BIBLIOGRAPHIC DATA SHEET	1. CONTROL NUMBER PN-AAJ-823	2. SUBJECT CLASSIFICATION (695) AP10-0000-0000

3. TITLE AND SUBTITLE (240)
Non-agricultural uses of irrigation systems: household water supplies

4. PERSONAL AUTHORS (100)
Jones, B. J.

5. CORPORATE AUTHORS (101)
Agricultural Development Council, Inc.

6. DOCUMENT DATE (110)	7. NUMBER OF PAGES (120)	8. ARC NUMBER (170)
1981	166p.	628.72.J76

9. REFERENCE ORGANIZATION (130)
ADC

10. SUPPLEMENTARY NOTES (500)

11. ABSTRACT (950)

12. DESCRIPTORS (920)
Irrigation
Water resources
Water supply and health
Water management
Water use
Development strategy
Project planning
Water pollution
Health aspects
Pesticides
Water quality
Nutrition
Household
Disease vectors

13. PROJECT NUMBER (150)

14. CONTRACT NO.(140)
AID/otr-0082-A-00-10-88-00

15. CONTRACT TYPE (140)

16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

NONAGRICULTURAL USES OF IRRIGATION SYSTEMS:

HOUSEHOLD WATER SUPPLIES

Barbara J. Jones

Agricultural Development Council

June 1981

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In seeking ways to provide greater access to social services for the world's poor, innovative ideas and alternative approaches to conventional methods will have to be considered. This preliminary research on the non-agricultural uses of irrigation systems examines the feasibility of designing irrigation schemes to serve multiple water use demands. The extent to which irrigation systems can be used as a source of household water supply has been the specific topic explored through interviews and literature reviews. There is little consensus of opinion regarding design feasibility. Nor does there appear to be agreement about the extent to which irrigation systems are used as a source of household water supply. Literature on the subject is sparse and gives little indication of how extensive the combined use of agricultural and domestic water systems may be. Articles examining the types of sources used for household water supplies generally talk about ground water and surface water. Surface water generally refers to rivers or lakes. Only rare reference is made to irrigation canals as sources of surface water, or to wells situated close to channels for seepage and ground water.

The lack of consideration of this topic, as reflected in the paucity of literature, argue well for some in-depth investigation into the multiple uses of irrigation systems.

THE MAGNITUDE OF NEED

Will the U.N. Drinking Water and Sanitation Decade underway, consideration of the multiple uses of irrigation systems is a timely subject. The goals of the decade, to provide clean water and sanitation services to everyone by 1990, are formidable. Water must be provided to 2280 million people and sanitation facilities for 2390 million people. Thirty-one percent of the world's urban

population is without reasonable access to safe water and 25 percent is without access to an adequate means of sanitation. In rural areas the percentages without access to an adequate means of sanitation. In rural areas the percentages without access to safe water and sanitation facilities are 86 and 85 percent respectively. (R.M. Bradley) The cost of providing conventional water and sanitation services is staggering and prohibitive: approximately $60 billion for water supply and $300 to $600 billion for sewerage.* (Kalbermatten et al.) Alternative approaches, therefore, will be essential to realize the Decade's goals at affordable cost.

Because priority has often been placed on economic development rather than the delivery of social services, water development has tended to favor irrigation schemes rather than community water supplies in rural areas. Certainly the critical food situation facing the world makes the development of cultivatable land and increased agricultural production necessary. Increased population pressure also brings greater demand for household water supplies. The greater the population density, the more critical the health needs for water and sanitation facilities become. The health and economic functions of domestic water supplies and irrigation systems are intricately interwoven. While their purposes are not the same and they are thus planned as separate systems, it is difficult to completely break apart their functions.

Consideration should be given to the agricultural and domestic functions of water resources to see how they differ and where they overlap. On the agricultural side, irrigation contributes to food production, essential for nutrition and health benefits. This is also the employment side of the picture, either

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* Estimates are based on 1978 per capita costs.

directly through cultivation or in related agricultural activities. On the other side, domestic water use affects the prevalence of water-related diseases which directly contributes to (or detracts from) health and nutritional status. The labor productivity of the work force is affected by its health and nutritional status and will thereby improve or constrain employment capacity and efficiency.

In view of recognizing the relationship between agricultural production and domestic use and mindful of the high financial costs of developing separate water sources, is it possible to design new or modify old irrigation systems to satisfy both functions? What problems are involved? What benefits might be realized?

WATER RESOURCES DEVELOPMENT

Most research documenting the health aspects of irrigation systems has usually focused on the irrigation system as the cause of various health problems. Indeed, there is good reason for this focus. Schistosomiasis has greatly increased in areas where perennial irrigation schemes have been introduced and is now a major health problem in much of Africa, the Caribbean, Southeast Asia, Brazil and Egypt. Various diseases, i.e. cholera, typhoid and infectious hepatitis, are easily transmitted via irrigation waters to individuals within the local area or to other communities through various means of water contact and use.

