biodiversity and productivity, disturbance of their functioning and loss their resource potential. The contemporary state of the pastures of desert and semidesert regions of Uzbekistan show evidence for the need to take urgent measures to revegetate, improve and protect. The mobilisation of phytogenetic resources of wild perennial fodder plants and their introduction in culture is one of the best ways to utilise damaged desert lands. The successful reproduction of many wild species of Fabaceae is difficult because they .produce durable, hard, with very low germination rates, seeds.

In wild desert flora Fabaceae species consist more than 9,8% of species (Korovin, 1961). Among the species of specifial significance are the representatives of the genus Astragalus. In the flora of Uzbekistan more than 756 species are described, and about 350 species are endemic to territories of Central Asia and Kazahstan. Most species of Astragalus are large grass , long-term perspective fodder, technical and medicinal plants. The shrubs forms of Astragalus have value or fuel wood.

However the presence of a big number of durable seeds (87-92%) in the seed material of some wild species of Astragalus creates complexities in practice of arid fodder production from this genus.

It is generally assumed that the reasons for hardness are connected with specificity of the structure of the seed coat with its complete water impermeability (Popthov, 1976, Nikolaeva at al 1985 , Tran et al., 1981).

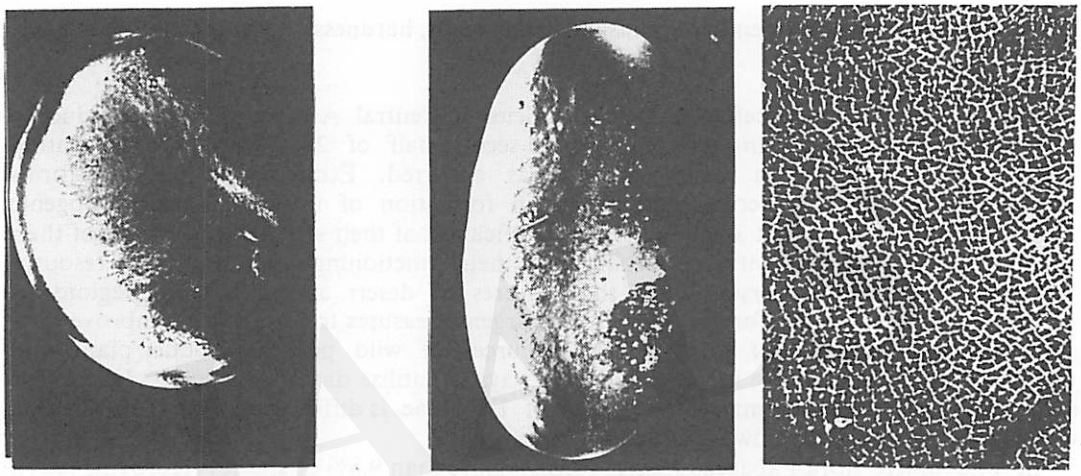
The purpose of the present research is to determine the peculiarities of seed germination among some species of Astragalus under the influence of different treatments. The special attention was given to the action of sulfuric acid - as a stress agent on the cellular structure of organs of seeds

*' *** Department of Desert Research, Samarkand Division of Uzbek's Academy of Sciences, 703000 Samarkand, ul. Timur Malik, 3, Uzbekistan. tel. 33-39-50; Fax.: 366 2 31-00-39.
** Adam Mickiewicz University, Faculty of Biology, Laboratory of Electron Microskopy, 61-701 Poznan, Poland. Phone: 4861 52-45-92; Fax.: 4861 52-36-15.

2. .Morphology of seeds: structural-anatomical peculiarities of the seed coat, endosperm and embryo.

The study of the morphology of seeds by scanning electron microscopy has revealed distinctions in the form ,sizes, colouring, in features of seed surfaces, form and degree of depth of seed scar. These diagnostic morphological seed indices can be useful with regard to the systematics and phylogeny of the genus Astragalus.

The surface of seed coats, (fig.1 a, b) is lustreless, smooth with small reticulations. The analysis of cross sections of seeds during their ontogenesis has revealed some xerophyllic structural-cellular features; as well as features with penetration of moisture and activation of embryos to germinate.



a) Astragalus alopecias Pall. b) A. villosissimus Buge

Fig 1. (a, b). The morphology of seeds and structure of it surface (SEM-analysis).

In our opinion seed hardness is developed gradually during the drying of seeds in the last stages of ripening. The comparative study of the anatomy of seeds up to and after processing with sulfuric acid to induce on idea, that the phenomenon of hardness is stipulated by availability of a thick cuticule layer on a surface of epidermis and well developed palisade tissue. The considerable significance in this process is played also so by named light line.

As a result of action of sulfuric acid the cuticule layer, decomposes, pigments dissolve and the integrity of palisade tissue is destroyed . Significant changes occur in degenerated cell layers of the endosperm.

The products of disintegration after processing with sulfuric acid are allocated through scar slot , which functions as a channel through which water passes into the seed during the activation of embryo. Concentrated sulfuric acid has no destructive influence on the quality of seedlings or their growth dynamics. This is confirmed by normal growth of plants during 1,5-5 months in pots and in field conditions.

Thus, sulfuric acid affects the integrity of the cell structure of seed coats, slightly affects the endosperm and does not affect the embryo-structure.

3. Methods of increasing of sowing qualities of seeds of some Fabaceae species

Comparison of seed treatments before sowing of various desert species of Astragalus involved:

- scarification by mechanical treatment of seed with abrasive paper followed by immersion in distilled water ; treatment on laboratory mill " Pyruet" type;
- long stratification of seeds with variable temperatures;
- treatment by various solutions of salts, phytohormones and sulfuric acid;

Table 1. Dynamics of germination of seeds of Astragalus agameticus after different treatments.

Treatment	Percentage of germinating seeds (%)	Peculiarities of seedlings growth
Scarification with abrasive paper	39+2,26	Slow germination (1-1,5 month) and growth of seedlings;
Treatment on laboratory mill "Pyruet" type	66+1,53	Some anomalies in the structure and growth of seedlings. Slow seedling growth.
Changing regime of temperatures (8° C during 2-3 days than 30° C)	17+ 0,76	Insufficient germination of seeds and slow growth of seedlings;
Treatment with con. H_2SO_4 30 min 1h 1h 30 min	29+ 0,88 57+2,61 36+0,93	Prolongated period of seed germination. Sometimes the appearance of mycelia;
Treatment with H_2SO_4 followed by immersion in solution of $KMnO_4$	88 +2,06	Accelerated swelling and growth of seedlings. High biomass of seedlings;
Treatment with hormones	57 +4,7	Dynamics of germination is higher than in all of above -analysed ways;
Control	7+0,58	Slow growth of seedlings and prolonged seed germination. Low quality of seedlings (thread like seedlings with developed roots)

As seen from Table 1 treatments that increase seed swelling in A.agameticus are scarification with abrasive paper followed by immersion in distilled water and treatment with sulfuric acid. The percent of germinate seeds have been increased 8-10 times more than in control . Both of the above- mentioned methods destroy the integrity of the cellular structure of seed coats and so accelerate swelling and growth of seedlings.

Seeds of dark coloration with large quantities of pigments can germinate only after treatment by sulfuric acid .

Seeds of dark coloration with large quantities of pigments can germinate only after treatment by sulfuric acid .

There are more such seeds in years of drought. Apparently there is a direct correlation between the structure of seeds and aridity of climate. The hardness of seeds of Fabaceae can be considered as one of the adaptative features of wild arid species growing in extreme desert conditions.

The treatment of seeds with concentrated sulfuric acid appeared to be the most effective treatment. The method of treatment with sulfuric acid is shown on the Fig. 2.

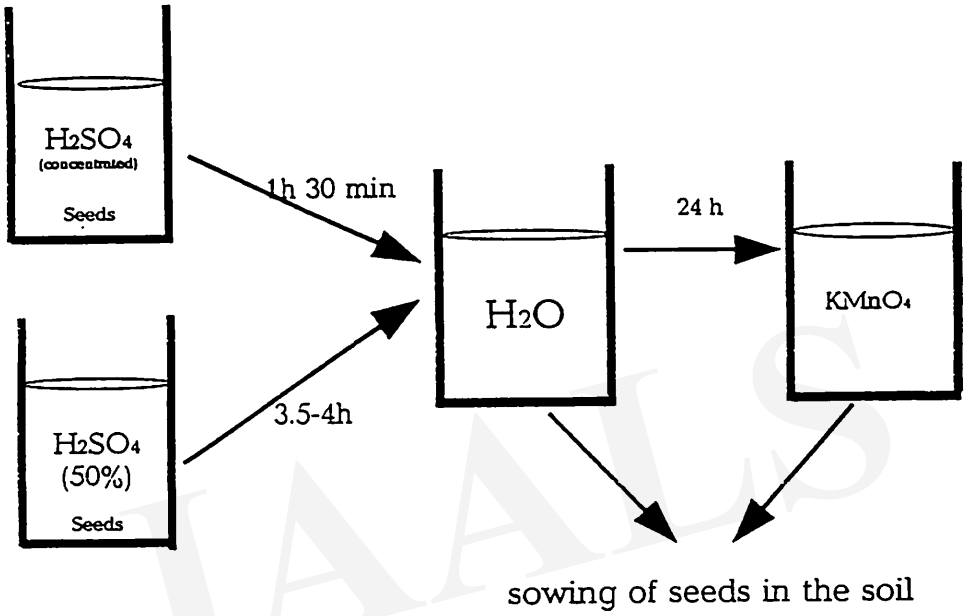


Fig . 2. The treatment of seeds with sulfuric acid.

All treatment process takes no more than 24 h for durable seeds and 2.50-4h for less durable seeds.

4. Conclusion.

The treatment of seeds by ambrasive paper followed by immersion in distilled water and concentrated sullfuric acid turned out to be the most economically effective for Fabaceae asiatic arid species. We recommend them for wide usage in arid fodder production .

References:

Korovin Sh. K. 1961: Cover vegetation of Middle Asia and Kazahstan. Tashkent: 523 p.
Nicolaeva M.G. , Razumova M.V., Gladkova V.M.1985. Reference book in germination of seeds' dormancy.L., Nauka.: 345p.
Popthov A.V. 1976. The biology of hardness of seeds. M.: 168p.
Tran V., Cavanagh A.1980 Taxonomic implication of fracture load and deformation histograms and the effects of treatments on the impermeable seed coat of Acacia species. Australia Jour. Botany., v. 28:p. 39-51.

New Technologies for Sustainable Production in Arid Areas

Papers Not Presented at the Conference

沙漠研究 7S, 141-144 (1998)
Journal of Arid Land Studies

Numerical Simulation of Ascending Current for Artificial Rainfall

Satoshi MATSUDA*, Takako SANO* and Yasunori OKANO*

Abstract: It is essential for large scale CO_2 fixation in arid and semiarid land that water should be supplied and controlled efficiently. A possible alternative may be artificial rainfall. One of the basic conditions required for rainfall is ascending current. If the temperature of the ground surface can be kept much higher than the surrounding atmosphere, it may be possible to create artificial ascending current with minimum energy consumption. The possibility and feasibility of this concept should be examined by estimating quantitatively the following issues; e.g. how large an area of black-body like ground surface should be required, how high the ascending current can reach, and so on. In this study, an improved numerical model for more realistic simulation of ascending current is proposed. It is expected that the results of this model simulation can be used for rough estimation of the required land area.

Key Words: Artificial Rainfall, Numerical Simulation, Ascending Current, Thermal Convection

1. Introduction

There have been many measures for CO_2 recovery and disposal proposed to tackle the global warming issue. The conditions required for practical and effective CO_2 fixation are as follows; 1) a large enough amount to affect global scale CO_2 reduction, 2) net positive CO_2 fixation, 3) long retention time of carbon fixed, 4) ecologically sound. In fact, only a few measures can meet the strict requirements. Greening of arid and semiarid land is thought to be one of the most hopeful alternatives. Water supply and control in an efficient way is essential in this kind of greening for CO_2 fixation on an enormous scale. Fresh water must be obtained efficiently from salt water using abundantly available solar heat. A possible alternative may be artificial rainfall. One of the basic conditions required for rainfall is ascending current. If the temperature of the ground surface can be kept much higher than that of surrounding atmosphere by absorbing solar radiation, it may be possible to create artificial ascending current with minimum energy consumption. The possibility and feasibility of this concept should be examined before on site experiment on a real scale by estimating quantitatively the following issues; e.g. how large an area of black-body like ground surface should be required, how high the ascending current can reach, and so on. In the previous study, we presented a simple model of two-dimensional, steady-state, natural convection on a finite size, horizontal plate (Matsuda et al.,1995), however, several unrealistic assumptions were adopted to simplify the numerical calculation for simulation.

In the present study, an improved numerical model to simulate more realistic ascending current is proposed in order to examine the viability as a means of water supply. It is expected that the results of this model simulation can be used for rough estimation of the required land area as well as optimum land location.

2. Numerical Model of Ascending Current by Thermal Convection

2.1 Temperature and density profiles of atmosphere and ascending fluid

In the case of thermal convection, ascending current is generated by buoyancy due to the difference in density between warmed fluid (air) and the surrounding atmosphere. The density as well as the temperature of the atmosphere decreases along altitude because of adiabatic expansion of the air. Thus, change in density of both ascending fluid and the surrounding air should be incorporated into the buoyancy term of the equations for numerical simulation.

* Dept.. Chem. Eng., Shizuoka Univ., 3-5-1 Johoku, HAMAMATSU, 432, JAPAN
FAX: +81-53-478-1173 E-mail: tcsmats@eng.shizuoka.ac.jp

In this study, the following approximative expressions are adopted.

Temperature of the surrounding atmosphere $T_{(ref)}$: −0.6 ℃ per 100m in altitude Y(m).

$$T_{(ref)} = 30 - 0.006Y \quad (1)$$ Ground surface is assumed to be 30℃.

Density of the surrounding atmosphere $\rho_{(ref)}$: Changing with adiabatic expansion.

$$\rho_{(ref)} = 0.013T + 0.76 \quad (2)$$ where T is temperature (℃)

From eqs.(1) and (2), the relation (3) is obtained :

$$\rho_{(ref)} = -1.2 \times 10^{-4} Y + 1.15 \quad (3)$$

Temperature of the ascending air $T_{(up)}$: 60℃ at Y=0 m, and 0℃ at Y=5000 m.

$$T_{(up)} = 60 - 0.012Y \quad (4)$$

Thus, the density of the ascending air $\rho_{(up)}$ is expressed as ;

$$\rho_{(up)} = -0.0038T + 1.29 \quad (5)$$

2.2 Basic Equations of Flow and of Energy

Fig. 1 shows the basic configuration and a co-ordinate system to formulate the problem. Here, a simple model of two-dimensional, steady-state, natural convection on a finite-size, horizontal plate is supposed. The assumptions adopted in this study are as follows: 1) incompressible fluid with constant properties, 2) dry air condition, 3) Coriolis parameter force neglected, 4) Boussinesq approximation applied. Basic essential equations have the following form (Nakayama, 1995):

Equation of continuity :

$$\frac{\partial u_j}{\partial x_j} = 0 \quad (6)$$

Navier-Stokes Equation :

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_j}\left\{u_j u_i - \left(\nu + \nu_t\right)\frac{\partial u_i}{\partial x_j}\right\} = -\frac{1}{r}\frac{\partial p}{\partial x_i} + g_i \beta\left(T - T_{ref}\right) + \frac{\partial}{\partial x_j}\left(\nu + \nu_t\right)\frac{\partial u_j}{\partial x_i} \quad (7)$$

where β ,volumetric coefficient of expansion, is assumed in this study to be expressed as a function of density and temperature as follows :

$$\beta = \frac{\ln \rho_{(ref)} - \ln \rho_{(up)}}{T_{(up)} - T_{(ref)}} \quad (8)$$

In the previous study, β was given as a constant value. This is an important improvement.

