PRACTICE OF WASTEWATER MANAGEMENT

Shakuli Saxena

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CHAPTER 1

A BRIEF INTRODUCTION OF WASTEWATER MANAGEMENT

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ABSTRACT:

A crucial component of contemporary urban infrastructure and environmental care is wastewater management. This abstract offers a succinct summary of the complex problems and potential solutions related to wastewater management. Wastewater creation grows as global urbanization picks up speed, presenting serious dangers to the environment and human health. The collection, treatment, and ethical disposal or re-use of wastewater are all parts of effective wastewater management. In order to combat impurities, including organic matter and dangerous chemicals, advanced treatment methods have been developed, protecting ecosystems and human health. There are various advantages to effective wastewater management. It first reduces water pollution, protects aquatic ecosystems, and makes sure that supplies of drinking water are safe. It also promotes public health by reducing the spread of waterborne illnesses. Thirdly, it preserves freshwater resources by reusing treated wastewater for a variety of non-potable uses and relieving pressure on finite supplies. However, issues with insufficient infrastructure, a lack of resources, and the effects of climate change present difficulties for wastewater management. Sustainable wastewater management requires cutting-edge legislation, infrastructure spending, and increased public awareness.

KEYWORDS:

Environment, Management, Pollution, Water, Wastewater.

INTRODUCTION

Wastewater is water that has undergone physical, chemical, or biological changes as a consequence of the addition of specific compounds, making it unfit for drinking or other uses. Man's daily activities rely heavily on water, thus they release "waste" into the water. Body wastes i.e. feces and urine, hair shampoo, hair, food scraps, fat, laundry detergent, fabric softeners, toilet paper, chemicals, detergent, home cleansers, dirt, and microorganisms that may harm the environment and make people sick are a few of the items. It is well known that a significant portion of the water provided ends up as wastewater, making its treatment crucial. To promote a safe environment and excellent public health, wastewater treatment is the technique and procedure utilized to eliminate the majority of toxins contained in wastewater. Therefore, wastewater management refers to the treatment of wastewater in a way that preserves the environment while promoting public health, economic, social, and political stability [1], [2].

Water Treatment History

Despite the fact that drainage systems were constructed well before the eighteenth century, wastewater treatment is a relatively modern activity. Before this, "night soil" was collected in buckets along streets, which were then filled with "honey wagon" tanks by employees. This was dispersed across agricultural grounds and delivered to rural communities. Flushing toilets increased the amount of waste produced on these agricultural fields in the nineteenth century. Cities started using drainage and storm sewers to transport wastewater into water bodies as a result of this transportation difficulty, going against Edwin Chadwick's 1842 suggestion that "rain to the river and sewage to the soil." Waste disposal into waterways caused severe pollution and health issues for people downstream. In Hamburg, Germany, an English engineer by the name of Lindley created the first "modern" sewerage system for the transportation of sewage. The principals of the Lindley system are being followed today, with the main improvements being better materials and the addition of manholes and sewage appurtenances. Only until the water bodies' assimilative capacity was surpassed and health hazards grew unacceptable did the need for wastewater treatment become obvious. Before the procedures we use today were tested in 1920, a number of alternatives were explored throughout the late 1800s and early 1900s. But up to the mid-20th century, its design was empirical. Systems for centralized wastewater management were developed and promoted. Communities that discharge into the facility are responsible for paying for wastewater treatment. Great strides have been made in the creation of portable water from wastewater today. Nowadays, before discharge permits are given, a minimum treatment level is necessary, independent of the capacity of the receiving stream. The emphasis is now changing away from centralized systems to more sustainable decentralized wastewater treatment, particularly for developing nations like Ghana where traditional techniques are difficult to administer and wastewater infrastructure is subpar [3], [4].

Purposes for Treating Wastewater

Because of the aforementioned factors, wastewater treatment is very important. More importantly, the Reduction of environmentally harmful biodegradable organic chemicals: Organic substances like carbon, nitrogen, phosphorus, and sulphur in organic matter need to be broken down by oxidation into gases that are either released into the atmosphere or stay in solution. Reduction in the amount of nutrients in the environment: Nutrients from wastewater, such as nitrogen and phosphorus, enrich the environment and make water bodies eutrophic, which encourages the development of algae and other aquatic plants. These plants hinder aquatic life by reducing oxygen levels in bodies of water. Pathogens are organisms that cause illness in plants, animals, and people. Because they are too tiny to be seen with the human eye, they are sometimes referred to as microorganisms. Microorganisms include bacteria, viruses, fungi, protozoa, and helminthes.