While the health hazards associated with irrigation systems have been well researched and documented, the potential health benefits have not received the same attention. There is virtually no literature in which a positive relationship between irrigation and health is discussed. It is necessary, therefore, to examine

the literature on water and health in general and try to extrapolate some general principles for their applicability to questions regarding the use of water from irrigation systems for household use and health impact.

Cost-effective, engineering design feasibility and quality requirements may determine whether or not to design an irrigation system with household water use in mind. Where financial resources are limited, the careful delineation of goals to be achieved through a water supply program is essential for the most effective use of those resources. Richard Feachem has identified several stages of goals and benefits (Table 1) and three factors which will contribute to their achievement.

1). According to the goals of a water supply project an engineer can design a system with an appropriate combination of improvements for water quantity, quality, availability and reliability.

2) The cost-effectiveness of the design can be examined and compared with alternative designs.

3) National and regional development may proceed incorporating the goals into the planning process.

The basic aim of an improved water supply in low-income communities is to reduce the cost of water to consumers. The cost of water consists of:

1) any cash payments made to a water authority, vendors, standpipe owner, etc.;

2) the value of time and energy expended to procure water when water is not supplied to the house;

3) the cost of illness caused by the use of insufficient quantities or poor quality water or to diseases contracted during the trip to get water. Particularly in rural areas cash payments are the least likely to be present or to be changed by improvement of water supplies, so cost reductions are most likely to be

achieved through time/energy savings and through health improvement.

By determining the benefits that may accrue from a system of a particular design, priorities for financial allocation can be established. These will be based on the water-related costs that a low-income community must bear and which communities may most likely reduce those costs by a given per capita investment in water supply improvements. The planner may then make an informed determination as to which communities bear the greatest hardship due to water costs and where investments by the government may produce the best return. (Feachem, 1977)

Table 1 Aims and Potential Benefits of Water Supply Improvements

Immediate aims	Stage I benefits	Stage II benefits	Stage III benefits
Improve water: quality quantity availability reliability	Save time Save energy Improved health	Labour release Crop innovation Crop improvement Animal husbandry innovation Animal husbandry improvement	Higher cash incomes Increased and more reliable subsistence Improved health Increased leisure

Note: The horizontal alignment has no significance.

THE WATER AND HEALTH RELATIONSHIP

For centuries a relationship between water and health has been recognized although specific water-related disease mechanisms were not well understood. By classifying diseases into categories according to their means of water-related transmission, David J. Bradley has made a major contribution to the understanding of the water and disease relationship.

Through the use of this water-related disease taxonomy it is possible to see how a particular disease is transmitted through water supplies and what types of improvement in the supply may reduce its spread. (Tables 2,3,4).

For years standard wisdom held that clean water was necessary for good health and that polluted water was the cause of many illnesses. While there is a good bit of truth to that, it is now generally accepted that various diseases, particularly those of the eyes and skin and some diarrheas are subject to reduction or control through the use of larger quantities of water regardless of quality. (Feachem, 1977; Carruthers) Because irrigation schemes are designed to deliver a large volume of water, they may be an effective means to increase the quantity of water available for household use in low-income communities with poor access to other water sources. There are definitely problems of quality to be considered in using such a source for household supply, but effective treatment methods may be a solution and will be discussed later. The quality versus quantity issue needs to be dealt with first, however.

Water quality standards as set by the World Health Organization are increasingly considered to be too stringent for application in developing countries where limited financial resources make it impossible to design and construct high-level water and sanitation facilities. Strict adherence to the WHO standards would cause many water supply sources to be condemned and may be partially considered to blame for constraining the development of water supplies in developing countries. Recognizing that the standards for water quality are too high, they are currently in the process of being revised.

Table 2 Classification of infective diseases in relation to water supplies

Category	Examples	Relevant water improvements
I Water-borne infections		
(a) Classical	Typhoid, cholera	Microbiological sterility
(b) Non-classical	Infective hepatitis	Microbiological improvement
II Water-washed infections		
(a) Skin and eyes	Scabies, trachoma	Greater volume available
(b) Diarrhoeal diseases	Bacillary dysentery	Greater volume available
III Water-based infections		
(a) Penetrating skin	Schistosomiasis	Protection of user
(b) Ingested	Guinea worm	Protection of source
IV Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	Water piped from source
(b) Breeding in water	Yellow fever	Water piped to site of use
V Infections primarily of defective sanitation	Hookworm	Sanitary faecal disposal

Table 3 A classification of water-related diseases

Category	Example
1. Faecal–oral (water-borne or water-washed)	
(a) low infective dose	Cholera
(b) high infective dose	Bacillary dysentery
2. Water-washed	
(a) skin and eye infections	Trachoma, scabies
(b) other	Louse-borne fever
3. Water-based	
(a) penetrating skin	Schistosomiasis
(b) ingested	Guinea worm
4. Water-related insect vectors	
(a) biting near water	Sleeping sickness
(b) breeding in water	Malaria

(Feachem et al, 1977)

Table 4 Water-related diseases with their water associations and their pathogenic agents