Equation of energy :

$$\frac{\partial T}{\partial t} + \frac{\partial}{\partial x_j}\left\{u_j T - \left(\frac{\nu}{P_r} + \frac{\nu_t}{\sigma_T}\right)\frac{\partial T}{\partial x_j}\right\} = \frac{q}{\rho C_p} \quad (9)$$

Transport equation of k (turbulence kinetic energy) :

$$\frac{\partial k}{\partial t}+\frac{\partial}{\partial x_j}\left\{u_j k-\left(\nu+\frac{\nu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right\}=P+G-\varepsilon \qquad (10)$$

Transport equation of ε (rate of dissipation) :

$$\frac{\partial \varepsilon}{\partial t}+\frac{\partial}{\partial x_j}\left\{u_j \varepsilon-\left(\nu+\frac{\nu_t}{\sigma\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right\}=\left\{C_1\left(P+G-C_3G\right)-C_2\varepsilon\right\}\frac{\varepsilon}{\kappa} \qquad (11)$$

where

$$P=\nu_t\frac{\partial u_i}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right) \qquad (12)$$

and

$$G=g_i\beta\frac{\nu_t}{\sigma_T}\frac{\partial T}{\partial x_i} \qquad (13)$$

ν_t (eddy diffusivity) can be calculated by the following equation if k and ε are given by Eqs.(10) to (13) :

$$\nu_t=C_D\frac{k^2}{\varepsilon} \qquad (14)$$

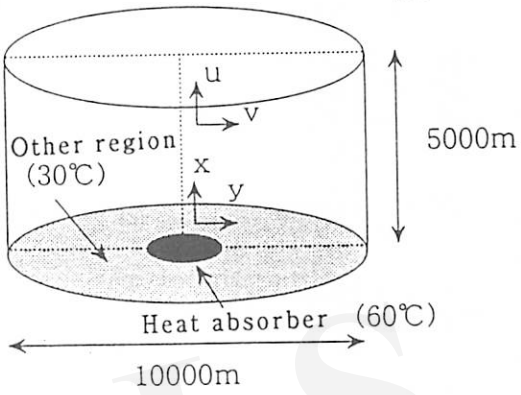


Fig. 1 Assumed System of Thermal Convection and Co-ordinate System.

Empirical constants used in these equations are shown in Table 1.

Table 1 Empirical constants for turbulent flow simulation.

C_D	C_1	C_2	C_3	σ_T	σ_k	$\sigma\varepsilon$
0.09	1.44	1.92	0.0	0.9	1.0	1.3

2.3 Boundary Conditions

As shown in Fig.1, the heat absorber (black-body like ground surface) is assumed to be 60℃ and other regions 30℃. Then, the boundary conditions are ;

$x=0: u=v=0,$

$T=60$℃ (Heat absorber)
$T=30$℃ (Other regions) (15)

$$x=L:\frac{\partial u}{\partial x}=0,\frac{\partial T}{\partial x}=0 \qquad (16)$$

$$y=0,R:\frac{\partial v}{\partial y}=0,\frac{\partial T}{\partial y}=0 \qquad (17)$$

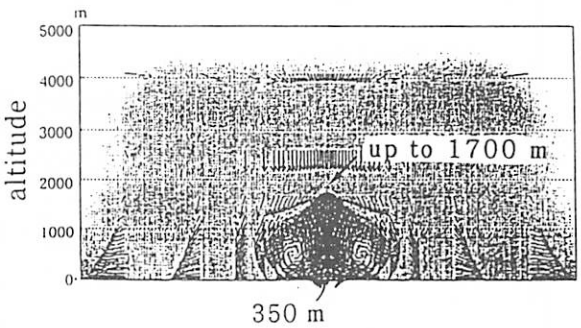


Fig. 2 An Example of Simulation Result (1)
Radius of heat absorber : 350 m
Ascending current up to about 1700 m

2.1 Numerical Procedure

The governing equations with boundary conditions were discretized by the control volume method on a staggered grid system. The SIMPLE algorithm was used for calculation.

3. Results and Discussion

Examples of the simulation results are shown in Figs.2 and 3 where velocity vectors are illustrated. The phenomenon was seen in these results that ascending current stops rising at a certain altitude. In the case of Fig. 2 (the radius of the heat absorber is 350 m), it can be observed that the ascending current reaches about 1700 m in altitude, whereas the ascending current can reach ca.4000 m in the case of Fig. 3, in which the radius is 700 m.

Fig. 4 shows the relationship between radius of the heat absorber and height of the ascending current. The area size effect of the black-body like ground surface on the height of the ascending current is clearly shown. According to this simulation, it is expected that a real effective ascending current can be generated if a black-body like zone of less than 1km in a diameter can be constructed. This area size may be feasible in unused arid or semiarid land. The result presented here, however, is still rather a rough estimation because there are several unrealistic assumptions —e.g. steady state, no wind, dry air, infinite heat capacity of the heat absorber— are still involved.

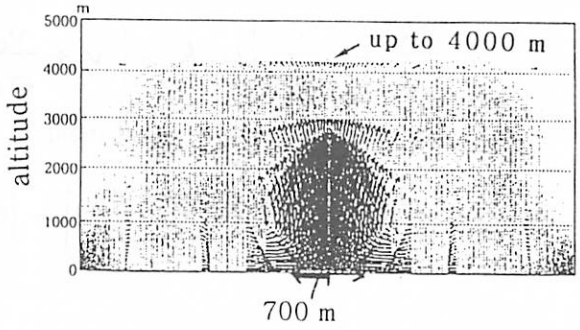


Fig. 3 An Example of Simulation Result (2)
Radius of heat absorber : 700 m
Ascending current up to about 4000 m

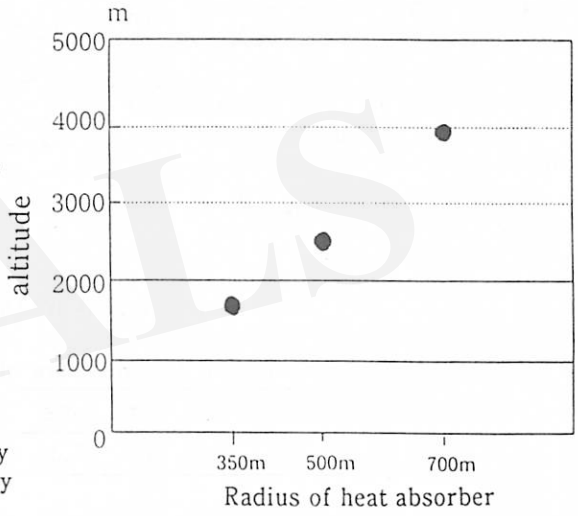


Fig. 4. Relation between the radius of heat absorber and the height of the ascending current.

4. Conclusion

An improved simulation model which can represent ascending current by thermal convection was constructed. According to the simulation result, the required diameter of heat absorber (black-body like ground surface) for effective size of ascending current to cause artificial rainfall may be less than 1km. Since this is still rather a rough estimation and there are many limitations in the simulation model, we will improve the model to simulate three dimensional, unsteady, and more complicated phenomena in the future.

Nomenclature : Cp: constant pressure heat capacity (J/mol K), g: gravitational acceleration (m/s^2), k: turbulence kinetic energy (m^2/s^2), p: atmospheric pressure (Pa), Pr: Prandtl number, q: heat generation (W/m^3), r: distance in radius direction, t: time (s), T: atmospheric temp. (℃), u: velocity in x-direction (m/s), v: velocity in y-direction (m/s), Y: altitude (m), β: coefficient of volumetric thermal expansion, ε: rate of dissipation (m^2/s^3), ν: kinetic viscosity (m^2/s), ν_t: eddy diffusivity (m^2/s), ρ: density (kg/m^3)

References :

Nakayama, A. (1995): PC-Aided Numerical Heat Transfer and Convective Flow, CRC Press
Matsuda, S., Goto, T. and Okano, Y. (1995): Journal of Arid Land Studies, 5S: 239-242

沙漠研究 7S, 145-147 (1998)
Journal of Arid Land Studies

The Utilization of Salt Water by Solar Distiller in Taklimakan Desert

Xu Xinwen* and Jiang Jin*

Abstract Taklimakan Desert is very rich in oil and natural gas resources .However, due to adverse climate and extreme shortage of fresh water ,many difficulties are brought about to the development of the oil field base and daily life of people. Since 1995, we have been doing a great deal of research work in the application of solar desalinization techniques and built facilities to desalinize salt water. Moreover, the shape selection of desalinization facilities and relationship between fresh water output and climate factors, monthly variation of fresh water yield, quality and utilization of desalinized water are demonstrated.

Key words: Taklimakan Desert, Salt water, Solar distiller,

.1. Foreword

There has been about 14 hundred million km^3 water resource in the world. Among of them ,there are 97.3% is sea water, 2.7% is fresh water, but in fresh water, there are about 75% is fixed in the two polar zone. So the fresh water that people can used directly is only 0.36% in all water resource. And its distribution is not fairly ,especially in Taklimakan Desert.

In Taklimakan Desert ,there is no fresh water to use and people have to use the salt water or use the fresh water from 200km place by water tank. Now day, in the process of oil prospecting and developing , a lots of fresh water to be needed ,and the method of resolving this question is from osmosis technology and from other place by water tank. It costs lot of money and very expensive .We begin to study another method using solar energy to produce fresh water for living and working .In Taklimakan Desert ,solar energy is very rich and so is salt water. From 1995, we begin to test salt water concentration by solar distiller to produce fresh water for oil production and green land.

2. Environment and Test conditions

The famous Taklimakan Desert is the second largest moving sand desert in the world .It is very hot in summer and very cold in winter. At the center of desert, the maximum temperature is over 40 ℃ in July and in January the minimum temperature is bellow -24 ℃. The yearly precipitation is only 50 mm, but the evaporation is over 3000mm, the average relative humidity is 45%, the sunshine time is 2661.21 hours and solar radiation is 6000billion J/m^2 per year. So the Taklimakan is called " dead sea " .

Although there is no fresh water and only minimal precipitation in the desert center , there is much underground water. The water level is 3--5 meters, in some places only 1 meter deep and easy to dig, but the water quality is not good , The salinity is about 5g/L, and can not be drunk directly. We measured the salt content of shallow salt water result in table 1 .

Table 1 The salt condition of shallow underground water ($g \cdot L^{-1}$)

SALT CONTENT	HCO^-_3	Cl^-	$SO^{=}_4$	Ca^{++}	Mg^{++}	$K^+ + Na^+$
4.232	0.069	1.646	1.100	0.143	0.204	1.070

*Xinjiang Institute of Biology, Pedology and Desert Research. Academia Sinica. 40 Beijing South Road.Urumqi, Xinjiang, P.R..China. (Fax: 991-3835459)

Natural evaporation and precipitation is the process producing fresh water ,and we imitate the natural process to produce fresh water by using a solar distiller.

First we set up a water pool as water store to hold the salt water .The water pool depth is 15-20 cm, area is 1m 2m,there is a water through around the pool to receive the fresh water . Above the water pool , there is a arched transparent plastic film cover to make an air -tight chamber. In daytime, sunlight enters the pool to heat up pool water and the salt water evaporates. The air-water vapor mixture can circulate in the arched chamber, because the temperature of arched top roof is lower than that of water vapor, the water vapor condenses and flows down the arched-inside to the fresh water through, and further flows to the fresh water storage pool to use.

For studying the relationship between the arched- roof shape and fresh water yield, we designed two kinds of solar energy salt distillers having different roof shapes. One is an arched roof and other is herring bone, but have the same pool area. From June of 1995, we began to measure fresh water yield every day, and analyzed the water quality. Different water sources were used to irrigate plants in order to test plant resistance and plant growth. Calculation and analyses followed.

3. Result and analysis

3.1. The relationship between the fresh water yield and arched roof shape, time and temperature

For study the relationship of water yield to roof shape, time, and temperature, we calculate and analyses the data we have got in two different distiller from June to December of 1995. and have the. result as bellow: (see table 2)

Table 2 Fresh water yield in two distillers ($kg \cdot m^{-2} \cdot day^{-1}$)

TYPE	MONTH	7	8	9	10	11	12
Herring -bone distiller	maximum	2.68	2.53	1.98	1.40	0.73	0.40
	average	1.84	1.88	1.56	0.97	0.51	0.25
Arched-roof distiller	maximum	1.60	1.48	1.33	0.68	0.48	0.30
	average	1.00	1.04	0.78	0.44	0.28	0.11

From table 2 we can see that (a) the fresh water yield of herring bone distiller is higher than that of arched -roof distiller. (b) during the period of June to September,the herring bone distiller water yield is 1.53-2.1kg/m^2, and then decreases to 1kg/m^2 from October. From the last ten day of November, the water yield decreased to the 0.5kg/m^2 and below. So, we know that at the center of Taklimakan desert, the distiller design should be the herring bone pattern and the distiller can be operated from April to the middle ten day of November every year.

Apart from different distiller shapes, the fresh water yield is also related to the sunshine time, solar radiation, air temperature, shallow soil temperature and wind speed and so on. Here we make a regression of the fresh water yield to the soil temperature in herring bone distiller:

$$W=0.2778+0.0645S \qquad (r = 0.955)$$

W : water yield. (kg) . S : maximum soil temperature. (°C)

3.2. The fresh water quality and its prospecting of utilization

We measured some water samples from different source.

table 3 different water sample and their quality

WATER SOURCE	FRESH WATER (DISTILLED)	SALT WATER	DRINKING WATER (FROM OUTSIDE BY CAR)
EC (ds/m)	0.445	7.22	1.65
SALT CONTENT ($g .L^{-1}$)	0.17	4.232	0.937

from table 3 we can see that salt water has high EC, fresh water has lowest EC in that water samples and is better than drinking water. The EC of fresh water is 6.16% of salt water and is 27% of that drinking water. It illustrated that after treatment by solar distiller ,the salt water become better and can be drunk directly. other wise, we use fresh water and salt water to irrigate plant. the result shows that using fresh water, the plant survial ratio and the growth condition is better than that of salt water treatment. although the plant irrigated by salt water can live, but its growth condition is limited obviously, and so is vegetation.