DISCUSSION

According to Awuah and Amankwaa-Kuffuor, these microorganisms are expelled in significant amounts in the feces of diseased people and animals. Water is a limited resource that is often taken for granted. Population growth over the latter part of the 20th century put strain on the already limited water supply. The rural aspect of many places has also been altered by urbanization. A rising population necessitates the cultivation of more food, and as agriculture already consumes the vast majority of the water resources, economic expansion is imposing further demands on them. Due to the overuse of groundwater resources, the regional and temporal distribution of water is also a significant concern. Because of these factors, recycling and reuse are essential to sustainability.

Treatment levels for wastewater

Treatment is divided into three categories: primary, secondary, and tertiary. Sometimes, initial therapy comes before main treatment.

1. **Preliminary treatment**

The first treatment eliminates grits and gritty suspended matter. Screening and grit chambers, respectively, may get rid of them. This improves the maintenance and operation of succeeding treatment units. At this stage of the treatment process, flow monitoring tools, often standing-wave flumes, are required.

2. Primary treatment

The first stage of treatment involves skimming floating materials and sedimenting settleable organic and inorganic substances. At this stage, it is possible to remove up to 50% of BOD5, 70% of suspended particles, and 65% of grease and oil. Heavy metals, organic phosphorus, and organic nitrogen are also taken out. However, at this point, the elements that are colloidal and dissolved are not eliminated. Primary effluent, according to FAO, is the effluent from primary sedimentation units.

3. Secondary treatment

In order to remove suspended particles and residual organics, primary effluent is subjected to secondary treatment. Utilizing aerobic biological treatment procedures, biodegradable organic debris that is dissolved and colloidal is also eliminated. When nitrogen, phosphorus, and harmful microbes are eliminated, organic debris is also removed. The treatment may be carried out mechanically, such as with trickling filters or rotating biological contactors for activated sludge, or non-mechanically, such as with anaerobic treatment, oxidation ditches, stabilization ponds, etc [5], [6].

4. Tertiary treatment

When certain wastewater elements that cannot be removed by secondary treatment need to be removed, tertiary treatment or advance treatment is used. Significant levels of bacteria, viruses, heavy metals, biodegradable organics, nitrogen, and phosphorus are eliminated by advanced treatment. Secondary effluent may be adequately filtered using both the older membrane materials and the typical sand filter. A few filters have been enhanced, and helminths are removed by both filters and membranes. The most recent technique is disk filtration, which filters water using large cloth media disks mounted to spinning drums. At this point, water may be disinfected to current international standards for agricultural and urban re-use by injecting chlorine, ozone, and ultraviolet radiation. Types pf wastewater can be described as in the below Figure 1.

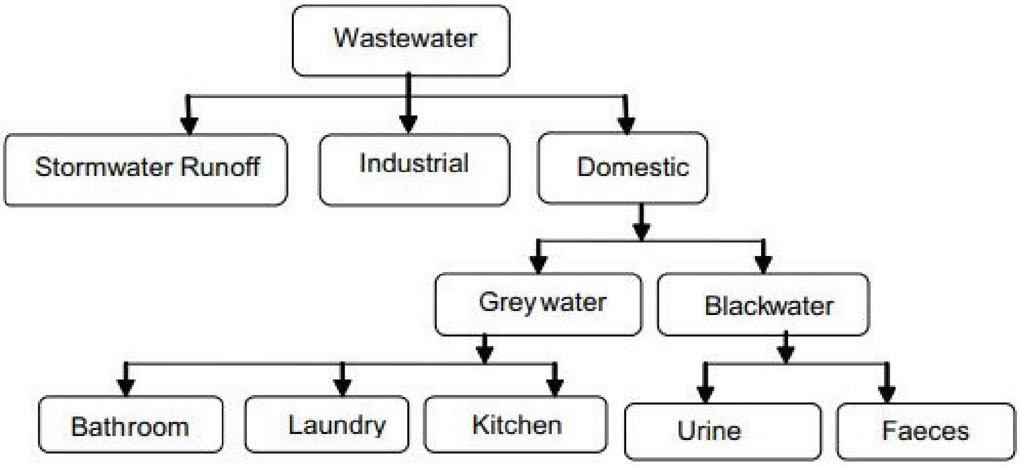

Figure 1: Types of Wastewaters.

Reusing Wastewater in Agriculture

Wastewater is effectively disposed of as in slow-rate land treatment via irrigation, which serves as both disposal and usage. Prior to being utilized for aquaculture, agricultural, or landscape irrigation, raw municipal wastewater must often undergo some kind of treatment. The minimal reapplication treatment standard needed for wastewater irrigation in many developed nations is primary treatment. If wastewater is used to irrigate non-human food crops, orchards, vineyards, and certain processed food crops, it can be deemed to have undergone adequate treatment. The nutrients in treated effluents and municipal wastewater are particularly advantageous as additional fertilizers. Adopting the right tactics targeted at improving crop yields and quality, preserving soil productivity, and protecting the environment will be crucial to the success of utilizing treated wastewater for agricultural production. For a certain set of circumstances, a combination of the available possibilities will provide the best outcome. Prior knowledge of the effluent supply and its quality should be available to the user. Either normal water or wastewater effluent may be utilized. It has sometimes been discovered that heavy metal concentrations in streams used for irrigation in and around metropolitan areas like Accra and Kumasi are higher than what is advised for irrigation purposes, which should raise health concerns. Countries must establish and implement standards that are consistent with the WHO recommendations [7]–[9].