Water-related disease	Category from Table 2	Pathogenic agent
Amoebic dysentery	1b	C
Ascariasis	1b	D
Bacillary dysentery	1b	A
Balantidiasis	1b	C
Cholera	1a	A
Diarrhoeal disease	1b	H
Enteroviruses (some)	1b	B
Gastroenteritis	1b	H
Giardiasis	1b	C
Hepatitis (infectious)	1b	B
Leptospirosis	1a	E
Paratyphoid	1b	A
Tularaemia	1b	A
Typhoid	1a	A
Conjunctivitis	2a	H
Leprosy	2a	A
Louse-borne relapsing fevers	2b	E
Scabies	2a	H
Skin sepsis and ulcers	2a	H
Tinea	2a	F
Trachoma	2a	B
Flea-, louse-, tick- and mite-borne typhus	2b	G
Yaws	2a	E
Clonorchiasis	3b	D
Diphyllobothriasis	3b	D
Fasciolopsiasis	3b	D
Guinea worm	3b	D
Paragonimiasis	3b	D
Schistosomiasis	3a	D
Arboviral infections (some)	4b	B
Dengue	4b	B
Filariasis	4b	D
Malaria	4b	C
Onchocerciasis	4b	D
Trypanosomiasis	4a	C
Yellow fever	4b	B

A = bacteria; B = virus; C = protozoa; D = helminth; E = spirochaete; F = fungus; G = rickettsia; H = miscellaneous.

(Feachem et al, 1977)

Because financial and human resources are limited in developing countries, provision of perfect water supply systems will be impossible. Thus the need for improved systems which can deliver the best service with the available resources. This is the basis for the suggestion (Kalbermatten,et al) that sanitation improvements be made by a sequenced approach. It is also the basis for criticism of the WHO quality standards. Additionally, as water needs become more critical it is imperative that ways of satisfying those needs are developed. Dual-purpose irrigation systems may be one way to address critical water needs and may serve as another example of incremental improvements in service as the best use of financial resources.

Tables 2 and 3 indicate the water-related disease categories and the types of water supply improvements necessary to control them. (Note that in Table 3 Feachem has added a "Fecal-Oral" category to D.J. Bradley's original classification in Table 2.) The fecal-oral category is the most difficult to deal with as these diseases may be water-borne or they may have other transmission routes putting them in the water-washed category. This makes it difficult to decide on the most appropriate supply design. Improvements in quality would affect the water-borne component of the fecal-oral diseases and also guinea worm and schistosomiasis where they are endemic. Increasing the quantity of water available would affect those fecal-oral diseases related to hygiene. These will predominantly be diarrheal diseases caused by fecal contamination of food from soiled hands during food preparation, dirty nipples and hands of lactating mothers, etc. The nonfecal-oral water-washed diseases are most likely to be prevented by quantity improvements as they are related to hygiene practices. Water-based diseases of schistosomiasis and guinea worm will, as previously mentioned, be most susceptible to quality improvements from protection of the water source.

Gastrointestinal diseases are the major public health problems in many developing countries. Research on diarrheal diseases, typhoid and cholera has not shown a positive relationship between improved water quality and the incidence of disease. There are several possible explanations: the diseases may not primarily be water-borne and children who have the highest prevalence of diarrheal disease do not properly use improved water supplies.

Studies show that where water availability has been improved for communal washing and laundry or through house connections there has been a decline in water-related disease. These results were found in studies on shigellosis in California and schistosomiasis in St. Lucia. In rural Bangladesh seasonal prevalence of diarrheas is highest during the periods of low water availability, making a credible argument for increasing water quantity. Scabies also present serious health problems in Bangladesh.

Improvements in water quality are important for the reduction of water-borne and water-based diseases. A disease like schistosomiasis which is transmitted percutaneously rather than through ingestion could also be controlled by eliminating body contact with infected water as well as improving the quality of that water. (Briscoe; Feachem et al, 1977 and 1978; G.F. White)

Despite improvements in quality or quantity, however, health benefits are likely to remain elusive in the absence of other supporting factors. It has been found that water is necessary but not sufficient ingredient for improved health. (Burton; Feachem et al, 1978; Saunders and Warford) Personal and domestic hygiene, storage, water-use patterns and sanitation all determine, to some degree, whether water supply improvements will contribute to the realization of health benefits. Health education is, therefore, an essential component of a water supply improvement program if improved health is one of the goals being sought. (Feachem et al, 1977; McGarry; Elmendorf & Buckles)

Water use patterns play a significant role in the transmission of particular diseases, as illustrated in a study of cholera prevalence in the Matlab area of Bangladesh. The unexpected findings showed little difference in cholera infection rates between tubewell and nontubewell users. In searching for an explanation were various hypotheses formulated all of which centered on the effect that water use and consumer preference could have on cholera infection. Despite the installation of tubewells, surface water continued to be the preferred source for drinking, particularly among children and for cooking because of the high iron content in the area's ground water. (Although water use data for other parts of the country are few, the available information suggests that ground water is usually used for both cooking and drinking.) Surface water was generally used for laundry and bathing. The amount of gargling and cleansing of the body orifices which takes place in this predominantly Muslim country may also contribute to cholera infection. (Briscoe; Isley)