We know that ,in Taklimakan desert ,there are large place and rich solar energy to use, the technology of using solar distiller to produce fresh water has a wide utilization prospecting. but there are still a many things to do ,something like the distiller shape ,size ,optimum structure, and the utility in winter and so on

References

Buch ,R.A.,Chaudhari,B.P. and Oza,M.R.(1993): " Physical properties of seawater concentrates obtained by solar evaporation " India

Hamed,O.A.,Eisa,E.I. and Abdalla,W.E. (1993) " Overview of solar desalination " Fac.UAE.,Univ.,Al Ain, United Arab Emirates.

沙漠研究 7S, 149-152 (1998)
Journal of Arid Land Studies

Water Resources and Their Sustainable Utilization in Arid of Northwestern China

Gao Qianzhao* Du Hulin* Ma Jinzhu*

Abstract - According to calculation, there are about 150 km^3 of total renewable water resources, and a large amount of nonrenewable resources of glacier water, deep groundwater, and saline surface and underground water in arid NW China. There are four aspects of serious problems in the exploitation and use. From now on the development and utilization of water do not only promote the regional economy, but most also protect and improve the environment based on their potential. Sustainable utilization needs firstly to broaden new sources and save water. Five measures are recommended for rational utilization..

Key word: Water Resources Sustainable Utilization Arid NW China

1. Introduction

The arid land, accounting for one-third of the total area of China, lies to the north of lat. 32°N and the west of long. 114°E. Water is not only the most valuable natural resource, but is also a very important environmental factor in the area. At present the exploitation and utilization of water resources is getting more and more important in pace with the economic development, and faces a lot of challenges. Therefore it is necessary to sum up the research findings, and to analyze the problems and the potential of water utilization in order to make overall planning and rational allotment, as well as sustainable exploitation in accord with the major problems of environment and development in the 21st century.

2. Renewable water resources

The total water resources of arid NW China are evaluated in terms of annual renewable resources composed of rain water, surface runoff and natural groundwater resources in the shallow aquifer.

2.1 Rain water resources Rain water distribution varies from region to region extremely in NW China, being plentiful in mountain regions, but deficient in the plains. The annual precipitation is less than 100 mm in most of the arid land. According to the distribution of the rainfall isohyets, long term mean annual rainfall volume in NW China is more than 500×10^9 m^3 (175mm).

2.2 Surface runoff Surface runoff is generated mainly by rain water and melt water coming from the mountain regions. The average runoff is up to 140.3×10^9 m^3, of which out externally draining river basins account for 34%, with a volume of 47.5×10^9 m^3, and inland river basins account for 66% with a volume of 92.8×10^9 m^3. It is obvious that runoff in the inland river basins is the dominant type of surface water in this arid area.

2.3 Natural groundwater resources of the plains Natural groundwater is recharged from two sources. The first is by seepage from streams, canal systems and irrigation, which come from surface runoff. The second is from lateral runoff and rainfall infiltration, which are calculated according to hydrological survey and water balance. The total natural groundwater resources are

* Institute of Desert Research, Chinese Academy of Sciences, Lanzhou, 730000, China (Fax: +86-931-8889950)

estimated to be 42.46 × 10^9 m^3 in five inland basins, of which about 60-80% is recharged by surface runoff. Groundwater resources in the plain of theYellow River , richer than that in any other regions of NW China, are estimated to be about 7.365 × 10^9 m^3, of which about 2.296 × 10^9 m^3 is recharged separately from rainfall infiltration and lateral runoff in the plain.

2.4 The total water resources It is a characteristic of arid NW China that surface runoff and groundwater are intimately related and are recharged by each other. Therefore the total water resources can be calculated in terms of the sum of surface runoff and groundwater that includes lateral runoff and recharge by rainfall infiltration(Cheng et al, 1992). The total water resources are 151.2 × 10^9 m^3 (Table 1).

Table 1: The total water resources in the arid NW China (10^9 m^3)

	Region	Surface Runoff	Non-repeated Groundwater	Total water Resources	Unexplored Water
	Hexi Corridor,Gansu	7.045	0.590	7.635	
Inland	Qinhai	9.405	1.252	10.706	2.853
	Inner Mongolia	0.024	0.000	0.024	
River	North Xinjiang	43.94	3.165	41.705	22.098
	South xinjiang	43.057	3.000	46.057	3.778
Basins	East Xinjiang	1.433	0.657	2.090	
	Sum	104.953	8.664	113.617	28.729
Yellow	Qinhai	22.800	0.776	23.576	
River	Gansu	11.670	0.703	12.373	
Basin	Ningxia	0.889	0.318	1.207	
	Inner Mongolia	0.000	0.415	0.415	
	Sum	35.359	2.212	37.571	24.760
	Total	140.31	10.876	151.188	

3. Non-renewable water resources

There are considerable non-renewable water resources in the arid NW China. They are the finest and the most valuable natural resources that need to be protected and utilized rationally.

3.1 The glacier resources Glaciers are a special kind of water resource in arid NW China that can result in great recharge of river water through melting. The total glacier area is 34.7 × 10^3 km^2 in the high mountain regions. The glacier storage is estimated about 3.541 × 10^{12} m^3 (Yang, 1991), which corresponds to about 3.2 × 10^{12} m^3 of water . The glacier area in the river source region is about 25.8 × 10^3 km^2 , and about 228 × $10^6$$m^3$ of melt water replenishes the rivers annually.

3.2 Groundwater in the plain aquifers The thick sedimentary formations in the plain basins store a great amount of fossil groundwater. The static storage of the Quaternary aquifer is at least 9 × 10^{12} m^3 according to the long-term hydrological survey.

3.3 Artesian groundwater It has been found that the aquifers of the Quaternary system are artesian in many basins, and the artesian head is 1~5m above the ground. Most of the water is fresh,

and the salinity is about 1~3 g/l in some regions. At the present, it is difficult to evaluate the quantity and quality of artesian groundwater in whole of the arid land, and much further research must be done in order to evaluate it correctly.

3.4 Groundwater in desert lands The central part of the large basin in the NW China is covered with sand, with the total area 694 $\times$ 10^3 km^2. There is a great amount of surface flow and groundwater. Although the annual precipitation averages about 50~100mm, most of it is from heavy storms that can generate temporary runoff or recharge groundwater at the thin sand region, where it can be stored in the aquifer as a convex lens. Groundwater recharged by rainfall is estimated at more than 5.0 $\times$ 10^9 m^3. The total storage to a depth of 200m under sand dune in deserts is about 10 $\times$ 10^{12} m^3.

3.5 Depression storage and lake storage According to recent statistics, there are about one thousand lakes in arid NW China, the area of which amounts to 1.7 $\times$ 10^3 km^2. The total storage is about 30.0 $\times$ 10^9 m^3. About 80% are semi-saline or saline lakes in which the water is renewable, the other fresh or brackish lakes are worth exploitation and utilization. Moreover, there is some groundwater under these depressions and lakes, the natural groundwater is about 3.3 $\times$ 10^9 m^3 according to data for eight lakes.

4. The problems in water utilization

The water resource is a decisive factor in the development of NW China. It is its economic life-line, and the ties of social development and the environment. The past state of floods and drought has changed initially through building water projects and constructing artificial oases, which have obtained obvious economic and environmental benefit. However, there are a lot of serious problems in exploitation and use: (1) Water resources were reduced and the quality contaminated, which has resulted in large area of sandy desertification, lakes dried up gradually and natural vegetation was destroyed seriously in the lower reaches because of increase of storage and drawing in the upper and middle reaches. (2) Sustained rise of the groundwater table due to flood irrigation with a large amount of water has brought about a large area of secondary salinisation in the plains irrigation area. Salinized soil is estimated about 1.144 $\times$ 10^6 ha , which is about one-third of the total irrigation area. (3) Local cones of depression and groundwater drawdown due to excessive exploitation of groundwater have led to degeneration of the original vegetation. (4) There arise serious water allotment conflicts between upper middle reaches and lower reaches, and between industry and agriculture because there is no overall planning of water resources to maintain the ecological balance and economic development of the whole basins. In water use, industry and agriculture are taken seriously, forestry and animal husbandry are taken lightly. On the other hand, consideration is given to short-term economic benefit whereas long-term environmental benefit is neglected.

5. The potential of water resources utilization

At present water efficiency is very low based on drawing surface water and net consumption of agricatural irrigation water in arid NW China.The overall allotment and planning of water resources must be considered while analyzing its development potentiality. Future sustainable exploitation and utilization of water resources can be carried out step by step. The first step broadens new water sources and reduces water consumption to use water more efficiently.

5.1 To broaden new water sources (1) Harvesting rain water, building storage reservoirs, and roof gathering etc. (2) Regulating runoff and groundwater in the river basins sufficiently, and exploiting boundary water bodies. (3) Using shallow groundwater sufficiently in the plains, lowering the properly groundwater table responsibly and controlling evaporation, and utilizing saline water.

5.2 Water saving Water saving is a key measure to solve the problems of water shortages in arid NW China , except for broadening the above new water sources. At the present, water is wasted seriously and irrigation efficiency is very low due to inappropriate exploitation, management and backward techniques. The grain yield averages about 0.2~0.5kg per m^3 of water and biological yield is 0.1~0.8kg per m^3 of water. Water saving potential is considerable: (1) Reducing consumption, treating and reusing wastewater in industry. (2) Applying advanced irrigation techniques, increasing irrigation efficiency, improving farmland cultivation and adopting drought resistant crops in agriculture. (3) Lowering the groundwater table properly and applying drought resistant plants as well as building artificial irrigated grassland in forestry and animal husbandry. (4) Controlling evaporation from water surface and soil.

6 . The ways for sustainable exploitation of water resources

It is imperative and important for sustainable exploitation and utilization of water resources to be carried out in the coming 21st century. It is necessary to concentrate on doing the following works as well as broadening new water sources and saving water as above: (1) To enhance protection and rational utilization of water resources, the glacier and water conservation forest in the mountain regions must be protected. We must also take action to protect water bodies in the plains from pollution of industry or agriculture, to maintain balance between mining and recharging and to preserve the environment and resources in the lower reaches of river basin. (2) To do the best to conserve water and use efficiently. Water resources must be used economically and scientifically in every stage from drawing the water to plant production in agriculture. Industry needs to take measures for saving and recycling water and for treatment and reuse of wastewater. (3) To exploit water resources rationally using the river basin as a unit of an integrated ecological system. Water resources must be allotted quantitatively for industry, agriculture, forestry and animal husbandry as well as for ecological environment in the whole basin. (4) To improve water coordination between economics, society and environment with legislative measures. It is imperative to draw up a rational water price, to increase investment, to enhance water projects' construction and its management in order to make up for additional loss of society and environment. (5) To improve water management. Rational utilization of water resources is a great problem in the future. Water is very limited and eco-environment is extremely fragile in arid lands. Therefore as a long-term measure to resolve the contradiction between large amount of water requirement and shortage of water resources, it is extremely necessary to enhance overall water planning and management, to utilize water with thoroughly coordinated allotment.

References

1. Cheng Longheng, Qu Yaoguang, et al, Water and land resources in Hexi Corridor and rational development and utilization, science press, Beijing, 1992.

2. Yang Zhenliang, The glacier water resources in China, Gansu Scientific and technology press, Lanzhou, 1991.

沙漠研究 7S, 153-156 (1998)
Journal of Arid Land Studies

Prospects of Halotolerant Microalgae Photobiotechnology in Uzbekistan Desert Zones

Alibai ABDULLAEV, Bakhtiyar KAMALOV, Valentina DEEVA*

Abstract - Results on the isolation, maintenance and cultivation of halotolerant microalgae are presented. A method of cultivation of the genus Dunaliella Teod representatives in laboratory and open installations in the conditions of Uzbekistan is suggested. Experimental data on optimization of photosynthetic productivity and biochemical composition of microalgal culture (proteins, β-carotene, tocopherol, ascorbic asid) are summarized. A laboratory installation for Dunaliella cultivation in intensive culture of high density (100 mln.of cells/ml) and parametric control of β-carotene biosynthesis has been designed.

Key words: microalgae, Dunaliella, optimization, productivity, biochemical composition, method.

1. Introduction

Over the last 20-30 years interest in the study of the halophilous green algae (Dunaliella, Asteromonas and other) has increased. On the one hand, this is conditioned by biological peculiarities of these organisms which are capable of reproduction in highly saline medium. This is, apparently, determined by the specific character of structure and functioning of their membrane systems. On the other hand, some of these algae, for example Dunaliella salina, are of great practical interest because under definite conditions they accumulate large amount of β-carotene and are considered as possible producers of provitamin A. It is interesting to note that D. salina is the richest vegetable source of provitamin A known at present. By its biological activity it isn't inferior to preparations obtained from carrots (Geleskul, 1964; Drokova, 1970; Masyuk, 1973; Abdullaev, Semenenko, 1974; Semenenko, Abdullaev, 1980; Ben-Amotz A., Auron M., 1983; Borowitzka et al., 1984; Abdullaev, Kamalov, 1995, 1996). One more characteristic feature of Dunaliella is its ability to synthesize large amount of glycerol (Ben-Amotz, 1977; Wegmann, 1971).

2.Materials and Methods

Dunaliella salina strains D-4A, D-6A, D-9; D.minuta strains D-5, D-7A; D.viridis, D-1A; D.terricola, D-8A were the objects of study. Algae were cultivated under sterile intensive culture conditions in the accumulating mass accumulation; cell growth - by change of their weight; β-carotene - by chromotographic method (Semenenko, Abdullaev; 1980); proteins - by Kjeldal method (Belozersky, Proskuryakov, 1951); carbon – by anthrone method (Trevelayn, regime in Abdullaev-Semenenko medium (1974) with permanent illumination by luminescent lamps (from 60 to 120 W/m^2 FAR) and barbotage with gas-air mixture (1,7% of CO_2), temperature was optimal for studied strains.

Growth of culture was determined by direct calculation of number of cells under the

*Institute of Botany,Uzbek Academy of Sciences, Tashkent, Uzbekistan
Tel.: (3712)-162-70-65
Fax: +7-3712-62-79-38

microscope or by optic density of suspension; productivity – by drymass accumulation; cell growth by change of their weight; β-carotene – by chromotograhic method (Semenenko, Abdullaev, 1980); proteins – by Kjeldal method (Belozersky, Proskuryakov, 1951); carbon – by antrone method (Trevelayn, Harrison, 1952); lipids – according to Holman and Hayes method (1958).

3.Results and Discussion

3.1. Isolation and maintenance of microalgae

At the Institute of Botany Uzbek Academy of Sciences for 50 years investigations have been carried out on finding, isolation, maintenance, cultivation and practical utilisation of microalgae in various fields of the national economy. A large collection (45 species and 96 strains) of Chlorophyta, Cyanophyta, Euglenophyta and other microalgae isolated from various reservoirs and soils of Uzbekistan was established. Ecologo-biologic, physiologo-biochemical characteristics of some representatives of Chlorococcales, Volvocales, Euglenales, Chroococcales, Oscillatoriales, Nostocales have been worked out. For this purpose freshwater algae were mainly studied, halophilous algae remain insufficiently known (Muzafarov, Taubaev, 1984).

We began to research and isolate prospective salt-tolerant species and strains of the genus Dunaliella in 1986. As a result 16 unialgal cultures belonging to 4 species of the genus Dunaliella (D.salina Teod., D.minuta Lerche, D.viridis Teod., D.terricola Masyuk) were isolated (Abdullaev, 1995).