Treatment of Industrial Wastewater

Generally speaking, the characteristics of the wastewater generated by that industry determine the kind of plant that should be erected. However, according to Kamala and Kanth Rao, the fundamental idea is waste avoidance via appropriate housekeeping practices, which would eventually lead to a decrease in volume and strength. Industrial wastewater is treated using the same preliminary, primary, secondary, and advanced treatment stages as household or municipal sewage. The majority of the therapeutic techniques mentioned are also useful. However, there could be oddities with certain industries depending on their main contaminant, for example, heavy metals, dye, etc. Breweries, distilleries, textile, chemical, and pharmaceutical industries, as well as institutions, hotels, and businesses located mostly in Accra and Tema, all produce industrial wastewater in Ghana. Mining operations predominate in Ghana's western and central regions, where they are the main cause of river pollution. The EPA-Ghana issues permits to businesses and mandates that businesses establish or construct an internal waste treatment facility.

These industrial wastewater treatment facilities provide samples to EPA-Ghana on a quarterly basis for testing in their own labs for monitoring reasons. Although not all of those with permits have treatment plants, the majority of them do. Small-scale businesses that process fruits and other foods have sprung up in the Tema light industrial region recently, but they lack the funding to construct treatment facilities. The majority of these small-scale businesses discharge their effluent untreated into neighboring drains. The two breweries, a soft drink bottling facility, and an abattoir are the main sources of industrial wastewater in Kumasi.

The condition of Ghana's wastewater treatment facilities

On-site treatment systems are used relatively often. Septic tanks used for private residences and communities are favored. The effluent from septic tanks only partly treats sewage and still contains a lot of organic matter. The septic tank has to be cleaned out sometimes, and disposing of the sludge has a serious negative impact on public health and the environment, especially in metropolitan areas. Major wastewater treatment technologies found in Ghana comprise stabilization ponds, trickling filters and activated sludge plants. In Ghana, there are 46 wastewater treatment facilities, according to a recent study. The Greater Accra area, namely the capital city of Accra and the port city of Tema, is home to more than half of all treatment facilities in Ghana. There are no treatment facilities at all in the Brong Ahafo and Upper West areas. The stabilization pond approach is the one that is most often utilized, being used in almost all faecal sludge and large-capacity sewage treatment facilities. Most trickling filters and recorded activated sludge systems are limited capacity private businesses like bigger hotels. Only 10 of the treatment facilities are now in use, and it is unclear if these facilities fulfill EPA effluent standards. This is due to the energy dependence of traditional technologies and the high maintenance costs associated with importing replacement mechanical components when they break. However, low-tech, low-cost approaches can be controlled [10], [11].

Wastewater Management Difficulties

Although not technically challenging, wastewater management might sometimes confront socio-economic difficulties. Below are some of the difficulties mention:

1. Infrastructure

Most of the time, governments do not prioritize sewage infrastructure, and as a result, very little money is invested in it. However, since practically all of the water generated is wasted, wastewater infrastructure must be given the same importance as water treatment facilities.

2. Water source pollution

The effects of wastewater discharge on receiving water quality are significant; they alter the aquatic ecosystem through changing the aquatic environment. Our meal includes salts, minerals, trace elements, and carbonaceous materials, which are also found in our urine and feces. Chemicals, medications, and, more recently, hormones are also dumped into the wastewater treatment facility. Discharge regulations must be followed to the letter. Water supplies will remain sustainable as a result for future generations. The precautionary and polluter-pays principles, which help avoid or decrease wastewater pollution, have been shown to be quite effective in developed nations and need to be adopted there as well.

3. Choosing the right technology

Donors provide the majority of the funding for wastewater treatment facilities since the economies of most developing nations are donor-driven. They often suggest the technology that ought to be used for this purpose. since of this, when the beneficiaries take control of the facility, managing its operations and maintaining its components becomes fairly difficult since the technical know-how, electricity needs, etc. are not sustainable.

4. Production of sludge

Sewage sludge is created as a consequence of wastewater treatment. A trustworthy technique of disposal is required. The hazards associated must be taken into account if it must be utilized in agriculture. It is sometimes thought that heavy metal deposition in soil from agricultural usage might contaminate crop yields due to the presence of heavy metals in wastewater [12], [13].

5. Reuse

Aquaculture and irrigation of farmlands are two examples of agricultural uses for effluents that fulfill discharge criteria. The difficulty is that reuse becomes problematic if wastewater treatment facilities are not controlled and continually observed to maintain adequate effluent quality.