Poor personal and domestic hygiene habits also limit the health impact of improved water sources. Increased or more effective use of water may be difficult to encourage particularly in areas where there is not a germ theory explanation of disease. In such areas proximity and easy access may be highly valued factors for a water source, thereby rendering a good quality source at an inconvenient distance a poor investment. (Elmendorf and Buckles) It is known that installation of taps in a house will result in a three to four-fold increase in per capita water use. There is little information, however, regarding the volume of water use where supply improvements are more limited. While it might be expected that a standpipe or well situated closer to a dwelling than the traditional source would result in increased water usage, this may not be the case. Again the reason may be preference for the taste of water from the old source, the new standpipe or well may be inconveniently located or a long wait in a

queue may discourage more trips to retrieve greater quantities of water. (Dworkin & Dworkin, 1980; Feachem et al 1978; Carruthers)

The way in which water is stored after being drawn from a clean source will determine whether or not it remains of good quality. Water stored in open containers is likely to be contaminated by insects or debris. Dirty hands or vessels used to dip the water from a storage jar will repeatedly contaminate the water.

In 16 rural villages of Gujarat, India, it was found that the length of storage time and the type of storage container were important factors for improving and maintaining water quality. In this area brass and copper vessels are commonly used for in-house water storage due to the belief that water stored in such vessels is good for health. A comparison was made between the metal vessels and earthenware pots for effectiveness of reducing coliform count. The study results showed that a minimum of 24 hours of storage was necessary to effect a drop in coliform count. Forty-eight hour storage in the metal vessels reduced the count further. Hand contamination of the water in metal caused no rise in coliform count after 48 hour storage. While the earthenware pots did reduce coliform count slightly after 24-hour storage, the metal vessels were much more effective (10 MPN/100 ml in 24 hours The water was safe for drinking in 24 hours and maintained that quality after 48 hours. The study is useful for presenting a relatively inexpensive and easy way to improve water quality during in-house storage by the use of metal pots. (Desai et al.) Clay pots may be preferred in some areas, however, because their porous texture cools the water by evaporation.

Improvements in water supply without simultaneous improvement of waste disposal are not likely to produce any health benefits. Because so many diseases

are spread by fecal contamination of water, it is impossible to separate water-related diseases and sanitation. Some diseases such as hookworm would also be affected by sanitation improvements alone as transmission is from feces to soil to human skin penetration. (Bradley; McGarry)

The need for sanitation in rural areas has not been considered as great as that in urban areas. Lower population density and natural assimilation of wastes have meant less environmental pollution in rural areas. The lack of sanitation poses a potentially significant problem, however. In rural areas where the bulk of the population relies primarily on one water source or on surface water for household supplies, contamination will cause community-wide infection.

Irrigation schemes raise both the potential for health benefits and health problems depending on how well the schemes are planned and what other services are planned simultaneously. Gilbert F. White maintains that it is possible to pump irrigation water to tube wells and provide abundant, good quality water at reasonable cost. He also maintains that the installation of sanitation facilities <u>before</u> the construction of an irrigation system is necessary to make the area less vulnerable to vectors and intermediate hosts of disease. If not carefully planned, the development of an irrigation system will cause increased health problems as population density increases and as newcomers introduce new diseases into the area. (G.F. White, 1978; Pescod)

Just as water supply improvements need to be planned to get the optimum benefit at the most affordable cost, so too with sanitation improvements. A sequenced approach, designed for maximum health benefits at minimized cost is advocated by various engineers. In this way sanitation improvements can be designed according to consumer preferences, available financial resources and

personal hygiene habits. As these change over time facilities may be subsequently upgraded.

There is quite a range of effective, low-cost sanitation methods available. The choice of alternatives should be based upon hygiene practices, geographic and climatic factors, cost, location, etc. (Pescod; Yager; Kalbermatten et al.)

NUTRITION AND CONVENIENCE BENEFITS OF IMPROVED WATER SUPPLIES

Any discussion of health benefits, whether related to water supply or some other means of improvement is limited by the difficulty of quantifying those benefits. While industrial and agricultural projects produce quantifiable outputs, household water supply projects do not result in "products." How is it possible to determine the health benefits attributable to water supplies and sanitation when other factors such as nutritional status and nonwater-related diseases also affect health? Labor productivity may be one possible indicator. But, how is it possible to determine the health effect upon labor productivity of exclusively water-related diseases? (Carruthers; Prescott; Kalbermatten et al)

In addition to improved health, time and energy savings are ways to reduce the cost of water to consumers. Surveys in West Africa have shown that up to five hours per day in the dry season may be spent collecting water for household use. Reports from East Africa show that people may spend anywhere from 46 to 264 minutes per day on water carrying chores. (White, Gilbert F. et al, 1972) Feachem suggests that the benefits of time/energy savings from improved access to water supplies can be quantified in several ways. "Express the time and energy spent in water collection as a percentage of the total

available daytime time and energy. These percentages may be calculated for the existing situation, and for the anticipated situation following the construction of an improved supply, and so a meaningful measure is obtained of the impact of the scheme on the water collection journey." Another method places a monetary value on water carrying chores by figuring how much staple food must be consumed to produce the number of calories needed to retrieve water. (Feachem, 1977)

Improved nutrition may be another benefit of increased quantities of household water supply. When it is for the cultivation of kitchen gardens household food consumption may increase. This is particularly important in areas where people are suffering from marasmus or protein-energy malnutrition. Diarrheal diseases and malnutrition are cyclical, each contributing to the severity of the other.