3.2. Cultivation under laboratory conditions

To investigate physiological and biochemical peculiarities of Dunaliella species two stationary laboratory installations (SLI-2A) were designed and microalgal culture biomass cultivation technology in controlled conditions was worked out (Abdullaev, Kamalov, 1996a). Optimal light and temperature conditions of cultivation were determined for several species. Temperature 28-30°C, light intensity 60 W/m^2 FAR and pH 7,5-8,0 are found to be optimal and ensure the highest growth of D.salina, D-9 (59,6 mln.cells/ml), D.minuta, D-5 (93,9 mln.cells/ml) for 8 days. The protein content is 55-50% abs.dry weight, lipids-28-30%, β-carotene - within the range 1100-300 mg %.

The study of temperature effect on biosynthesis of β-carotene in cells of different Dunaliella species shows that D.salina strains D-4A, D-6A, D-9 grow well at temperature 32°C, weight of dry biomass reaches 14-16 g/l on the 8-th day, these indices were 2-3 times lower in the other strains. Species D.viridis, D-1A, D.minuta, D-7A, D.terricola, D-8A have better growth. In experimental conditions of cultivation at temperature 28°C D.minuta strain S-7A was determined to accumulate small amount of β-carotene (2,0-2,5 mg/l). In D.viridis strain D-1A and D.terricola D-8A accumulation of large amount of β-carotene is observed at 32°C-12,0 and 8,7 mg/l, respectively, but the productivity is lower than at the optimum temperature (28°C). When temperature falls to 24°C biosynthesis of β-carotene decreases in D.viridis, D-1A to 8,5 mg/l and in D.terricola, D-8A to 4,5 mg/l. In 3 studied strains of D.salina D-4A, D-6A, D-9 inverse correlation is observed. Under the optimal temperature conditions lower accumulation of β-carotene is observed than at low temperature (28-24°C). Quantitative accumulation of β-carotene in the cells of different strains of D.salina is higher in variants with low temperature regime: in D-4A it is 20,4; D-6A-25,2 and D-9-23,5 mg/l. It is determined that D.salina strains D-4A; D-6A; D-9 are more productive and accumulate greater amount of β-carotene. These strains of D.salina are carotene-bearing within the range of this genus (Abdullaev, Kamalov, 1996b).

Technology of β-carotene biosynthesis control has been developed in D.salina, D-9. Daily increase in β-carotene is over 1300 mg/10^9 cells and its content amounts to 100 mg/l of suspension.

3.3. Technology of cutivation in the open air

Technology has been developed for halophilous microalga cultivation with permanent mixing by circular method and barbotage with or without CO_2 in a large volume of medium (50-500 l). Regimes of mass cultivation have been optimised in several species. Light and temperature conditions of cultivation in the open air have been studied.

Salt conditions were investigated. The nutrient medium was selected. The nutrient medium was investigated. The composition of this medium is as follows (g/l):
NaCl-58; $MgSO_4$-25; KNO_3-2,5; K_2HPO_4-0,2;
$NaHCO_3$-0,5; pH-7,4-8,0.

Dunaliella minuta. D-5 was grown in the Artari nutrient medium containing 58 and 116 g/l NaCl from March to November, 1989. The intensity of solar illumination in the open air was 400 W/m^2 FAR, temperature of suspension ranged from 22 to 31°C, pH-7,0-8,5. Light intensity 40-200 W/m^2 FAR and temperature of suspension 28-31°C at thickness of the medium layer not more than 10 cm was determined to be the optimum for culture development and increase in cell number. It was revealed that the active circulating mixing doesn't give the positive effect in comparison with the other methods of cultivation. Barbotage mixing was found to be more effective. Maximal productivity reached to 42,5 g dry biomass/m^2 per a day, while without mixing of suspension-25 g dry biomass/m^2 per a day (Abdullaev et al., 1996).

Study of dependence of Dunaliella salina, D-9 growth rate on suspension mixing showed that mechanical mixing affects negatively the growth and development of algae and the synthesis of valuable substances. In the subsequent experiments barbotage method was used, which is more favourable for growth, development and physiological state of cells and also for vitamin and protein production. Under these conditions the content of β - carotene reached 1100 mg%, vitamin C-128,2 mg%, vitamin E-73,0 mg%, protein-62,5%. The maximal vitamin content (580 mg% of β-carotene, 78,5 mg% of tocopherol, 142 mg% of ascorbic acid) falls on day 8-10 of cultivation. Without mixing of suspension alga cells reached the most active state day 12-15 of cultivation.

The study of the seasonal changes in vitamin content in D.minuta biomass showed that it varies within a wide range from February to September. The period from April to September is the most favourable for alga cultivation. At that time the increase in growth rate and content of ascorbic acid and tocopherol is observed. In June-July β-carotene accumulation in D.minuta cells was 15% higher (654-672 mg%) than in the other seasons (Abdullaev, Kamalov, 1996c).

Thus, to obtain D.minuta biomass with a high content of carotene it should be grown in summer in installations of the open type under high light intensity. Biochemical analysis of the composition of halophilous microalgae showed that they are not inferior to Chlococcales and Euglenales in the content of chemical compounds and in the content of several components (β-carotene, glycerol, tocopherol, ascorbic acid) the content is higher.

4. Conclusion

Thus, microalgae selected could be utilised for photobiotechnology. The determined optimal cultivation parameters provide biomass with high content of physiologically valuable compounds (β-carotene, glicerol, tocopherol, etc.); its utilization for the second order consumers will solve the problem of intensification of biological processes and their control in saline reservoirs in Uzbecistan.

References.

Abdullaev A.A. (1995): V sb."Aktual.problemy botaniki", Tashkent, p.44.
Abdullaev A.A., Semenenko V.E. (1974): Phisiol. rastenij, v.21,6,pp.1145-1158.
Abdullaev A.A., Kamalov B.Sh. (1996): Ustanovka dlja kultivirovanija microvodoroslej. Patent Respubliki Uzbekistan. 3460.
Abdullaev A.A., Kamalov B.Sh. (1996b): V sb."Biol.osnovy optimizatsii skorospelosti i produktivnosti rastenij", Tashkent, 1996, p.121.
Abdullaev A.A., Kamalov B.Sh. (1996c): V kn."Ecologo-physiologicheskie issledovanija vodoroslej i ikh znachenie dlja otsenki prirodnykh vod", Rossijskaja Akademija Nauk, Yaroslavl, p.121.
Abdullaev A.A., Kamalov B.Sh., Ismailkhodzhaev B.Sh. (1996): Doklady Akademii Nauk Respubliki Uzbekistan. 10, pp.49-51.
Ben-Amotz A. (1977): Glicerol production in Dunaliella algae. "Eur.Semin.Biol.Solar Energy Convers. Syst., Grenoble-1977, Austrans, L-13.pp101-104.
Ben-Amotz A., Auron M. (1983): Plant phisiol., v.72, 3, p.593.
Borowitzka L.G., Borowitzka M.A., Maulton T.P. (1984): Hydrobiologia, 116/117: p.115-121.
Drokova J. (1970): Ukr.botan.j., v.27,3,pp,370-372
Geleskul Yu.F. (1964): Ukr.biohim. j.v.36, 5, pp.778-783.
Holman R.T., Hayes H. (1958): Analyt.Chem., 3001,8.
Masyuk N.P. (1973): Morphologija, sistematika, ecologija, geographicheskoe rasprostranenie roda Dunaliella Teod.Kiev, 441.p.
Muzafarov A.M., Taubaev T.T. (1984): Kultivirovanie i primenenie microvodoroslej. Tashkent, 133.p.
Semenenko V.E., Abdullaev A.A. (1980): Phisiol. rastenij, v.27,1,pp.31-41.
Trevelayn W.E., Harrison G.Z. (1952): J.Biochem., 50,3.
Wedman K. (1971): Biochim. Biophys. Acta, 234, pp.317-323.

沙漠研究 7S, 157-160 (1998)
Journal of Arid Land Studies

Growing Cotton in the Uzbekistan Arid Zone

A.A. ABDULLAEV* and V.P. KLJAT*

Abstract - This paper describes the results of long term investigations into drought resistance in wild species of cotton in the arid zone of Uzbekistan. Adaptations to the arid environment include structural specialisations in the leaves, stems, and vascular system.

Key Words: Cotton species, Morphology, Anatomy, Adaptation.

1. Introduction

The Republic of Uzbekistan is the most northern cotton growing region in the world, located in the northern zone. Deserts and semi-arid lands occupy vast territories in the southern region. The climate is arid with an abundance of warmth and light. There are difficulties in growing cotton because of the deteriorating ecological situation and shrinkage of the Aral Sea. The main requirements are preserving and effectively utilising water resources, improved growing technology, increased yield, and the development of drought resistant varieties. Early ripening varieties could help to ensure good yields in short growing seasons, and promote economic and effective utilisation of water resources. The adaptations of wild growing cotton species the arid environment may provide ways of meeting these requirements. This paper describes some of the these adaptations which have identified in long term studies.

2. Materials and Methods

Our laboratory has established a large collection (genetic fund) of wild and cultivated species of cotton plant. It is the basis for biological, morphological, ecological, genetic and other investigations. Different varieties of cotton are sought from all over the world. Investigations are conducted on wild species, grown in hothouses (autumn, winter), in the field (spring, summer), in shortened daylight (10 hours), and under various experimental conditions.

3. Results

Over many years of investigation, 30 varieties of cotton (out of 37 known) from a range of geographical zone and climatic conditions have been studied. These have proved to be a valuable source of genetic features that are necessary to meet current requirements and conditions for economic cultivation. Some early-ripening, highly-productive, heat and drought resistant varieties have been found. The valuable characteristics can be transferred to to cultivated species through remote hybridisation and experimental polyploidy.

Extensive material is now accumulated on wild varieties of different form from arid and semi-arid areas. Biological characteristics and structural changes have been found in leaves

* Institute of Genetic and Experimental Biology of Plants, Uzbek Academy of Sciences, Tashkent, Republic of Uzbekistan.

and radial organs which provide adaptation to arid environments (Kljat, 1988, 1990; Kluyev, 1960). Analysis of morphologic-anatomical structures of leaves and radial organs in ontogenesis indicates that arid adaptations develop by the formation and gradual accumulation of different xeromorphic features, specific for the variety. These features include the reduction of leaf blades, shortened life cycle, thicker leaf hairs, changes in mesophyll structure, cuticle, and wax film, mucous cells under the epidermis, water bearing cells in the parenchyma of conducting clusters, changes in the quantity of vessels in xylem and shortened vessel elements. If conditions gradually become more extreme, arid adaptations are developed which enhance the survival of the varieties.

Table 1 shows comparative data, related to morphologic-anatomical structures of leaves and xylem of mature cotton plants, belonging to two large groups: American (Integrifolia) and Australian (Hibiscoidea). Growing conditions of the American continent vary substantially. Areas of trees and large arborescent shrubs are located in central America which receives precipitation of 500-600mm per year. These varieties have large leaves, ranging from solid forms to those with 3-5 lobes with dorsoventral (D) mesophyll and moderate length nerves (Table 1). *G.gossypioides* and *G.raimondii* are more mesomorphic in structure and grow in more humid regions with annual precipitation of 500-1000m, most of which falls in spring and summer.

Table 1. Structural features of leaves of wild cotton species.

Features		American sec. Integrifolia			Australian sec. Hibiscoidea		
		G.gossypioide	*G.raimondii*	*G.thurberii*	*G.sturtii*	*G.australe*	*G.bickii*
Thickness of leaf blade(μm)		186	166	230	220	241	200
Height of palisade layer(μm)		132	98	104	71	86	59
Mesophyll type		D	D	I	I	II	I
Epidermal cells (mm^{-1})	Upper	1986	2528	1952	1722	1400	1300
	Lower	2375	2732	1800	1685	1700	1700
Stoma(mm^{-1})	Upper	48	130	68	163	150	181
	Lower	396	350	184	254	200	200
Radial hairs(mm^{-1})	Upper	4.3	3.3	2	-	49	14
	Lower	6.0	44.0	3-4	-	50	15
Nerve length($mm.m^{-2}$)		1014	1414	1140	1300	1100	1200

G.thurberii is a small tree that grows in the Sonoran Desert of southern USA and northern Mexico (annual precipitation 125-380mm). The leaves are greatly parted with a sulcate cuticle on upper and lower surfaces, mucous cells under the epidermis, numerous stoma, and a thick net of nerves. The leaf mesophyll is mostly dorsoventral but isolateral (I) arrangement may also occur. In mature plants there are many vessels with short xylem segments (Table 2). These features of *G.thurberii* are associated with enhanced drought resistance compared to the other representatives of the Integrifolia section.

A group of 12 cotton-plant species grow in Australia, some existing in extreme arid and semi-arid conditions. They are of great interest, being the most drought resistant and productive species (subgenus *Sturtii*). Members of this group have prostrate, half prostrate and straight form, and show leaf blade reduction and overall size reduction. Some species have leaves that are small, solid, and thickly haired, with mucous cells under the epithelium, isopalisade mesophyll. Other species are have naked dense leathery leaves with a thick layer of cuticle and wax film, and isolateral mesophyll. The xylem is characterised by many vessels with short segments (Table 2). In our view these features are adaptations to extreme arid and semi-arid conditions in central and northern Australia, where the annual precipitation of 160-360mm mostly falls in summer. The most drought resistant species (*G.australe, G.nelsonii, G.bickii*) exhibit period cleistogamy (closed flowers), a further adaptation to extreme arid conditions.

Table 2. Structural features of stems of mature (3-4 years) wild cotton species.

	American sec. Integrifolia			Australian sec. Hibiscoidea		
Features	*G.gossypioides*	*G.raimondii*	*G.thurberii*	*G.sturtii*	*G.australe*	*G.bickii*
Vessels						
Primary Stem Diameter (cm)	1.8-2	2-2.5	1.8-2	1.5-2	1-1.5	1-1.2
Number (mm^{-1})	17-20	25-40	60-70	71	130	120
Segment Length(μm)	207	170	146	200	150	140
% of Occupied Squ.	6.1	3.9	8.4	6.8	6.6	7.5
Libriform						
Fibre Length (μm)	945	802	898	631	524	589
Cavity Diam. (μm)	5.0	5.0	5.1	6.6	3.4	6.3

Discussion

The data obtained indicate that phylogenetic changes in leaves and shoots of wild cotton plant species are adaptive responses in the structure of protective and conductive tissues. This is consistent with data obtained in cultivation trials where plants were subjected to different watering regimes (Klyuev, 1960). During the vegetative period plants reacted to limited

availability of water through significant changes in the morphology of leaves. All the changes; reduction of leaf blades, thickness of mesophyll and hairiness, diminution of stoma; reduce water loss.