CONCLUSION

We cannot live without water, thus wastewater has always been and always will be a part of our lives. When the provided water is utilized for the many human activities, it either gets polluted or has its qualities altered, becoming wastewater. Wastewater may and must be treated in order to promote public health and a safe environment. There are both conventional and unconventional methods of treating wastewater, and the decision on which method to use should be based on a number of factors, including the characteristics of the wastewater, whether it comes from a municipality or an industry chemical, textile, pharmaceutical, etc., the technical know-how required for operation and maintenance, the potential financial impact, and the amount of power needed. Low-tech, low-cost techniques like waste stabilization ponds have been effective in most underdeveloped nations like Ghana, although trickling filters and activated sludge systems have failed. When discharge regulations are met, effluent may be utilized for irrigation and aquaculture. Even though waste water management has certain difficulties, they may be overcome with the right attention and financial backing.

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CHAPTER 2

AN OVERVIEW OF WASTEWATER AND SLUDGE USE IN DEVELOPING COUNTRIES

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ABSTRACT:

The chapter defines concepts related to the usage of wastewater and sludge before highlighting their worldwide drivers and importance using examples from various developing nations. It is important to distinguish between unplanned wastewater usage brought on by inadequate sanitation and planned wastewater use intended to solve issues like physical or economic water shortage in the debate. Both uses of wastewater may have substantial socioeconomic benefits, but they can also pose institutional risks and obstacles that call for separate management strategies and, preferably, different rules. The existing WHO Guidelines, which attempt to be universal in scope, are difficult to comprehend and implement because of this variability. While planned reuse will continue to be the norm in nations that can afford treatment, the majority of developing nations are expected to utilize untreated or just partly treated wastewater for as long as sanitation and trash management cannot keep up with the rise of urban populations. However, there are ways to connect the management of urban faecal sludge and wastewater with urban food needs or other types of resource recovery, which provide chances to securely shut the water and nutrient loops.

KEYWORDS:

Management, Sludge, Water, Wastewater.

INTRODUCTION

It is difficult to describe how contaminated water, feces, and sludge are being used in agricultural operations in impoverished nations. It is challenging to compare data and create global inventories because, on the one hand, there is a shortage of trustworthy and adequate information and, on the other hand, the information that is available does not utilize consistent phrases and units to represent these activities. The informal nature of the practice and, in certain situations, the deliberate decision not to give data are contributing factors to the general absence of data. This may be the case because either governments do not want to admit what looks to be malpractice, or farmers fear difficulties when marketing their goods. For these reasons, this chapter will first define a few words that will be used throughout the whole book, and then it will analyze the information already available from various sources utilizing, for the reasons mentioned, non-standard reporting techniques. Despite these drawbacks, the descriptions offered are helpful in giving a general picture of the degree to which wastewater, excreta, and sludge are used for agricultural activities in low- and middle-income nations [1], [2].

In many nations throughout the globe, the practice of applying wastewater, sludge, and excrement to the land has a long history. Chinese farmers have been using animal and human waste as fertilizer for generations. Like manure, wastewater and sewage sludge have also been used by northern European and Mediterranean civilizations. For example, wastewater was recycled in the Milanese Marcites and Valencian huertas in the 14th and 15th centuries, respectively. Before the development of wastewater treatment technology, sewage was often dumped onto agricultural fields in many European and North American towns to avoid polluting water sources. For instance, until the middle of the 20th century, partly treated wastewater was often used in Paris. Wastewater has long been utilized as a source of agricultural nutrients in developing nations including China, Mexico, Peru, Egypt, Lebanon, Morocco, India, and Vietnam. As a result, the use of untreated wastewater in agriculture for soil application and crop development has been going on for millennia. However, as treatment technologies have advanced and public awareness of the environmental and health risks associated with the practice has grown, it has lost some of its appeal in developed nations. In contrast, farmers in developing nations make extensive use of it, sometimes even benefiting their own livelihoods [3]–[5].

The first mentions of the usage of excreta originate from several Asian nations where it was used in aquaculture to boost fish output, 2006. Even in developed nations, sludge management has only recently become a problem due to the high production of sludge and excrement in densely populated areas, which prevents natural assimilation into the environment and leaves little room for stockpiling, 2008. In addition, management is difficult and there is a lack of social support: whether in rich or developing nations, people prefer to ignore what happens to excreta once it is disposed of in latrines and feel uncomfortable if it is brought to their attention. This chapter aims to provide an overview of the uses of wastewater, excreta, and faecal sludge in agriculture. It also describes these uses, the benefits obtained from them, the costs associated with them, especially in terms of the effects on human health, and offers perspectives for the future. It should be emphasized that while recovered or recycled water will be included where appropriate, the focus will mostly be on non-treated wastewater.