Fecal contamination of the external and home environments is related not only to intestinal infection but to gastrointestinal alterations and malabsorption. Research conducted in Guatemala suggests that gastrointestinal alterations are influenced by nutritional status as well as the presence or lack of nonspecific diarrhea. The findings presented indicate that the alterations are widespread in areas characterized by a high prevalence of malnutrition, diarrheal disorders and poor sanitation.

Studies on absorption have shown that 40-51 percent of rural adult males have a decreased capacity to absorb nitrogen, calories and fat from their normal diet. These men lose through feces 200-300Kcal/day per individual more than the average fecal excretion among healthy Guatemalan males. In conjunction with the marginal diet normally consumed by the study subjects, this fecal loss represents a serious burden to health and nutritional status and to physical

capacity for work. (Schneider et al)

IRRIGATION WATER FOR HOUSEHOLD WATER USE

Where people have a choice of water sources there is evidence that one type of source may be used for certain household tasks while a different source will serve different needs. This was found in Bangladesh where both ground water and surface water are available in abundant supplies. The water drawn from wells was used for drinking (unless taste due to mineral content made it unpleasant) and cooking, while canal, river, tank and other sources of surface water were used for bathing and laundry tasks. In other countries, as previously mentioned, factors of preference such as convenience, and abundance influence the choice of source. Perceived quality of the source also determines preference, but may be judged in terms of taste, temperature, odor and appearance rather than bacterial content. Where convenience of the source is highly valued, the proximity of the source regardless of quality may determine use. In several regions of Kenya, little or no increase in water use was found after improved supplies had been installed. Reasons included: 1) the outlet was located on the opposite side of the farm from the house; 2) the distance to the new communal tap was greater than to the traditional source; 3) the new source was contaminated. Reasons 1 and 2 both relate to factors of convenience while 3 is a judgment about quality. (Carruthers; A.U. White)

Choices of source development and treatment

To reiterate an earlier discussion, reduced consumer cost for water is a basic aim of water supply improvements and can be realized through benefits of

improved health or time and energy savings. The dominant issues in the realm of health will be the quantity and quality of the water supply. The degree of treatment that may be needed to make a water source of sufficient quality for human intake will be a factor in quality determination. For time/energy savings the issues relate to consumer preferences and perceptions of convenience and/or quality. With these issues in mind, is it possible to make a determination on whether to develop household water supplies through surface water and how might an irrigation system be used? Certainly the investment cost to the government is going to be a critical factor in determining the use of either type of water source. These other issues, however, may help predict what the reduced consumer costs will be and what type of water supply system has the greatest chance of success, thus making the investment worthwhile.

Ground water has often been the preferred source for development of community water supplies and may be a particularly effective source in smaller communities. But, where the population is growing the demand for water may begin to exceed the capacity of ground water supply. Surface water then becomes the more economic and effective source. (McGarry)

Where the water table is relatively high people will make use of it for shallow wells. Ground water is often clean enough for household use without treatment. Indeed, that has been a major advantage of ground water sources. However, any well can become contaminated if not protected: if a pump breaks down and is replaced by a bucket and rope, etc. Contamination is also possible where latrines are improperly located too close to the well. (Pit latrines should be at least 30 meters away from a well.)

As sources of surface water, rivers, lakes, streams and irrigation systems have the advantage of often providing abundant quantities of water for household use. However, surface sources may be easily polluted. Unless the rate and distance of flow are sufficient to allow adequate aeration, disease pathogens may be easily transmitted through a river or irrigation canal to communities along the way. With the health benefits of increased water quantity being recognized and as population pressure demands water sources of greater volume, the use of surface water may have to be carefully considered as a cost-effective (for government and consumer) way to provide essential community services.

An open canal irrigation system can be used like a river to provide a source of water for household use as well as agricultural use, thereby making it a dual-purpose system. The health problems associated with irrigation systems such as schistosomiasis and malaria are well-known and well-documented. Planning an irrigation system, however, to function as a dual-purpose system may necessitate special design features to prevent health problems, rather than relying on after-the-fact attempts to cure or control resultant health problems.

Gilbert F. White has suggested that irrigation systems designed to supply water for household use may enhance conditions for health improvements through: 1) increased water availability; 2) nutritional benefits due to agricultural production; 3) development of new settlements in irrigated area provides opportunity for planning housing and health care facilities; 4) the general improvement in living standards due to increased economic activity provides the most effective deterrent to the major cause of disease - poverty. White stresses that beneficial health effects from irrigation do not occur on their own, but

must be carefully planned. Likewise, the detrimental health impact of irrigation systems can be prevented or controlled if the system is carefully designed with health considerations in mind.