Three representative Australian species were chosen and recommended by us for genetic selective work as donors of drought-resistant, early-ripening, and high productivity characteristics. There appear to be some difficulties with remote hybridisation; such as non-crossing, difficult crossing, reduced vitality, and increased sterility in hybrids of the first generation. This is because of genetic discrepancies in the chromosome structure of species, especially wild and cultivated tetraploids. Thus, the rich potential of the genetic fund in cotton plants is still meagrely utilised in world cotton growing. We are working on ways and methods to include wild varieties into the selection processes. The latest work has shown the possibility of including wild American species in the selection processes. To obtain successful hybrids we consider it necessary to take into account the degree of phylogenetic affinity of parental varieties according to created schemes (Rizaeva and Abdullaev; 1987, Abdullaev, 1996) that promote harmonious combinations of features in new genotypes. New methods for obtaining various hybrids which combine valuable features in new genotypes have been elaborated. Present studies are focused on heritable siccostabile characteristics in hybrids of different generations, obtained from parental species contrasting in degrees of drought resistance. Thus, crossings by genome pairs resulted in unique three-genome hybrids which produced homogeneous selective material with siccostabile properties. Some representatives with valuable economic and biological features in adaptations to conditions of arid zones have been defined.

References

Abdullaev, A.A. (1993): Uzb. Biological Journal, 4:60-63.

Abdullaev, A.A. (1996): Cotton, 4:5-8.

Klyuev, G.A. (1960): Some data on drought resistance of cotton plant genus. In: "Cotton Plant", Vol. III.

Kljat, V.P. (1988): Thes. for "Actual problem of botany in the USSR of AII", Alma-Ata:332-333.

Kljat, V.P. (1990): Thes. for II All Union Conference on Ecological Anatomy. Vladivostok.

Rizaeva, S.M., and Abdullaev, A.A. (1987): Thes. of 5th Union Society of Geneticists and Selectionists. Moscow.

沙漠研究 7S, 161-164 (1998)
Journal of Arid Land Studies

CONJUNCTIVE USE OF RAINWATER AND SALINE GROUNDWATER FOR DESERTIFICATION CONTROL IN PAKISTAN THROUGH AGRO-FORESTRY AND RANGE MANAGEMENT.

Muhammed Akram * and Bashir Ahmed Chandio**

Abstract - Rainfall in arid and desert lands of Pakistan is low and could not alone support a good vegetation cover. The other source of water to be used for irrigation is ground water, but unfortunately it is mostly saline. Therefore, conjunctive use of rainwater and saline ground water become important to grow beneficial vegetation for desertification control in deserts. The Pakistan Council of Research in Water Resources (PCRWR) has practised conjunctive use of rainwater and saline ground water at Dingarh located in the Cholistan desert about 75 kilometer from Bahawalpur city by developing a source of irrigation water through rain harvesting and pumping ground water for planting trees, bushes, grasses and forage crops on sandy soils.

Key Words: Conjunctive, desertification, water harvesting, vegetation.

1. Introduction

More than 26 percent of arid lands in Pakistan consist of the main deserts, namely the Thar, Cholistan, Thal, Chagi and Kharan. Total cultivated land in Pakistan is 21 million hectares, of which 15 million hectares are under irrigated agriculture while the remaining 6 million hectares are under dry agriculture. More than 50 percent of the country has become under medium to severe desertification due to soil degradation caused by natural and man-made factors. The main sources of irrigation water in Pakistan are surface and ground water. It is estimated that about 194248 million m^3 per year irrigation water is available from rivers and tubewells. The rivers and tubewells contribute 136970 million m^3 and 57278 million m^3 respectively. About 85 percent of the river flow is during summer, while only 15 percent is in the winter. The agricultural production in the country is not increasing to the proportional of population. The demand for food, milk, meat, fodder and fuel etc. is increasing day by day. To cope with food problems it is essential that desertification be controlled and waste desert lands be used for sustainable production for the benefit of the country. Irrigation water is the main problem for using desert lands because water can not be provided due to existing shortages in irrigated areas for potential production. Therefore, scientific and technical skills are needed to be used for local water resources development in deserts for desertification control and rehabilitation of desertified areas. Although rainfall is very low in the deserts of Pakistan, ranging between 100 and 250 mm per annum, rain water is still the primary source of fresh water. The other source of water is ground water, but it is mostly saline. The main factors of desertification in deserts are wind erosion and soil salinity. Wind erosion is due to poor vegetation cover due to overgrazing and cutting of woody species, while soil salinity and sodicity is due to salt accumulation during subrecent periods. The Cholistan desert is one of the major and driest areas in Pakistan covering about 26000 sq.km. The land of Cholistan consists of 44 percent sand dunes, 37 percent sandy soils, 2 percent loamy soils and 17 percent saline-sodic dense clayey soils. All area of desert is prone to desertification due to poor vegetation, wind erosion and soil salinity. A Field Research Station has been established by PCRWR at Dingarh in the Cholistan desert to conduct desertification control research in deserts under conjunctive use of rain water and saline ground water. The area of the station is 200 hectares consisting of mobile sand dunes, sandy soils, dense saline-sodic clayey soils, poor rangeland and underlying saline ground water. The research at the station is conducted on various aspects e.g. rainwater harvesting, conjunctive use of rain and saline water, sand dune fixation and stabilization, rangeland development, afforestation, cultivation of salt tolerant and drought resistant grasses, forage crops, bushes and shrubs etc. The area of the station is representative of the Cholistan and Thar deserts.

2. Water sources

2.1. Rainwater Harvesting. Rainwater harvesting from suitable catchments can be used to supply water for domestic use, livestock, wildlife, afforestation and crops etc. in the Cholistan and Thar deserts of Pakistan (Akram etal., 1995). Runoff depends on quantity of precipitation and characteristics of soil. About 17 percent of Cholistan desert consists of dense clayey

* Pakistan Council of Research in Water Resources, Regional Office, 29-Sajid Awan Colony, Bahawalpur, Pakistan. Fax.92-621-83128.
** Pakistan Council of Research in Water Resources, Islamabad, Pakistan.

soils devoid of vegetation of having poor vegetation canopy.This area is mostly flat,impervious,saline-sodic and has a pH more than 9.0. The extent of such area in Cholistan desert is 441900 hectares. This area is the best catchment for rain water harvesting and collection already developed by nature. We have to manage this area for enhanced runoff and efficient water collection. A 90 hectares suitable catchment area for water harvesting and collection was identified at Dingarh by contour survey. The catchment area is flat and consists of dense saline-sodic clayey, impervious, very poorly drained soils. The overall vegetation in the catchment area is less than 10%. The slope of the catchment area is 0.006% from North toward South. The rainfall of the catchment area has been recorded regularly since 1989. The runoff in the catchment area starts after continuos rainfall of between 7 to 9 mm. The runoff in the catchment area has been increased substantially by developing a network of macro and micro ditches in the catchment area. The runoff of the catchment area has also been increased by cleaning hummocks and vegetation causing obstacles to the flow of rainwater. All the low lying points in the catchment area have been interconnected by ditches. To store harvested rainwater from 90 hectares, the PCRWR have excavated and constructed six ponds scientifically. These ponds have been designed to catch maximum rainwater within the shortest possible time and to minimize water losses. The depth of ponds varies between 4 to 6 meters. The storage capacity of ponds is between 2067 m^3 and 15000 m^3. Each pond has been connected with the main catchment area through a main channel and network of ditches connecting all lowest points in the catchment area via a small pond to settle soil material before reaching the big pond. The purpose of the channel and ditches is to collect runoff promptly during and after rain. Seepage has been minimized by spreading polyethylene on the bed of ponds covered by 15 cm thick dense impervious clay layer and clay mud coating on the sides. Evaporation has been minimized by reducing the surface area and increasing the depth of ponds as well as by planting trees around the banks.

Table 1. Rainfall runoff available at Dingarh Station and from effective catchment area of Cholistan

Year	Total rainfall (mm)	Total No. of rains.	No.of threshold rains.	rainfall runoff available at Dingarh (Ltr.million)	Rainfall runoff of Cholistan (m3 million)
1989	83.0	7	3	29.0	166.0
1990	136.1	15	6	35.0	215.0
1991	160.0	11	8	60.0	368.0
1992	239.4	17	11	90.0	552.0
1993	157.0	12	5	72.0	442.0
1994	300.0	17	13	117.0	718.0
1995	213.0	8	6	108.0	663.0
1996	152.0	7	7	58.0	348.0

The data of Table-1 revealed that only a portion of the total rainfall received during the years from 1989 to 1996 was available for runoff collection under the water harvesting system. The runoff available for harvesting and collection during the eight year period was respectively 49%, 36%, 53%, 64%, 55%, 70% and 63% making an average of 55 percent. The total rainfall runoff available at Dingarh for harvesting and collection varied between 29 and 117 million litres while water storage facilities available with PCRWR are for 49 million litres. Total runoff available from the Cholistan catchment area consisting of 441900 hectares varied between 166 and 718 million m^3 making 165713 and 718088 million litres respectively.

Table 2. Drinking water capacity from rain water available for storage in Cholistan desert for people and livestock.

Year	Net water available after 30% water losses (million litres) in the Cholistan desert.	Drinking water capacity (million heads) per year				
		Human	Sheep	Goat	Cattle	Camel
1989	115999	33	65	65	11	7
1990	150799	42	85	85	14	9
1991	265140	74	149	149	25	16
1992	386663	109	217	217	36	24
1993	309330	87	174	174	29	19
1994	502661	141	282	282	47	31
1995	463995	130	260	260	43	29
1996	243596	68	138	138	23	15

Drinking water requirement per day in Litres: Sheep=5 Goat=5 Cattle=30 Camel=45

The data in Table-2 indicates that the minimum water available for drinking in the Cholistan desert is for 33 million people, or 65 million sheep, or 65 million goats, or 11 million cattle, or 7 million camels, while the maximum water available for humans is 141 million, or 282 million goats, or 47 million cattle, or 31 million camels. The total human population in the Cholistan desert is about 0.1 million, while total the population of livestock in the shape of one unit i.e. sheep is nearly 3.0 million head. The data in this table reveals that after providing water for drinking to human and livestock population there is a surplus water which can be used for desertification control under an economical irrigation system. The rainwater harvested and stored by PCRWR at Dingarh Research station is more than 49 million litres per annum. This amount of water is used for drinking by the human population and for some livestock as well as for wildlife at Dingarh. The surplus water is utilized for growing trees and grasses etc. under conjunctive use of saline ground water and rainwater.

2.2. Conjunctive use of rainwater and saline ground water.

Availability of irrigation water is a fundamental necessity in the deserts to develop good vegetation cover for desertification control. There is no canal, river or any other source of fresh water except rainwater in the Cholistan and Thar deserts. Rainfall is low and could not support alone the growth of trees, grasses, bushes and crops etc. The other source of water to be used for irrigation is ground water, but unfortunately it is mostly moderately saline to highly saline. Therefore, conjunctive use of rainwater and saline ground water becomes important in order to grow beneficial vegetation for desertification control in deserts (Akram etal., 1991). The PCRWR has installed a 90 meter deep turbine pump to draw 0.5 cusec water for irrigation on deep sandy soils under conjunctive use with rain stored water. The quality of tubewell water is of Ec=4.6 dS m^{-1} SAR=14, RSC Nil and pH 7.5, while rainwater quality is Ec=0.58 dS m^{-1}, 0.700 dS m^{-1}. The rainwater is used to irrigate baby plants in the nursery stage and after transplantation in the field till the age of six months, then after wards saline ground water is applied for irrigation alternately at intervals. The trees and plants grown at Dingarh station under conjunctive use of saline water and rainwater are: Tamarix, Acacia, Prosopis, Zizyphus, Parkinsonia, Eucalyptus camaldulensis, iple iple, hohoba etc.

Table 3. Growth of tree species grown under conjunctive use of water at the age of 5 year

Tree species	Rainwater irrigations (%)	saline water irrigation (%)	Height(cm)		Canopy(cm)		Girth(cm)	
			Min.	Max.	Min.	Max.	Min.	Max.
Tamarix	41	59	111	208	139	200	19	40
Acacia	46	54	208	375	128	313	20	52
Zizyphus	47	53	182	420	111	294	18	41
Eucalyptus	54	46	246	530	151	348	14	40

The salinity level of ground water in the Cholistan desert varies from site to site. About 31 percent of ground water has an Ec below 2.5 dSm^{-1}, 23 percent below Ec 5.0 dS m^{-1}, 11 percent below 7.5 dS m^{-1}, 6 percent below Ec 10.0 dS m^{-1} and 29 percent above 10 dS m^{-1}. The results obtained by PCRWR at Dingarh suggest that the Cholistan and Thar deserts can be used for planting trees on sandy soils under conjunctive use of rainwater and saline ground water. It will help to control desertification to produce a stable environmental system.

3. Desertification Control

Desertification in sandy areas and the sandy deserts of Pakistan is a major problem due to poor rangelands and wind erosion. Wind erosion is mainly due to poor vegetation cover which has resulted from overgrazing, cutting of woody vegetation for fuel and timber as well as due to poor physical properties of sandy soils. The PCRWR has stabilized more than 20 hectares of mobile sandy areas under poor vegetation cover at Dingarh in the Cholistan desert by increasing vegetation cover under conjunctive use of rainwater and saline ground water. The site was surrounded by micro windbreaks of Saccuram munja and date sticks till the establishment of planted tree species i.e. Eucalyptus camaldulensis, Acacia, Tamarix, Prosopis, Zizyphus, Parkinsonia and bushes e.g. Atriplex Spps. Before plantation, the mobile sandy area was stabilized by erecting micro-barrier fences in the checkerboard form by using dead plant material. Before fencing and plantation of the study site, the canopy of the natural vegetation was measured to compare after five years. The canopy cover before fencing and plantation as well as after 5 years is given in Table-4.

Table 4. Change in canopy cover after fencing and plantation.

Traverse No.	1	2	3	4	5	6	7	8	9	10	11
				Canopy cover (%)							
Before fencing and plantation.	10	14	15	22	18	25	32	26	27	27	20
After plantation of 5 years.	85	75	90	96	96	93	90	98	92	95	90
Difference	75	61	75	74	78	68	58	72	65	68	70

The canopy cover before fencing and plantation was between 10 and 32 percent, while after a five year period it has become between 75 and 98 percent. Now the area under study is free from wind erosion and presents a good example of desertification control. The tree species created a more favourable environment for the growth of natural vegetation and acted as windbreaks to protect the soil surface against strong winds. Agroforestry has been developed by planting forest trees e.g. Acacia and Zizyphus, with forage and oil seed crops i.e. barley, cluster bean and mustard. Atriplex Spp. and hohoba have been also planted,

4. Conclusion

The results of this research revealed that desert areas in Pakistan can be made productive if desertification is controlled under scientific management by utilizing local resources effectively.

References

1) Akram, M., Abdullah, M. and Majeed, M., 1991. Role of surface and ground saline water for agriculture development in the Cholistan desert. In:Proceedings of the National Seminar on People's participation in the management of resources in arid lands, 11-13 Nov.1990,Bahawalpur. pp. 53-60.

2) Akram, M., Abdullah, M., Khan, W.A., Sheikh, B.A. and Khan, A.D., 1995. Rehabilitation of Cholistan desertified lands for sustained production. In:Proceedings of the Sixth all Pakistan Geographical Conference, 26-29 Dec. 1993, Islamia University, Bahawalpur, Pakistan. pp.1-11.