DISCUSSION

There isn't a thorough worldwide inventory of the amount of untreated wastewater used for irrigation in the literature; in fact, there isn't one for treated wastewater either. It is estimated that more than 4-6 million hectares are irrigated using wastewater or dirty water based on statistics from the nations giving data on irrigated areas. According to a different estimate, there are 20 million hectares worldwide, or around 7% of the world's irrigated land. The area that has been claimed to be watered with treated effluent, however, only makes only 10% of this total. In reality, the discrepancy can be substantially bigger as a result of underreporting of regions that use dirty water for irrigation. According to WHO, the area utilizing untreated sewage or contaminated water was 3 million hectares; however, more recent statistics indicate that the area is now six times bigger. Given the rising volumes of wastewater created as well as the urban food demands, it is unclear if this discrepancy reflects a de facto growth in the area or just in the data that is now accessible. Unless treatment or self-purification mechanisms are in place, the ensuing agricultural activities may be visible in rural areas situated downstream of where cities discharge. However, these activities are most prevalent in and near cities. This usage, which is often unintentional, results from cities' poor sanitation and waste disposal methods polluting water sources. According to a study conducted in the developing world by Raschid-Sally and Jayakody, wastewater without any significant treatment is utilized for irrigation in four out of five cities.

The amount of wastewater utilized for different reasons varies greatly from one nation to the next. According to the United Nations, 75% of the world's irrigated land is found in poor nations. Only a tiny percentage is reportedly utilised in certain rich countries, even if this is not anticipated. 46 nations report using contaminated water for agriculture in a recent assessment that incorporates information from Jimenez and Asano and the UNHSP. The usage of both kinds of water in middle-income nations shows a shift from unplanned and uncontrolled to planned and managed reuse. Countries with sanitary coverage of at least 87 percent solely use treated water for irrigation. The overall impact of wastewater to the food supply hasn't been quantified in many research. In Pakistan, roughly 26% of all vegetables are grown using wastewater as an irrigation method, however in Hanoi, Vietnam, which is significantly wetter than Pakistan, over 80% of vegetables are grown in urban and peri-urban regions using diluted wastewater as an irrigation method.

Between 50% and 90% of vegetables eaten by urban populations in large West African cities are grown in or around the city, where most of the irrigation water is contaminated. Because greywater often mixes with blackwater, the usage of greywater alone has not been well-documented. It is becoming more frequent in the Middle East for irrigation, however it is often utilized as an internal technique in such situations, making evaluation difficult. There are laws and regulations allowing the use of greywater for domestic irrigation in various US states. Australia, a country with significant resource shortage issues, commissioned research on greywater reuse, but no thorough information is available. Greywater is sometimes used for toilet flushing following treatment in nations where this is legal. Greywater is used for irrigation of non-edible crops and gardening in low and middle-income nations including India, Mali, Jordan, Palestine, South Africa, Nepal, Sri Lanka, Costa Rica, and Malaysia [6], [7].

Greywater is channeled down sewers in the majority of sub-Saharan African cities, where it often mixes with rainwater, solid trash, and human waste before reaching natural water bodies. It is challenging to discern between greywater and wastewater usage since these drains or streams are often utilized for irrigation. In spite of the fact that blackwater and greywater have distinct networks and the right use of greywater may be encouraged, a recent study in two Ghanaian cities revealed that the use of greywater for backyard irrigation is quite low. In drier regions where natural water supplies are few and tap water is expensive, the situation can be different. As an example, at the Jerash Refugee Camp, where greywater is separated and released from all homes into the environment via tiny ditches and open canals that assist farmers growing vegetables, Jordan is testing programs with a view to scaling up greywater usage. According to Godfrey et al, India uses partly treated greywater for kitchen-garden irrigation and sanitation, and it seems that this practice is starting to catch on across a number of locations.

Excreta, Feces, and Biosolids

The issue of managing faecal sludge is made worse by the huge number of on-site sanitation systems, such as latrines, public restrooms without sewers, or septic tanks that are utilized by the majority of the populace in densely populated cities to dispose of blackwater. Faecal sludge collected from on-site sanitation facilities is sometimes sent to treatment ponds, but it is more often thrown in gullies, streams, or the ocean, or recycled untreated on farmland, released into lakes or fish ponds, or disposed of within the residential neighborhood. A truckload of 5m3 dropped randomly is comparable to 5000 open defecations, assuming a per-person production rate of 1 litre/day of faecal sludge.

The employees who empty the tanks and trucks, their families, the nearby houses, and vulnerable groups in cities with a large latrine population are all at significant risk for illness as a result of these activities. Farmers are known to pay off septic truck drivers in Ghana, Mali, and Benin to deposit human waste on their fields. Thankfully, there is no danger to consumer health when there is adequate sun exposure, a lengthy dry season that causes pathogen die-off, or where cereal crops are cultivated. Experimental stations in Ghana and Nigeria have reported using co-composting systems where the faecal sludge is first dried and then combined with solid trash. As shown in Accra, Ghana, settled sludge from sludge treatment ponds has also been used to 'blend' compost from solid waste.