The increased volume of water available from an irrigation system for household use is an important health effect in areas where water is scarce. Improved water quality is likely to occur as well because water pumped from the irrigation system to tube wells is often of adequate quality for drinking. Good quality water should be obtainable at minimal cost if the tube well is tight, taps are maintained and drainage is adequate.

In areas where houses are quite far removed from the cultivated fields, and particularly where cultivation takes place in a valley or depression where houses are located on the hills, a dual-purpose system may cause problems. The conveyance system from the fields to the houses is likely to be expensive as well as difficult to install and maintain. A pump would be necessary which will increase costs, energy usage (if a motorized pump is used) and maintenance problems. In such a circumstance it may be more appropriate to install a separate household water supply by drilling deep wells if necessary.

Water drawn off irrigation canals either through feeder canals or a pipe mechanism will have to be treated. Water drawn off through tube wells located adjacent to the canals, where they use a combination of groundwater and canal seepage will be less likely to need treatment. The pathogenic organisms likely to be present in the water should determine the treatment method and will vary in complexity and cost. As a preliminary step water storage may be a simple and inexpensive means of reducing pathogen concentra . Some

organisms such as Ascaris eggs, and amoebic cysts may be reduced by settlement. The schistosome miracidae cannot survive more than 24 hours without finding a snail host and upon leaving the snail the schistosome cercariae must infect a human host within 48 hours. Viruses and bacteria are also subject to reduction through storage and settlement, particularly in sunlight where ultraviolet rays damage the nucleic acids of the organisms. Storage tanks may also act as reservoirs during dry seasons and provide a continuous source of water. (Evison and James)

There are some potentially serious health problems to be considered in connection with storage, however. Any body of standing water in the tropics may provide a suitable breeding habitat for mosquitoes which carry malaria. Stagnant water is also the breeding ground for snails, the intermediate hosts of schistosomes.

Slow sand filtration also provides an effective and relatively inexpensive treatment method. This method of filtration is advantageous in that it requires minimal management or maintenance and can use unskilled labor. By passing raw water through sandbeds particles are removed thus treating it mechanically by filtration and biologically by bacterial decomposition of trapped organic material. (Pickford; McGarry; Reid & Coffey)

Use of Bradley's classification for decision-making

Rather than using the traditional classification of water-related diseases as bacterial, protozoal, helminthic and viral, Bradley has re-categorized the diseases according to their mode of transmission and has thus provided an important tool for policy and planning decision-making. Any planning for water supply improvements should make use of this taxonomy.

It should be possible to compile an epidemiologic profile of an area indicating endemic diseases, incidence and prevalence rates, seasonal characteristics and severity of illness to establish some hierarchy of diseases. Identification of water-related diseases within the hierarchy, their transmission modes and means of control may be determined by Bradley's taxonomy. The category of water-related disease of the most consequence to the health of the community can be identified. Alternative engineering designs based on appropriate quality or quantity considerations, sources of available water supply, treatment requirements and sanitation facilities may then be proposed.

This may be an ambitious way to design a water supply stem, but if the objective is cost-effective investment for improving health, it may prove useful. Where health problems can best be ameliorated by having increased quantities of water available, an irrigation system appropriately designed may be the most accessible source of water for household use.

Dual-purpose irrigation systems

The scarce literature concerning dual-purpose irrigation systems provides little information about their effectiveness in supplying water for household use. The lack of literature and the lack of consensus among professionals working on water resources development in various organizations make it impossible to determine how widespread the design and use of dual-purpose irrigation systems may be.

The Haryana project in India and Gal Oya project in Sri Lanka are two irrigation projects which have been utilized for domestic water supplies. However, documentation of the projects concerning household usage is limited. There is little supporting discussion of how well the systems have worked, whether they have been used as planned, whether they deliver adequate quantities of water for household use without interfering with irrigation uses, etc.

The fact that people use irrigation canals as sources of household water whether or not the system has been intended to serve that purpose, has been established through observation and documented in the literature. Given that the canal is an established source of household water supply, it would seem reasonable to invest in methods of conveyance and/or treatment that would improve the quality of the water.