沙漠研究 7S, 165-169 (1998)
Journal of Arid Land Studies

STRATEGIES TO HARVEST SUSTAINABLE RICE AND WHEAT YIELDS USING BRACKISH WATER FOR IRRIGATION

A. Ghafoor, M. Qadir, G. Murtaza and H.R. Ahmad

Abstract: In a field experiment on a nonsaline-nonsodic soil (Ustalfic Haplargids), rice and wheat crops were grown from 1993-1996 with sump water (EC= 2.42-3.79 dS m^{-1}, SAR=7.7-29.0, RSC=4.0-11.0 $mmol_c\ L^{-1}$, Ca:Mg=0.37-0.43 $mmol_c\ L^{-1}$). The treatments included sump water, soil-applied gypsum @ water gypsum requirement (WGR), H_2SO_4 application through fertigation equivalent to water residual sodium carbonate (RSC), and farm yard manure (FYM) @ 25 Mg ha^{-1} annually. All the treatments were irrigated with sump water. The results indicated that EC_e, SAR and pH_s in general, increased with all the treatments at all the soil depths. Soil crust (0-5 mm layer) and surface (0-5 cm layer) strengths and water infiltration rate (IR) decreased statistically with all the treatments. However, soil bulk density (BD) increased non-significantly at all the soil depths with all the treatments. Wheat performed better than rice. For the last wheat crop, gypsum produced significantly high yield followed by FYM, H_2SO_4 and sump water. However, net income was maximum from FYM followed by sump water, gypsum and acid. Considering the health of soil and crop growth, it was better to apply gypsum @WGR.

Key Words: Drainage water, Chemical and physical soil properties, Rice, Wheat, Economics.

1. Introduction

Pakistan has the largest continuous gravity flow irrigation system which is capable of handling about 130 billion cubic meters of water (Mohtadullah *et al.*, 1993) for irrigating approximately 14 mha of land (Mian and Mirza, 1993). Due to increased cropping intensity, this seemingly enormous amount of irrigation water could not keep pace with the water requirement. This necessitates the development of unconventional water sources in addition to an efficient use of the existing ones.

Development of technology for using sub-surface/surface drain water at or near source will not only increase the irrigation water supplies but will also reduce the disposal problems of the effluent and, thus, reduce environment degradation. Experiments on the Hafizabad soil series were undertaken to: 1) evaluate the effect of drainage water on the physical and chemical properties of soil, 2) test different water treatments for safe use of drainage water for rice and wheat crops, and 3) assess the economics of water treatments.

2. Materials and Methods

The study was started during July, 1993 on a permanent layout on moderately calcareous sandy clay loam Hafizabad soil series (Coarse loamy, mixed, calcareous, hyperthermic, Ustalfic Haplargids) near Faisalabad. This series is developed in sub-recent alluvium and occurs in nearly level parts of the old river terraces under arid and semiarid climates. having. Soil profile (EC_e, SAR and pH_s of 2.2-4.9 dS m^{-1}, 8.5-15.7 and 7.1-7.7, respectively for the 120 cm) was deep but was saturated below 100 cm depth.

Treatments were arranged in a randomized complete block design (RCDB) with four replications with 14.18 mx 5.95 m plot size. The treatments were :T_1(tile drainage water from sump S1B9), T_2 (soil- applied agricultural grade gypsum, ≈ 90% pure of -30 mesh size) @ 100% WGR before planting every crop), T_3 (commercial grade H_2SO_4 applied through fertigation equivalent to water RSC with each irrigation), T_4 (FYM, as available with farmers, @ 25 Mg ha^{-1} before transplanting rice crops).

After layout and harvest of each crop, composite soil samples from three randomly selected sites were collected at 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths for chemical analysis (US Salinity Lab. Staff, 1954). Soil IR was measured by double ring method, BD by drawing undisturbed soil cores, surface strength (0-5 cm layer) by cone penetrometer and crust strength (0-5 mm layer) by pocket penetrometer (Klute *et al.*, 1986). The WGR was determined by the Eaton's formula (Eaton, undated), i.e. Water GR, $mmol_c\ L^{-1} = a + b + c$, where a = Na ($mmol_c\ L^{-1}$) x 0.43, b = CO_3 + HCO_3 ($mmol_c\ L^{-1}$) x 0.7, c = 0.5 as a constant.

About 35-40 days old two/three rice seedlings/hill of variety Basmati -385 were transplanted by keeping row

Department of Soil Science, University of Agriculture, Faisalabad, Pakistan (E-mail: magill@dssuaf.fsd.brain.net.pk)

to row and hill to hill distance of 22.5 cm without puddling the soil. The H_2SO_4 was applied through fertigation. Fertigation is a method of applying any chemical mixed in irrigation water prior to the entry of water into field. FYM was applied @ 25 Mg ha^{-1} before planting the rice crops every year. Half of N as urea, all the P and K as single superphosphate and potassium sulphate, respectively were applied at the time of transplanting rice. The rest of N was applied in two equal splits 30 and 45 days after transplanting. All the experiment plots were irrigated with tile drain water from sump S1B9 (EC = 2.42-3.79 dS m^{-1}, SAR = 7.7- 29.0 and RSC = 4.0-11.0 $mmol_c$ L^{-1}, Ca : Mg = 0.37-0.43). Crops were planted in their normal seasons following uniform cultural practices for all the treatments.

After rice harvest, the wheat cv. Faisalabad-85 was sown in the residual moisture each year in December using seed rate of 100 kg ha^{-1} and row to row distance of 20.0 cm. Half of the N as urea, and full doses of P and K as single superphosphate and potassium sulphate, respectively were applied at sowing. The rest of N was applied with the second irrigation. Gypsum and H_2SO_4 were applied similarly as for rice but no FYM was added. Economic yields were recorded at harvest. The I, II and III crops of rice received 125, 120 and 136 cm of sump water while corresponding values for wheat were 38, 30 and 35 cm, respectively. Rainfall during these crops was 520, 500, 800 mm and 468, 600 and 669 mm, respectively. The data about soil analysis and crop yields were analyzed statistically following the RCBD.

3. Results and Discussion

3.1. Soil Physical Characteristics: Strength of the soil crust (SSC) increased with sump water and acid while decreased with gypsum and FYM (Table 1). After wheat 1995-96, surface strength (SSS) decreased, rate being maximum with gypsum followed by FYM, acid and sump water. The IR increased with gypsum but decreased with other treatments showing statistical differences. Before the studies, average SSC, SSS, IR and BD were 189-231kPa, 466-565 kPa, 1.05-1.20 cm h^{-1} and 1.56-1.75 Mg m^{-3}, respectively. A decrease in SSS or IR with sump water was because of its high EC, SAR and particularly RSC. Higher values of SSC with acid were due to activated decomposition of organic matter. Physical presence of gypsum particles tended to help reduce the SSS and increase the IR (Minhas, 1996). A decrease in IR, except with gypsum, was due to the ambient higher BD compared to that at the start of the study.

Table 1. Soil physical properties after wheat 1995-96 and changes over the original values in May 1993

Treatment	Soil Strength, kPa		Infiltration rate (cm h^{-1})	Bulk density (Mg m^{-3}) for soil depth		
	Crust(0-5mm)	Surface(0-5cm)		5-10 (cm)	20-25 (cm)	35-40 (cm)
Sump water	207ab (+10)	416a (-15)	0.60b (-50)	1.77 (+09)	1.72 (00)	1.71 (+01)
Gypsum	149b (-36)	295b (-37)	1.20a (+14)	1.72 (+10)	1.77 (+03)	1.75 (+02)
H_2SO_4	233a (+ 04)	443a (-17)	0.80ab (-26)	1.74 (+12)	1.76 (+01)	1.71 (+02)
FYM	162b (-16)	373ab (-34)	1.10ab (-08)	1.77 (-11)	1.76 (+01)	1.69 (+02)
LSD (0.05)	59.5*	131*	0.50*	Treatment= 0.05^{NS}, Depth= 0.04^{NS}		

Figures in parenthesis are per cent decrease (-) or increase (+).

3.2. Soil Chemical Characteristics

3.2.1. Soil electrical conductivity (EC_e): The EC_e was between 3 and 4 dS m^{-1} in the 0-15 cm which decreased gradually to ≈ 3 dS m-1 in the subsoil at the beginning of the experiment. After wheat 1995-96, EC_e increased considerably in the surface layer but changed little at 90-120 cm soil depth Treatments and depths differed statistically. In terms of % increase in EC_e, the treatment effect was in the order of gypsum, sump water, FYM and acid (Table 2). With all the treatments, except acid, there was slower increase in EC_e in the lower soil depths.

3.2.2. Sodium Adsorption Ratio (SAR): The soil had SAR between 13 and 16 at 0-15 cm soil layer during May 1993 and ≤ 12 at lower depths. After wheat 1995-96, the whole of soil profile attained SAR values > 13 which is the lower limit for the sodic soils (US Salinity Lab. Staff, 1954). Treatments and depths differed significantly. In terms of % increase in SAR by this time, the treatment effect was in the order of FYM, gypsum, acid and sump water (Table 3). The results have shown that by the time of rice (1994) harvest (data not presented), the soil attained an almost steady-state with the irrigation water. Thereafter, soil sodication started in response to high EC_{iw} inducing salt precipitation due to increased EC_e (Rhoades *et al.*, 1988; Minhas, 1996), SAR_{iw} and RSC_{iw}. Cultivation of rice - a high water

requirement crop, high water intake rates of the soil and/or applied amendments failed to completely arrest the sodication process. Of course, the rate of increase in SAR has been decreased by the treatments. For each treatment, SAR increased with soil depth. Hence additional management, like inclusion of canal water irrigation (blended and/or cyclic use) or higher rates of gypsum/FYM might be required to sustain the soil productivity for longer periods

Table 2. Soil EC_e after wheat 1995-96 and per cent increase over the original values in May 1993

Treatment	Soil depth (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
Sump water	5.19 (28)	4.88 (51)	3.44 (34)	3.54 (39)	2.66 (22)	3.94 ab (35)
Gypsum	6.36 (65)	4.74 (37)	3.55 (56)	3.27 (31)	2.84 (26)	4.15 a (43)
H_2SO_4	4.98 (01)	3.62 (00)	3.11 (14)	2.91 (09)	2.55 (08)	3.43 c (06)
FYM	5.51 (62)	4.03 (26)	3.13 (09)	2.86 (25)	2.52 (11)	3.61 bc (27)
Mean	5.51a(39)	4.32b(28)	3.31c(28)	3.15c(26)	2.64d(17)	

LSD (0.05): Treatment =0.368 *, Depth =0.41*. Figures in parenthesis are per cent increase.

Table 3. Soil SAR after wheat 1995-96 and per cent increase over the original values in May 1993

Treatment	Soil depth (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
Sump water	23.55 (73)	18.92 (75)	15.26 (71)	15.31 (68)	17.19 (102)	18.05a (78)
Gypsum	16.50 (12)	15.65 (40)	14.16 (48)	15.28 (76)	15.23 (66)	15.37b (48)
H_2SO_4	20.72 (36)	18.23 (45)	15.93 (52)	16.10 (53)	15.10 (57)	17.22a (49)
FYM	23.39 (49)	18.85 (58)	16.54 (57)	15.22 (37)	14.84 (39)	17.17a (48)
Mean	21.04a(43)	17.91b(54)	15.47c(57)	15.48c(59)	15.59c (66)	

LSD (0.05): Treatment = 1.23*, Depth = 1.37* Figures in parenthesis are per cent increase.

3.2.3. Soil Reaction (pH_s): The pH_s ranged from 7.0 to 7.7 at the start of experiment. After wheat 1995-96, pH_s increased to range from 8.0 to 8.5 with significant differences for treatments and depths (Table 4). An increase in pH_s was because of high RSC which increased the proportion of Na^+ in soil solution after the precipitation of $CaCO_3$ (Rhoades *et al.*,1988). A higher proportion of Na^+ promoted its adsorption onto cation exchange sites inducing an increase in pH_s (Oster, 1994). Acid treatment of water neutralized $CO_3^{2+} + HCO_3^+$ in irrigation water (Miyamoto, 1993) before their entry into the field to maintain high Ca^{2+} activity in soil solution. Gypsum supplied Ca^{2+} directly, while FYM did so through the evolution of CO_2 upon biochemical oxidation which formed H_2CO_3 to dissolve soil lime. Applied acid dissolved lime from the 0-15 cm soil to affect Ca^{2+} activity in solution. Originally the soil had 2.88- 4.20 % lime.

3.3. Crop Growth and Yield

3.3.1. Rice (*Oriza sativa* L.): There was a slight but gradual improvement in paddy yield with time with similar treatment effects (Table 5). This increase could be due to a slightly decreased soil IR (Table 1) in response to increased soil SAR which induced submergence - an ecological requirement of rice (Yoshida, 1981; Ghafoor *et al.*, 1985). However, soil SAR was still within tolerance limits of rice (Pearson, 1960) and same was true regarding the EC_e (Ayers and Westcot, 1985). Paddy yield was lower than the normal one because submergence could not be maintained in this well drained soil where nutrient losses in draining water and weeds growth adversely affected rice crop. Soils having high IR are not suitable for rice, although it provides drainable surplus, necessary for sustainable production of crops with poor quality irrigation waters.

3.3.2. Wheat (*Triticum aestivum* L.): Grain yields from the first two wheat crops were higher than those from the third one, with similar treatment effects (Table 5). The third wheat crop responded significantly, gypsum being the

best treatment followed by FYM, acid and sump water. Similar effectiveness of gypsum over H_2SO_4 has been reported by Ghafoor *et al.* (1986). A decrease in yield of the last wheat crop was due to low germination (data not presented) because of less residual moisture in soil at sowing time of wheat. Otherwise, SAR and EC_e values were within the tolerance limits of wheat in the 0-15 cm soil depth (Ayers and Westcot, 1985) from which crops meet their water and nutrient requirements up to the extent of 60-70% (Singh, 1989).

Table 4. Soil pH_s after wheat 1995-96 and per cent increase over the original values in May 1993

Treatment	Soil depth (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
Sump water	8.38 (18)	8.35 (17)	8.39 (16)	8.40 (18)	8.35 (17)	8.37 (17)
Gypsum	8.21 (07)	8.39 (18)	8.41 (18)	8.55 (19)	8.50 (19)	8.41 (16)
H_2SO_4	8.39 (16)	8.49 (20)	8.50 (19)	8.38 (17)	8.55 (19)	8.46 (18)
FYM	8.31 (15)	8.42 (19)	8.34 (15)	8.53 (20)	8.41 (14)	8.40 (17)
Mean	8.32b(14)	8.41ab(18)	8.41ab(17)	8.46a(19)	8.45a(17)	

LSD (0.05): Treatment = 0.08^{NS}, Depth = 0.094^{*}. Figures in parenthesis are per cent increase.

Table 5. Yields (kg ha^{-1}) of rice and wheat crops grown in a nonsaline-nonsodic field with tile drain water

Treatment	Rice 1993	Rice 1994	Rice 1995	W. 1993-4	W. 1994-5	W. 1995-6
Sump water	733	996	1118	4448	4458	3178b
Gypsum	1085	914	1244	4122	4472	3959a
H_2SO_4	644	946	1208	4508	4559	3501ab
FYM	630	1035	1319	4567	4642	3810a
LSD (0.05)	612^{NS}	536^{NS}	248^{NS}	820^{NS}	711^{NS}	469^{*}

In Tables 4 and 5, W stands for wheat.