Although the use of excreta in agriculture and aquaculture is seldom acknowledged, it has been done for millennia in Asia, particularly in China and Vietnam. Excreta usage in agriculture is still widespread in China, and as a result, there is a close economic relationship between urban residents and urban farmers. Vegetables cultivated on excreta-conditioned soils thus get greater prices at the market. The first information on urine reuse has been revealed as initiatives to install toilets that separate urine increase. Sludge disposal is a problem that is becoming more of a concern in both developed and developing nations as the amount of wastewater being treated increases. Sewage sludge has always been seen as trash that should be disposed of as cheaply as feasible. Due to this, it has historically been disposed of in drainage systems, holes, landfills, and any other vacant surface. However, due to the high cost of modern landfills that meet all environmental requirements, the challenge of finding suitable landfill sites, the advantage of recycling plant nutrients, and the improvement of soil properties, faecal sludge, excreta, and biosolids are increasingly being applied on land in low- and middle-income countries. More than 60% of the time, they are used to fertilize lawns or other green spaces across the globe. Another significant application of sludge is to repair damaged soils at mining sites, building sites, and other disturbed places. This method addresses a problem for towns, aids farmers in lowering their expenses for organic and mineral fertilizer, and protects or increases soil fertility [8], [9]. Urbanization, socioeconomic circumstances, and inadequate financial and physical resources for water treatment all contribute to unplanned and unregulated wastewater usage in developing nations. According to a research commissioned by the Comprehensive Assessment of Water Management in farmland, a combination of the following factors account for the majority of wastewater consumption in irrigated farmland across 53 cities in the developing world:

1. The inability of cities to adequately clean their wastewater, which pollutes soils, waterways, and conventional irrigation water supplies;
2. The absence of other water sources in the real world;
3. The commercial incentives that favor food production close to cities, where water supplies are often contaminated, and the urban food demand.

Jimenez also emphasized the impact of socioeconomic issues on households, such as poverty and poor education levels in developing nations where a lack of work prospects and a lack of knowledge of health dangers coexist. In these situations, wastewater reuse might give a potential prospect for the growth of income crops or to increase the availability of food. It is difficult to modify behavior after wastewater reuse is established and the public has evaluated its benefits, particularly if changes come at a cost or are connected to previous water rights. Reduced freshwater resource availability, whether due to physical or economic constraints, may exacerbate this. Farmers naturally detect the nutritious potential of wastewater and sludge, which is another factor influencing their utilization. In contrast, water reuse and recycling are increasingly recognized in more developed nations as ways to address physical water scarcity , reallocating water from agriculture to other uses, and providing an economical alternative to expensive inter-basin transfers. The strict environmental regulations, which make land application of wastewater and sludge both economically viable and necessary, are another factor influencing recycling.

Sludge and excreta reuse in agriculture is motivated more by disposal concerns than by a desire to salvage parts of them. However, a lot of farmers see them as a useful resource on par with farmyard waste. With the goal of completing nutrient loops and ensuring that nutrients are returned to agricultural land to boost soil fertility, this beneficial use is gaining traction. As sludge and excreta have traditionally been seen, in most cultures, as not only poisonous but also an object of shame, one of the primary contrasts between the use of wastewater and that of sludge and excreta is a wider acceptability of wastewater usage .

Advantages and Disadvantages of Reusing Wastewater and Sludge

Although the motivations for using wastewater, sludge, and excreta in agriculture vary by area, this practice provides a variety of benefits in addition to the well-known hazards.

Advantages

It is not unexpected that agriculture is the largest consumer of wastewater globally as a result of the increasing global demand for food. Wastewater is significant because it is a dependable supply of water since it is accessible year-round, unlike seasonal streams or pluvial precipitation. As a result, it makes it possible to produce crops all year long and to irrigate a wider variety of crops, especially in arid and semi-arid regions. According to research done in Hubli-Dharwad, wastewater made it possible to grow during the dry season, when farmers could sell their crops for three to five times as much as they could during the kharif season. Additionally, various cultivation cycles and flexibility in the crops planted are made possible by wastewater dependability. Haroonabad, Pakistan; Accra, Ghana; and Dakar, Senegal have all been mentioned as having comparable circumstances. Farmers can now live more reliably thanks to the growth in productivity and associated income and food supply advantages, with the added benefit of utilizing the money for indirect benefits like funding healthcare and education. A more well-balanced diet may be a significant overall benefit for society if vegetables are the major product produced from wastewater. For instance, in Accra, every day more than 200,000 people consume vegetables grown using wastewater. On the other hand, since farmers and consumers may experience unfavorable health impacts, this group is also one that may be at risk [10].