CONSTRAINTS ON THE DEVELOPMENT OF RESOURCES

A major problem in the allocation of financial resources and investment in household water supplies and sanitation facilities has been inadequate justification of intended benefits based on quantifiable data. Water and sanitation are essential for improved health, but how those benefits can be quantified, or how much time will pass before benefits begin to accrue, are questions which remain largely unanswerable. (Carruthers, Cvjetanovic, Kalbermatten et al)

The main constraints on operation and use of a water supply and sanitation system are likely to be caused by maintenance problems. It is estimated that 30-50 percent of water installations are out of commission within 3 to 5 years after construction. (Burton) Reasons for this vary, but breakdown of the

pumping mechanism is common. The simplest system is generally best, but even simple devices require upkeep. Lack of trained local people for maintenance, inadequate attention from government water authority workers and poorly designed pumps all contribute to mechanical failures. Fuel shortages are a cause of shut-down in systems which depend on a motor-driven pump. Administrative and management problems also plague the system and cause them to fall into disrepair. (Pacey; Burton; Saunders & Warford; Dworkin, 1980)

Organizational difficulties are another stumbling block of water systems, be it an irrigation system or a community water supply. What would be the additional organizational problems of a dual-purpose system? Would the problems be compounded by having two different interest groups involved? Would one use of water i.e., irrigation be perceived as more important with those users (farmers) being more powerful or dominant in a users association? Would women participate in the users association? How would fee schedules be determined and how would payments be made.

Participation in a water supply program often involves some financial investment on the past of the community and individual users, giving rise to another problem. For women who have little control over the use of household income, participation in a community water supply improvement program may be difficult or impossible. In households where the finances are dominated by a man, the husband's approval would be a prerequisite for a woman to become involved in a household water supply system. Where community labor is a factor in construction of the water system, the village men will usually have to be involved. (A.U. White; Elmendorf & Buckles)

Government agency responsibility for water supply is often a complicated situation. There may be several agencies or ministries involved in rural water supply programs, but for slightly different purposes, or in different size areas or regions. While a multiple agency approach may be effective in some places, it is often suggested that better management, reduced repetition and more effective resource allocation could be achieved if water supply programs came under the rubric of one agency.

The objective of a rural water supply program might be the determining factor in deciding what agency should be charged with responsibility. Other agency members should be involved in some type of advisory board to get the benefit of their expertise, but control would rest with one agency. This is not likely to be the situation when rural water supplies will be furnished through a dual-purpose irrigation system. This system is almost certain to involve the Ministry of Agriculture and other ministries with some related jurisdiction as well as the agency (or agencies) responsible for rural water supplies. It is unlikely, therefore, that the dual-purpose system will simplify government level administrative and organizational functions.

Division of responsibility between central government and local agencies is often problematic and must also be considered. The planning and resource allocation may be the domain of the central government and local agencies may be most effectively charged with building and running the water supplies. As discussed previously local authorities are hindered in their efforts by inadequate staff, the inaccessibility of some areas, limited transportation, etc.

There is certainly no ideal combination of agencies or organizational structure to resolve the administrative difficulties which accompany water supply programs. Choosing the right agency to oversee a program intended to

achieve an identified goal may help promote cooperation and reduce duplication of effort. (Saunders & Warford; Feacham et al, 1978)

CONCLUSIONS

Based on the available literature and interviews, it is not possible to make any conclusive statement about the feasibility or desirability of designing irrigation systems to provide household water supplies. The range of professional opinion and organizational experience seems too varied and the literature too scarce to accurately know how widespread the use of dual-purpose irrigation systems may be and how effectively they can satisfy the water needs of people.

However, four main categories of issues emerge which could "make or break" the feasibility of a dual-purpose system: 1) engineering considerations; 2) investment costs; 3) administrative and organizational arrangements; 4) convenience and health benefits.

1) Engineering considerations. Not all types of irrigation systems would be appropriate sources of household water supply. For those systems that are, however, methods of lifting, conveyance and treatment are the main design considerations. Storage and sedimentation tanks which are simple and low-cost will provide a supply of water during periods when the irrigation system is closed. Slowsand filtration is also a very effective, yet fairly simple and inexpensive form of treatment. Chlorination is often advocated as a simple form of disinfection for a well or storage tank. Tube wells dug parrallel to canals can take advantage of seepage and ground water and benefit by the natural filtering process through the earth.

Gravity systems are simpler than pumped systems and less prone to maintenance problems. Pumps which are motor driven are subject to mechanical problems. Their use is also dependent upon the availability of fuel, an expensive item for poor communities.

It appears, therefore, that under certain circumstances engineering capabilities assure the feasibility of a dual or multi-purpose irrigation system. The technology used, however, must be carefully chosen to make the system function effectively, providing water of adequate quantity and quality. Simplicity in system design and treatment method should be utilized as much as possible.

2) Investment costs. Whether or not a dual-purpose system will be planned and constructed may ultimately depend on cost. While no figures are available, it has been suggested that drilling wells in reasonable proximity to dwellings will probably be less expensive than the lifting, conveyance and treatment necessary for converting irrigation water to household water usage. While that may be true in some areas, in others topographic conditions and location of houses in relation to irrigated land may make a dual-purpose system financially and technically feasible. The perfect system is not the objective, but rather one that is a substantial improvement over existing water sources. Additional improvements in the quality, quantity and availability of water and sanitation services may be phased in over time as the community can afford to pay more and comes to want more.

The construction costs of a dual or single purpose irrigation system or a village water supply system can be quantified. However, social costs are less readily calculated and are often excluded. Irrigation systems designed and built without adequate environmental protection are likely to impose addi-

tional costs in the form of serious health hazards to surrounding communities. The long-term costs of environmental contamination and disease which might otherwise be alleviated by improved water and sanitation facilities, should also be considered.