3.4. Economics of Treatments

The expenditures and income were calculated for the quantities of amendments applied and produce obtained, respectively. Total income was maximum from FYM followed by gypsum, acid and sump water (Table 6). Net income was maximum from FYM followed by sump water, gypsum and acid. Use of acid for water treatment has already been found expensive (Ghafoor *et al.*, 1986). The FYM remained the best so far. More income was received from wheat than that from rice because of lower paddy yields.

Table 6. Economic evaluation of treatments of irrigation water from sump S1B9 (Figures in US $ ha^{-1})

Treatment	Income from							Net income	Expenditure
	Rice I	Rice II	Rice III	W-I	W-II	W-III	Total		
Sump water	93	156	175	500	502	407b	1833	1833	--
Gypsum	137	142	194	459	503	507a	1942	1619	323
H_2SO_4	81	148	189	502	513	449ab	1882	457	1425
FYM	80	162	206	508	522	488a	1966	1856	110
LSD (0.05)	76.9^{NS}	74.6^{NS}	38.8^{NS}	91.4^{NS}	69.8^{NS}	60.0^{*}			

3.5. Conclusions: Keeping the soil health and crop growth in view, gypsum proved better for counteracting the adverse effects of high water EC, SAR, RSC and/or low Ca:Mg ratios than acid or FYM. Gypsum proved to be an economical ameliorant to use. However, if casual irrigation with sump SIB9 water is given, FYM application will be very useful under the socio-economic conditions of Pakistan. Rice proved unsuitable crop for these well drained soils.

References

Ayers, R.S. and D.W. Westcot. 1985. Water quality for agriculture. Irrig. and Drainage paper 29. FAO, Rome, Italy.

Eaton., F.M. Undated. Gypsum requirement of water . In: Report of Water Quality Committee. WRC , CA, USA.

Ghafoor, A., S. Muhammed and N. Ahmad. 1985. Reclamation of the Khurrianwala saline-sodic soil. Bull Pak. Council of Res. in Water Resources. 15: 23-28.

Ghafoor, A., S. Muhammed and G. Mujtaba. 1986. Comparison of gypsum, H_2SO_4 HCl and $CaCl_2$ for reclaiming the subsoiled calcareous saline-sodic Khurrianwala soil series. J. Agric. Res. 24: 179-183.

Klute, A. 1986. Methods of soil analysis. Part. 1. Agron. 9. Soil Sci. Soc. Am. Madison, WI, USA.

Mian, M.A. and M.Y.J. Mirza. 1993. Pakistan's soil resources. Environ. and Urban Affairs Div., Govt. Pak., Islamabad.

Minhas, P.S. 1996. Saline water management for irrigation in India. Agri. Water Management. 30:1-24.

Miyamoto, S. 1993. Potentially beneficial uses of inland saline waters in the South-Western USA. p. 407-422. In: H. Leith and A. Al Masoom (eds.) Toward the Rational Use of High Salinity Tolerant Plants (Vol. 2). Kluwer Academic Publishers, The Netherlands.

Mohtadullah, K., C. A. Rehman and C.M. Munir. 1993. Water for the 21st century. Envrion. and Urban Affairs Div., Govt. Pakistan, Islamabad.

Oster, J.D. 1994. Irrigation with poor quality water. Agric. Water Management. 25: 271-279.

Pearson, G.A. 1960. Tolerance of crops to exchangeable sodium. USDA Inf. Bull. 216, Washington, D.C., USA.

Rhoades, J.D., F.T. Bingham, J. Letey, P.J. Printer Jr., D. Lemert, W.J. Alves, G.J. Hoffman, J.A. Replogle, R.V. Swain and P.G. Pacheco. 1988. Reuse of drainage water for irrigation: Results of Imperial Valley study. Hilgardia. 56:1-44.

Singh, N.T. 1989. Salt-affected soils: Some reflection on the state of knowledge. J. Indian Soc. Soil Sci. 37: 620-644.

US Salinity Lab. Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handb. 60, Washington,D.C.

Yoshida, S. 1981. Fundamentals of rice crop science. The Int. Rice Inst., Los Banös, Laguna, Philippines.

沙漠研究 7S, 171-174 (1998)
Journal of Arid Land Studies

APPLICATION OF SALT PREDICTION MODELS IN IRRIGATED ENVIRONMENT FOR DIFFERENT FIELD CONDITIONS

Muhammad Latif[1], Sultan Mahmood[2] and Sajid Mahmood[2]

Abstract: Salinity build up in the root zone profile depends upon the soil type, quantity and quality of irrigation water applied, initial salt and water contents in the root zone. Modelling of root zone salinity profiles have been studied with the help of theoretical based piston flow and partially mixing salt flow models for different field conditions. Results of the study shows that original piston flow model underestimates salt profiles compared to the observed data, and is ineffective under different field conditions. But results of the partially mixing salt flow and improved piston flow models were satisfactory.

Key Words: Root zone, Salinity, Modelling and Comparison

1. Introduction

Pakistan has the largest contiguous irrigation system in the world serving an area of over 16 million ha. This large scale irrigation development has brought great prosperity to the nation but due to salanization, irrigated agriculture in the indus plain of Pakistan is facing many problems of serious nature that are hampering the full productive potential of land and water resources. Salinity occurs not only because of insufficient rainfall or irrigation water available to leach down the salts but also because of high evaporation rates essentially from shallow saline groundwater. Restricted drainage further contributes to salinization of soils by causing high groundwater levels.

Installation of drainage system is not an easy task, because it needs lot of investment. Fortunately, modelling of the complex processes and interaction have made rapid progress and overcome many problems. Therefore, it is of paramount importance that before installing any drainage system, the field behavior should be tested with the help of suitable salinity model. Keeping this in view, Piston Flow Model (PFM) and Partially Mixing Salt Flow Model (PMSF) were used for predicting the influence of irrigation with different quantities and qualities of water on the rootzone salinity profiles under farmers' fields.

2. Theoretical Overview of the Models

2.1 Piston flow model (PFM)

Position flow model simulates irrigation water application in the soil, similar to a piston entering in a cylinder. Almost all the air and water in the pores are displaced and replaced by the entering water, while the entering irrigation water does not mix with the displaced water already present in the root zone. This approach was used to calculate soil salinity after irrigation. Soil salinity after irrigation depends upon the soil moisture before irrigation, electrical conductivity (EC) of soil before irrigation, amount and EC of the irrigation water, water content at field capacity and the soil moisture deficit. Dinar et al. (1986) was among the first researchers to introduce this model. This is actually a mass balance based model of salt transport to calculate soil salinity after irrigation. The equation reads as:

$$EC_{a1} = \frac{EC_0 + I.\ EC_i - [I - .(\theta fc - \theta_0)]\ .EC_0}{\theta_{fc}} \qquad (1)$$

[1] Director and [2] Graduate Students, Centre of Excellence in Water Resources Engineering, University of Engineering & Technology, Lahore, Pakistan.

where EC_{sl} = EC of soil water after irrigation (dS/m)
EC_o = EC of soil water before irrigation(dS/m)
θ_o = depth of water contained in the root zone before irrigation (mm)
I = depth of irrigation water applied (mm)
EC_i = EC of irrigation water (dS/m)
θ_{fc} = volumetric water content at field capacity (mm)

2.2 Partially mixing salt flow model (PMSF)

When soil is irrigated, the greatest amount of water is retained in the upper part of the root zone where plants' extraction and soil evaporation are the most. More leaching also takes place in the upper parts. The rain or applied irrigation water fills the root zone to field capacity, the excess water percolates downward leaching residual salts. The applied water mixes with the soil water already present in the upper root zone, but the ECs of these waters are different. EC of the soil can be calculated from the amount of water leached from the root zone when irrigation is applied and soil physical properties. The final modified form of the equation is (Latif, 1988):

$$D = (I - ET) \cdot \left[\frac{\theta_{fc} - ET}{\theta_{sat}}\right] \cdot \left[\frac{\theta_{fc} - ET}{\theta_{fc}}\right] \qquad (2)$$

where D = depth of water displaced from a layer (mm)
I = depth of irrigation water entering the soil layer (mm)
ET = depth of water excavator from the layer since last irrigation filled the soil to field capacity (mm)
θ_{fc} = volumetric water content at field capacity (mm)
θ_{sat} = volumetric water content at saturation (mm)

Water passing one layer becomes the water entering the next layer. The total depth of the root zone for a mature crop was divided in to layers of fixed thickness. Eq. 2, was used to calculate water displaced from the remaining soil water. Total water leached from any layer was calculated from water balance. The EC of the soil water was calculated by using the soil water remaining in the layer at the time of water application, the amount retained from the irrigation water, the undisplaced water and their ECs. Also the EC of the drainage water was calculated by using the amount of water displaced from the remaining soil water, and the total water passing through the layer and their ECs. Total salts leached from the root zone was calculated from the amount of water leached below and its EC.

3. Study Site and Data

Data was taken from Saeed (1990). The experimental site comprised of seven fields. All the factors including soil type, fertility level, crop variety, and all other water and non-water inputs were almost same in the plots except salinity. A hard pan was present in the root zone of plots 2 and 4 which were severely affected by salinity while plots 5 and 6 were slightly and moderately affected by salinity respectively. Wheat crop was grown in these fields and a total of four irritations were applied during the wheat season. The type of soil is categorized as silt clay to sandy loam. Root zone of each plot was divided into six layers of equal thickness. The water label depth varies from 5 to 6 meters below the ground surface. Average EC of irrigation water varies from 0.67 to 0.81 dS/m.

3.1 EC Profile and Moisture Data

The EC and moisture data were collected before and after each irrigation, samples were taken on about 24-36 hours before irrigation while in case of after irrigation, samples were taken at field capacity. Samples were collected from 0-20, 20-40, 40-60, 60-80 and 100-120 cm depths.

4. Results and Discussion

Due to lack of space it is not possible to present the results in details. A brief account of the results are given herein and for more details, the readers are referred to Latif (1988), Mahmood (1994), and others.

4.1 Salinity profiles

Plot 1 The EC profiles predicted by original position flow (PFM), improved piston flow (IPFM) and PMSF models were compared with the observed data. Results of the original piston flow model show that EC of soil water after 2nd irrigation at all depth is 0.67 which was the EC of applied irrigation water. This may be due to the piston flow approach used in this model but it does not happen in reality. The results of the PMSF and IPFM are almost same as compared with the observed data.

Plot 2 In this plot, PFM model's results again show underestimation of EC profile as in plot 1 (Table 1) but the results of the PMSF and IPFM models closely matched the observed data points. The performance of IPFM and PMSF models was found almost the same as both of these models were following well the observed data. Somtimes both of these models slightly over- or underestimated which may be due to the salt uptake by plants, salt deposition or dissolation which are not considered in this study. From the above discussion it is concluded that the PMSF and IPFM models can be used successfully for predicting root zone EC profiles for irrigated agriculture.

Table 1. Comparison of observed and predicted EC profiles by PMSF, piston flow and improved piston flow models in Plot 2, ds/m.

	Layer No.	Observed	Calculated by PMSF	PFM	IPFM
	1	12.5	12.5	12.5	12.5
	2	12.2	11.7	0.67	12.03
	3	11.8	11.82	0.67	11.09
Ist IRR	4	9.6	9.72	0.67	8.37
	5	8.7	8.79	0.67	8.87
	6	7.8	7.14	0.67	7.05
	1	6.3	7.8	0.75	8.38
	2	8.8	11.94	0.75	12.32
	3	11.0	12.01	0.75	11.44
2nd IRR	4	10.3	9.87	0.75	10.30
	5	9.3	8.92	0.75	9.31
	6	8.0	7.65	0.75	7.56
	1	9.6	11.4	0.0	8.71
	2	12.5	12.35	0.38	12.85
	3	11.0	12.30	0.51	12.05
3rd IRR	4	10.8	10.09	0.56	10.96
	5	8.8	9.12	0.56	10.96
	6	7.7	8.25	0.59	8.31
	1	10.0	13.04	0.80	9.2
	2	11.0	12.71	0.65	13.30
4th IRR	3	3.7	12.57	0.64	12.53
	4	3.7	10.31	0.64	11.48
	5	6.2	9.31	0.64	10.55
	6	6.3	8.88	0.64	8.90

4.2 Salt balance

To further verify the performance of the PMSF and IPFM models, salt balance for different fields were calculated and results of the PMSF model are given in Table 2 as an example. Once again, it was found that both the models performed well for different fields. Thus it is concluded that both the above models can be used with confident to model EC profiles in crop rootzone.

Table 2. Salt balance for the PMSF model, (tons/ha).

PT NO	INPUT		TOTAL INPUT	OUTPUT		TOTAL OUTPUT	BALANCE
	INS*	SIRR		SL	RZS		
1	27.6	1.34	28.94	1.19	29.61	30.81	1.86
2	26.38	1.494	27.88	1.046	24.82	25.86	-2.01
3	21.70	1.29	23.0	1.128	26.90	28.03	5.03
4	6.62	1.426	8.05	0.95	5.94	6.89	-1.16
5	3.36	1.56	4.92	0.92	4.94	5.86	0.94
6	11.17	1.556	12.73	1.128	11.89	13.01	0.29
7	10.45	1.408	11.86	1.06	10.16	11.22	-0.64
F3	5.26	4.8	10.09	4.48	6.07	10.56	0.466

* INS = Initial salt in the root zone (tons/ha), SIRR = Salts added by irrigation water (tons/ha), SL = Salts leached down of root zone (tons/ha) and RZS = Final root zone salts (tons/ha)

5. Summary and Conclusions

In this study modelling of root zone EC profiles were studied with the help of piston flow and partially mixing salt flow models. Realistically these models employ different approaches of salt transport. The working principle of the mixing salt flow model is that water enters the soil, the incoming water mixes up with the water already present in the root zone. Whereas in the piston flow approach incoming water does not mix but it pushes down and replaces the water already present in the root zone. The results of partially mixing salt flow are in good agreement with the observed data. Therefore this model can be used to predict root zone salinity profiles but the original piston flow model was found to underestimate EC profiles. Thefore, the original piston flow model was modified and the results of the improved model were better and matched well with the observed data.

References

Ayer,R. S. and Westcot, D. W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper No.29. Food and Agriculture Organization of United Nations, Rome Italy.

Dinar, A., Knapp, K. C. and Rhoades, J. D. 1986. Production function for cotton with dated irrigation quantities and qualities. Water Resources Research, Vol.22(11): 1519-1525.

Latif, M. 1988. Water management for crop production in a dynamic conjunctive use system, Ph. D. dissertation, Utah State University, U. S. A.

Latif, M. Mahmood, S. and Mahmood, S. 1996. Modelling root zone salinity behaviour in irrigated environment. Research Report No. 10, CEWRE, Publication No. 085, U.E.T, Lahore, Pakistan.

Saeed, M. 1990. Effect of soil salinity on moisture deficit and yield of irrigated wheat. M.E. thesis Asian Institute of Technology, Bangkok, Bangkok, Thailand.