Urban livestock, which is a component of the urban food-production systems, helps ensure the food security of cities by producing meat and dairy products. Livestock production in semi-arid regions is mostly dependent on natural pasture, which is sometimes constrained or diminishing as a result of low precipitation. According to research from Bonfoh et al. , the Food and Agriculture Organization of the United Nations , Sanon et al. , and Toutain et al. , plant species with lower nutritive value and palatability are increasingly common in Sahelian countries as forage biodiversity declines over time. But at the same time, urbanization and dietary changes are driving more dairy consumption in cities. For instance, the demand for dairy products is increasing by a ratio of 3.5 annually in Asian nations. Reusing wastewater or faecal sludge for the production of fodder looks to be a significant and relatively low-risk strategy that may help build the resilience of small and middle-sized towns in developing countries to climate change and food insecurity.

The nutritional content of wastewater and sludge is another well-known benefit of reuse. Wastewater recycles organic material and a wider variety of nutrients than any commercial fertilizer can, even after treatment. Numerous micronutrients, including cobalt, copper, iron, manganese, molybdenum, and zinc, are provided by biosolids, sludge, and excreta in particular and are crucial for optimum plant development. According to estimates from Qadir et al. , 1000 cubic meters of urban wastewater may deliver 16–62 kilogram of total nitrogen, 4–24 kg of phosphorus, 2–69 kg of potassium, 18–208 kg of calcium, 9–110 kg of magnesium, and 27–182 kg of sodium to the irrigation of one hectare. As a result, it may lessen the need for chemical fertilizers, particularly in areas where wastewater is not diluted, making crop nutrients more available to small farmers who are less well off. Excreta and wastewater may be important sources of phosphorus in light of the worldwide phosphorus shortage. However, high nitrogen levels in wastewater might result in overfertilization, excessive vegetative growth, delayed or uneven crop maturity, and decreased crop quality. The toxicity of certain trace elements in high amounts may also affect plants and sometimes endanger the health of agricultural consumers.

The economic benefits from nutrients in wastewater under real-world field circumstances have not been extensively studied. According to Keraita et al, the expected cost savings in Guanajuato, Mexico, from utilizing wastewater to provide crops with the nitrogen and phosphate they need was $135 per hectare. In Haroonabad, Pakistan, a study compared the production of vegetables using freshwater and untreated wastewater. It found that the gross margins were significantly higher for wastewater, as farmers used less chemical fertilizer and produced higher yields. The internal and external advantages greatly surpassed the expenses in a cost-benefit study of greywater reuse systems installed in Indian residential schools. Even though there haven't been many studies done to measure economic benefits, they consistently show that farmers that have access to wastewater benefit significantly. According to studies of this kind conducted in India, Ghana, Senegal, Kenya, and Mexico, yearly revenue per hectare ranged from US$420 to $2800. According to studies conducted in Ghana, the ability to grow crops that are in high demand and low supply at the right time, with the result that they can consistently be sold at above average prices, has a greater impact on farmers' profits than the yield that was achieved. Farmers' choices to pay more for wastewater than for regular water reflect the profitability of the company. Land rentals rose from US$170 to $350-950 year in the Mezquital Valley of Mexico as a result of the use of wastewater as irrigation water. According to Ensink et al, farmers in Quetta, Pakistan, paid 2.5 times more for wastewater than for freshwater [11], [12].

Disadvantages

The most apparent drawbacks of employing wastewater, sludge, or excreta that has not been fully or partly cleansed is the health concerns posed by germs. These are the topic of numerous chapters in this book as well as considerable discussion elsewhere. To provide an indication of the scope of the issue, a few references will be given below. First of all, it should be noted that illnesses vary geographically in accordance with the local public-health pattern and are related to the kind of pathogen in the wastewater. Second, dangers do not only affect farmers; they also affect four other groups: agricultural workers and their families, people who handle crops, people who consume crops or meat and milk from animals that graze on contaminated fields, and people who live in or close to places where wastewater, sludge, or excreta are utilized. Children and the elderly are the most susceptible demographics within these categories. Thirdly, between developing and industrialized nations, observable responses may differ significantly. This is due to the fact that both groups are exposed to highly varied pathogen distributions and concentrations, as well as very variable levels of disease resistance in developing and industrialized nations. Furthermore, due to the often subpar laboratory standards in poor nations, the data on food safety are untrustworthy. Although there have been isolated instances of plant absorption, pathogens often infect crops by direct contact. In addition to infections, significant concentrations of hazardous chemical compounds and heavy metals may also be found in wastewater and sludge. Metals and some organic chemicals can be contaminated through soil absorption, which is highly dependent on the location, environmental conditions, bioavailability, type of plant, and agricultural practices.