4) Administrative and organizational arrangements. Problems with organization and administration affect the user and the administrative agency. At the community level it is difficult to involve beneficiaries in the design of a system. How will water be equitably distributed and fees be fixed and collected? How will maintenance problems be solved? Will a dual-purpose system merely compound existing administrative problems?

As village water supply programs have suffered from administrative and management problems caused by different agencies with differing goals, would a dual-purpose system also suffer those problems?

5) Convenience and health benefits. Improved health and time and energy savings are the most common goals of water supply projects. Water available in greater quantity and in closer proximity to dwellings will free significant amounts of time for women. This would make more time available for productive labor, child care, food preparation, etc. Energy required for water retrieval could also be used in more productive pursuits.

Diarrheal diseases are the predominant water-related diseases and the leading cause of death in children 5 years old and under. These diseases are most susceptible to improvement through increases in the volume of water used. Although treatment raises the cost and complexity of a system, quality improvements are possible with simple treatment methods. Despite treatment and quality improvements, water is likely to become contaminated once it is drawn

and stored in the household. This is an additional argument for making increased water quantity the priority where incremental system improvements are the only choice. Limited financial and human resources demand that aspirations for the best available system be replaced by more realistic expectations for incremental improvements. In many, but not all, areas this means that increases in the quantity of water available is more likely to have a positive effect on water-related disease rates than would quality improvements. Therefore,an irrigation system designed to deliver large quantities of water may be a reasonable source of water supply to be accessed for household use.

The cyclical nature of diarrhea and malnutrition is also a critical health factor to be addressed by increased water availability. Control of diarrhea is essential for improving the nutritional status of all age groups, but is a crucial element for lowering the infant mortality rates.

Equal importance must be placed on improvements in sanitation facilities, which can be incrementally improved to prevent fecal contamination of water supplies. Without proper waste disposal irrigation canals, rivers, ponds, etc. will be the repository for human excreta, thus easily transmitting numerous diseases via water. Direct infection of individuals with fecal material will also be eliminated by proper disposal.

Health education and promotion of improved water supplies and latrines are necessary ingredients for increased and effective water use and the realization of health benefits. Unfortunately these programs have often been neglected. Patterns of water use are often little understood by planners and health educators, resulting in health education programs that are poorly designed and ineffective. The education (or re-education) process is slow and shows few quick results.

Generalizations about the feasibility and desirability of promoting dual-purpose water supply systems versus separate irrigation and village water supply systems are difficult to make. Geographic and climatic differences and the availability of water resources should determine the type of system and cost of installation. The same type of system planned for one geographic region may require a different level of financial investment in another region. Culture will also dictate consumer preferences for system design and use as well as perceptions about health and illness. The roles of men and women in society will influence how they may participate in community water organizations. Traditional societal roles will also influence the extent to which people may be involved in problem identification, design suggestions and decision-making.

A technology applicable in one area, therefore, may or may not be appropriate in another. The variables are numerous, at times unwieldy, and not given to generalizations. Technical failure can sometimes be corrected through design improvements. However, the technical failures due to organizational, institutional or cultural factors are of equal importance and necessary to understand for future improvements and success.

RECOMMENDATIONS

1) In many countries people draw water directly from irrigation canals to serve their household requirements because this is the most convenient or preferable source. While the practice may not be universal, it is sufficiently widespread to warrant greater recognition.

2) Poor maintenance and operation limit the effectiveness of household water systems. Innovative approaches to this problem such as training women

for upkeep and maintenance may be a partial solution. Women are the ones using the system every day and would know when adjustments or repairs are necessary. They are also the people with a vested interest in continuing service from a convenient supply. While it may be that in some areas cultural norms will not permit women to perform maintenance tasks, this is not likely to be the case everywhere. There may be some long-term self-generating effects also for as women involve their daughters in water retrieval chores, they may teach them maintenance tasks as well. The maintenance problems of a dual purpose system are likely to be more complicated than those of a single purpose system. Whether maintenance tasks can be divided between men and women according to their respective usage demands remains to be seen. More research into maintenance approaches should be undertaken.

3) Greater understanding of water use patterns and perceptions of health and hygiene are necessary for appropriate and effective health education and promotion efforts. Greater attention and financial support for health education may increase the effectiveness of water systems.

4) Water user associations in dual purpose water systems need to be researched and documented. How do they function, what problems are encountered which do not arise among single-purpose user groups? How do the landless get access to water rights in a dual-purpose system?

5) Donor institutions must become more sensitized to the fact that there are noneconomic benefits such as improved health which elude quantification. As population pressure mounts the search for ways to provide reliable and adequate quantities of water may have to be based on some other reasoning than investment costs and financial returns. To ignore the importance of household water supplies and sanitation systems because they do not produce quantifiable health improvements within a few years will invite greater problems in the future. Disease control and environmental protection are essential elements to achieve the objectives of long-term economic development.

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