沙漠研究 7S, 175-178 (1998)
Journal of Arid Land Studies

Calcium Losses During Reclamation of Medium-textured Low CEC Saline-Sodic Soils

G. Murtaza, A. Ghafoor, A. M. Ranjha and M. Qadir

Abstract - Efforts were made in a lysimeter experiment to quantify the leaching of unreacted Ca^{2+} during reclamation of a saline-sodic soil. In polyvinylchloride (PVC) pipes (40 cm long, 5 cm internal diam.), 30 cm soil columns were prepared using 3.5 kg clay loam soil (pH_s = 9.97, EC_e = 14.63 dS m^{-1}, SAR = 130, CEC = 7.83 $cmol_c$ kg^{-1}, lime = 5.40% , organic carbon = 0.25%). Agricultural grade gypsum was applied @ 0, 50, 75 and 100% of the soil gypsum requirement (GR). Total amount of irrigation water was assessed as 6.15 x 10^{-2} ha-m for one megagram soil GR. Five successive leachings with canal water (EC= 0.29 dS m^{-1}, SAR= 0.54), each equivalent to one pore volume (PV) of soil column, were applied. At each leaching cycle, leachates were collected and analysed for Ca^{2+} and Na^{+}. The cumulative Na^{+} removed from the soil was maximal with gypsum @ 75% GR ≈ 100% GR followed by 50% GR and the control. The cumulative Ca^{2+} leached from the soil was maximal with gypsum @ 100% GR, followed by gypsum @ 75%, 50% GR and the simple leaching. The gypsum treatments significantly decreased the soil SAR and pH_s. Effectiveness of the gypsum treatments for soil reclamation was in the order: 100% GR > 75% GR > 50% GR > control. For reclaiming native salt-affected soils, cost effectiveness could be possible through increasing the Na-Ca exchange efficiency by controlling the soluble Ca^{2+} in soil solution either by split application of Ca-sources or using coarser grades of gypsum.

Key Words: Calcium, Leaching, Saline-sodic soil, Gypsum, Soil reclamation, Infiltration

1. Introduction

Understanding of Na-Ca exchange in saline-sodic soils is important during their reclamation, particularly of those soils formed in the presence of Na_2CO_3 and $CaCO_3$. Much of the investigations have been conducted on Na-Ca exchange under laboratory conditions which fall short of explaining some of the soil behaviors under field conditions. Discrepancies in Na-Ca exchange, even in the same soil series, are expected due to heterogenetic nature of parent material, soil development and complex nature of exchange colloids. The soils of Pakistan have lower CEC because of the dominance of illite type clay minerals (Ranjha et al., 1993) and low organic matter. Hence, high amounts of soluble Ca may not cause a proportional increase in the Na-Ca exchange during their reclamation and hence unreacted Ca^{2+} might get leached below the amendment receiving soil depth. The present study was planned in soil columns to study the composition of the leachates and the leaching losses of soil-applied Ca^{2+}.

2. Materials and Methods

The experiment was conducted in lysimeters on a calcareous saline-sodic soil. Composite soil samples were collected from A horizon of the soil (hyperthermic Aquic Haplargids). The soil samples were air-dried, ground, passed through a 2mm sieve and mixed thoroughly. Gypsum @ 0, 50, 75 and 100% of the soil GR was mixed well into soil of each lysimeter separately and filled (3.5 kg per lysimeter) in the special permeameters made of PVC pipes (40 cm long, 5 cm internal diam.). A wire gauze was fixed at the bottom of PVC pipes with the help of rubber bands. This wire gauze was covered with a thin layer of glass wool and that of sand (2.5 cm) to check the movement of clay in the leachate.

Pipes filled with soil were placed in a 30 cm deep water tub. This way, soil in each pipe was packed uniformly through soaking the pipes from under-neath. A plastic funnel was fitted at the bottom of each pipe. The treatments were replicated thrice. Total amount of irrigation water was assessed as $6.15x10^{-2}$ ha-m for one megagram soil GR which approximated to about 5PV. This calculated amount

Dept. Soil Science, University of Agriculture, Faisalabad-38040, Pakistan (E-mail magill@dssuaf.fsd.brain.net.pk)

of irrigation water was added in 5 splits. At beginning additional water equal to soil saturation percentage for soaking was also added. One PV water was calculated as:

One pore volume (PV) = [(wet wt. of soil - dry wt. of soil)/(oven dry soil wt. x water density)]100

Leachate was collected when 1PV of water infiltrated through the soil. After collecting the first leachate, water equal to 1PV was again added. In this way, five leachates were collected and analysed for Ca^{2+} and Na^{+}. Particle-size analysis of the soil was carried out by the Bouyoucos hydrometer method. The pH of the saturated soil paste (pH_s), EC of the saturation extract (EC_e), soluble $Ca^{2+} + Mg^{2+}$ and Na^{+}, exchangeable Na^{+}, lime percentage, cation exchange capacity (CEC) and gypsum requirement (GR) were determined by the methods of U. S. Salinity Lab. Staff (1954). After the completion, soil columns were sampled and analysed for pH_s, EC_e, soluble $Ca^{2+} + Mg^{2+}$ and Na^{+}, CEC, ESP and lime.

3. Results and Discussion

3.1. Leachate volume Maximum amount of water passed through the soil columns where gypsum @ 100% GR (796 mL) was applied, followed by gypsum @ 75% (780 mL), 50% GR (575 mL) and the control (551 mL). This could be due to the application of Ca^{2+} in the form of gypsum that caused flocculation of the Na^{+}-dominated dispersed soil (Shainberg et al., 1989; Qadir et al., 1996) which helped promote the infiltration rate (IR).

3.2. Calcium in leachate Removal of Ca^{2+} in the first leachate with gypsum @ 50% GR treatment was statistically similar to that from the control (Table 1). Later, Ca^{2+} removal in 2nd and 3rd leachates increased and thereafter decreased to the level to that from the control. Gypsum @ 75 and 100% GR resulted in high Ca^{2+} removal in leachates but generally attained a level similar to that of the control or gypsum @ 50% GR by the termination of experiment. With gypsum @ 100% GR, Ca^{2+} removal remained higher throughout. It could be inferred that Ca^{2+} released for gypsum @ 50% GR was maximally consumed in Na-Ca exchange where with gypsum @ 75 and 100% GR, Ca^{2+} remained higher than the amount permissible to replace adsorbed Na^{+} from soil because of low CEC (7.83 $cmol_c\ kg^{-1}$). However, higher release of Ca^{2+} improved infiltration and resulted in a significant decrease in SAR.

Total Ca^{2+} leached remained maximum with gypsum @ 100% GR followed by gypsum @ 75% GR, 50% GR and the control throughout the study period. It is concluded that lower Ca^{2+} in irrigation water or soil solution will improve the Na-Ca exchange efficiency, however, longer time will be required to achieve the desired level of reclamation as was recorded in the present studies.

Table 1 Effect of treatments on Ca^{2+} removal in leachate during reclamation of the soil

Treatment	Ca^{2+} removed ($mmol_c$)					
	L_1	L_2	L_3	L_4	L_5	Total
Control	1.19 c	0.53 c	0.23 c	0.25 c	0.18 c	2.38
Gyp. @ 50% GR	2.27 c	7.97 b	1.27 b	0.22 c	0.08 c	11.81
Gyp. @ 75% GR	10.23 b	7.10 b	0.65 bc	1.09 b	1.30 b	20.37
Gyp. @ 100% GR	15.67 a	12.57 a	5.37 a	5.17 a	2.44 a	41.22

Figures with same letter(s) in a column are statistically similar at P= 0.05. Gyp. = Gypsum L = Leachate
Ca^{2+} removed ($mmol_c$) = [Ca^{2+} concentration in leachate ($mmol_c\ L^{-1}$)] [volume of leachate collected (L)]

3.3. Sodium in leachate The results indicate that gypsum treatments resulted in removal of more Na^+ during the first leachate (Table 2). This efficiency decreased consistently in the subsequent leachates as the Ca^{2+} reservoir was depleting with time. Moreover, higher leaching of replaced Na^+ in the first leachate followed by second leachate caused a decrease in the sodicity hazard. At lower SAR, the efficiency of Na-Ca exchange decreased due to a decrease in statistical probability of exchange between Na^+ and Ca^{2+} (Shainberg et al., 1980). The integrated effect of these factors resulted in a rapid leaching of Na^+ during initial cycles from the gypsum treated soil columns.

The total Na^+ leached remained maximum with gypsum @ 75% GR ≈ 100% GR followed by 50% GR and the control throughout the study period. From this it could be inferred that split doses of gypsum could be added to sustain the Na^+ removal.

Table 2 Effect of treatments on Na^+ removal in leachate during reclamation of the soil

Treatment	Na^+ removed ($mmol_c$)					
	L_1	L_2	L_3	L_4	L_5	Total
Control	125.4 a	63.7 b	29.6 b	13.3 b	3.7 b	235.7
Gyp. @ 50% GR	26.7 b	112.0 a	80.5 a	31.1 a	12.0 ab	262.3
Gyp. @ 75% GR	128.7 a	106.0 a	39.5 ab	32.7 a	16.8 a	323.7
Gyp. @ 100% GR	131.3 a	95.7 a	35.0 b	37.8 a	20.3 a	320.1

Figures with same letter(s) in a column are statistically similar at P= 0.05. L = Leachate
Na^+ removed ($mmol_c$) = [Na^+ concentration in leachate ($mmol_c\ L^{-1}$)] [volume of leachate collected (L)]

3.4. Soil reclamation

3.4.1 Soil salinity Progressive desalination was observed with all the treatments but EC_e was still higher than the critical level of 4.0 dS m^{-1} in the control treatment (Table 3). The overall effectiveness of the treatments for decreasing EC_e was in the decreasing order of 75% GR > 100% GR > 50% GR > control with nonsignificant differences among the treatments. Gypsum application, helped sustain electrolyte concentration (Oster, 1982) which helped better leaching of soluble salts.

Table 3 Treatment effects on reclamation of the Khurrianwala soil after addition of 5PV of water

Treatment	EC_e (dS m^{-1})	SAR	pH_s	CEC ($cmol_c\ kg^{-1}$)	ESP	$CaCO_3$ (%)
Control	5.58	28.19 a	9.63 a	7.95	63.62 a	4.70(12.96)*
Gyp. @ 50% GR	4.08	24.79 a	8.88 b	7.46	51.94 ab	4.73(12.41)
Gyp. @ 75% GR	2.17	17.94 b	8.78 b	8.25	32.42 bc	4.76(11.85)
Gyp. @ 100% GR	3.32	14.22 b	8.45 c	8.61	25.91 c	4.78(11.48)
LSD (0.05)	6.27^{NS}	5.50*	0.22*	1.27^{NS}	19.53*	0.17^{NS}

*Figures in parenthesis indicate per cent decrease over the original values of $CaCO_3$ content of the soil
Original soil had EC_e = 14.63 dS m^{-1}, SAR = 130, pH_s = 9.97, CEC = 7.83 $cmol_c\ kg^{-1}$, ESP = 89, $CaCO_3$ = 5.40%

3.4.2 Soil sodicity Analysis of soil samples, after completion of studies, indicated a statistical decrease in SAR with the treatments (Table 3). The decrease being maximum with gypsum @ 100% GR which was statistically similar with gypsum @ 75% GR. Control and gypsum @ 50% GR were statistically similar with each other but significantly inferior to higher rates of gypsum. Statistically similar SAR with gypsum @ 75 and 100% GR reflects that with the later treatment, all the calcium from applied sources (gypsum, irrigation water, dissolution of lime) could not exchange with the adsorbed sodium because of illite type minerals where the exchange reactions are generally slow (Bear, 1964). Hence a lot of Ca^{2+} was recorded in leachates as discussed in the preceding section.

3.4.3 Soil reaction Effectiveness of the treatments to decrease pH_s was in the decreasing order of gypsum @ 100% GR > gypsum @ 75% GR> gypsum @ 50% GR > control (Table 3). A higher decrease in pH_s with the100% GR treatment than the others might have been due to sustained electrolyte concentration in soil solution for a longer time than the other treatments (U. S. Salinity Lab. Staff, 1954). Since Na^+ is considered a major ion elevating the pH_s (Ghafoor *et al.*, 1989), it's removal decreased pH_s.

3.5. Soil Lime The soil had 5.40% lime ($CaCO_3$). There was a small decrease in lime contents for all the treatments over the original values, however, the treatment effect was non-significant (Table 3). The observed decrease in lime appears to be due to accumulation of CO_2 which helped convert $CaCO_3$ to more soluble $Ca(HCO_3)_2$ (Robbins, 1986). Since Ca^{2+} in excess of Na-Ca exchange requirement and replaced Na^+ continuously moved out of columns in leachates, the consistent dissolution of native lime was a natural consequence to affect a decrease in lime. The slightly higher values of $CaCO_3$ with $CaSO_4$. $2H_2O$ @ 100% GR might be due to higher released Ca^{2+} from applied gypsum which depressed the dissolution of lime through common ion effects (Chaudhry and Haq, 1983).

4. Conclusions

All the treatments ameliorated the soil. Gypsum application significantly decreased the SAR and pH_s. Higher amount of unreacted Ca^{2+} passed through the soil when gypsum was applied @ 75 and 100% GR. Cost-effective reclamation of soils can be achieved through increasing Na-Ca exchange efficiency by controlling the soluble Ca^{2+} in soil solution by application of gypsum in split doses.

References

Bear, F.E. 1964. Chemistry of the soil. Reinhold Publishing Co., NY, USA. p. 310-314.

Chaudhry, A. and M.I. Haq. 1983. Effect of gypsum rate and fineness on precipitation of carbonates and bicarbonates in saline-sodic soils. Pakistan J. Soil Sci. 1: 25-28.

Ghafoor, A., M.M. Ahmad, N. Ahmad and S. Muhammed. 1989. Efficiency of gypsum grades and quality of leaching water for reclaiming a saline-sodic soil. II. Chemical improvement of soil. Pakistan J. Agri. Sci. 26: 313-321.

Oster, J.D. 1982. Gypsum usage in irrigated agriculture. a review. Fert. Res. 3: 73-89.

Qadir, M., R.H. Qureshi and N. Ahmad. 1996. Reclamation of a saline-sodic soil by gypsum and *Leptochloa fusca*. Geoderma. 74: 207-217.

Ranjha, A.M., S.M. Mehdi and R.H. Qureshi. 1993. Clay mineralogy of some selected alluvial soils of Indus plains. Pakistan. J. Soil Sci. 8: 3-7.

Robbins, C.W. 1986. Carbon dioxide partial pressure in lysimeter soils. Agron. J. 78: 151-158.

Shainberg, I., J.D. Oster and J.D. Wood. 1980. Sodium/Calcium exchange in montmorillonite and illite suspensions. Soil Sci. Soc. Am. J. 44: 960-964.

Shainberg, I., M.E. Sumner, W.P. Miller, M.P.W. Farina, M.A. Paran and M.A. Few. 1989. Use of gypsum on soils: A review . Adv. Soil Sci. 1: 1-11.

U.S. Salinity Lab. Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handb. 60, Washington, D.C., USA.