When wastewater, sludge, or biosolids are applied to soil, the permitted levels of heavy metals to which crops and soil may be exposed are generally well understood. In addition, wastewater, excreta, and sludge from home sources often have low enough levels of heavy metals to be used for agricultural fertilization in both developed and developing nations. Nevertheless, there are always situations when caution is required, such as when near tanneries or mining regions. In comparison to direct pesticide application, the danger from organic components obtained from wastewater is often much reduced. Even though pesticide levels on vegetables were high, they were seen as being of secondary relevance in the setting of a poor nation in compared to pathogenic health hazards.

CONCLUSION

The need to provide inexpensive nutrients that can support agricultural food production is driven by the worldwide energy and fertilizer challenges. The way garbage is processed has to change. A rise in the need for food and water is brought on by population expansion, urbanization, and a higher standard of living, which results in the production of significant amounts of garbage coming from metropolitan areas. A greater understanding of environmental water demands is another factor, as are the anticipated effects of climate change, which will diminish the availability of water. Biosolids, water, and nutrient resource recovery become crucial under these circumstances. The agricultural industry provides the best possibilities for reusing water and waste since it consumes, on average, roughly 80% of the water used in underdeveloped nations. Additionally, agriculture takes lower-quality water than other applications. Although water and nutrient recovery is currently widely practiced, there are still certain concerns involved. A plan that meets the demands of the users while also protecting the environment and the public health is necessary for progress. This plan should be created locally, depending on available resources and local requirements, and it may help pay for treatment facilities.

Urban planners and policy-makers have a clear opportunity to promote the importance of wastewater and excreta treatment infrastructure by tying it into goals for urban growth and food security. The fact that the current pace of economic expansion and the likely effects of climate change are already exceeding the ability of the earth's ecosystems to provide the necessary resources and to absorb the pollution brought on by human activity is a serious topic of worry. A comprehensive environmental sustainability plan for managing renewable resources must be defined in order to address the effects of the anticipated doubling of the global population by the middle of the next century, the majority of which will occur in developing nations.

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CHAPTER 3

IDENTIFYING AND REDUCING HEALTH RISKS ASSOCIATED WITH WASTEWATER IN LOW-INCOME COUNTRIES

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ABSTRACT:

Natural water bodies are becoming more contaminated in and near metropolitan areas. As a consequence, wastewater irrigation is a typical practice in the majority of developing-world towns. Effective treatments could not be accessible for years due to technological or financial constraints; as a result, international regulations protecting farmers and consumers must be realistic and provide workable risk-management solutions. An introduction to microbiological dangers is given in this chapter. When feasible, start with wastewater treatment before moving on to other pathogen barriers from farm to fork to handle these issues as effectively as possible. The emphasis on a holistic approach to achieving health-based targets, as opposed to prescribing irrigation water quality threshold levels that are frequently impractical, is a significant change in the most recent WHO Guidelines for the Safe Use of Wastewater, Excreta, and Grey water in Agriculture and Aquaculture. The health-based targets should not be seen as absolute values but rather as objectives to be met in the short, medium, or long term depending on the country's institutional and economic circumstances and technological capabilities. As the nation climbs the cleanliness ladder, local norms and actual implementation should advance gradually. While it is advised to conduct health-risk assessments to pinpoint entry points for risk reduction and health-based objectives, the Guidelines also provide workarounds in cases when research resources and data are limited.

KEYWORDS:

Agriculture, Diseases, Surface Water, Wastewater.

INTRODUCTION

Surface water polluted with wastewater as well as treated, partly treated, or untreated wastewater are often used in agriculture. More untreated than treated wastewater is used to irrigate an estimated 20 million hectares of land globally. As long as there are not enough treatment facilities to keep up with the contamination of streams caused by the effluents from expanding urban populations, this imbalance in favor of untreated wastewater will continue to rise. Wherever agricultural water demand is greater than availability, wastewater irrigation will become necessary due to the growing worldwide shortage of high-quality water. This is true anywhere farmers look for land and water to meet market demand, not only in dry areas. Urban and peri-urban regions in most developing nations are typical instances, when clean water supplies are not enough to supply even domestic demand [1], [2].

Since it may include excreta-related infections, skin irritants, and toxic compounds such heavy metals, pesticides, and pesticide residues, untreated wastewater or contaminated water in general presents threats to human health. The main risks to human health from exposure to wastewater used in agriculture come from viruses and certain chemicals. The two primary exposure pathways are consumption of products produced in wastewater and interaction with wastewater. Inadequate post-harvest handling may also cause cross-contamination of agricultural products and contribute to contamination.

Health Hazards from Wastewater Irrigation Exposure Trails

Excreta from sick people release the infectious agents that cause excreta-associated illnesses. They include harmful bacteria, viruses, protozoa, and helminths, all of which are excreted in the feces or urine of sick people or, in some situations, animals. The pathogens ultimately spread to other individuals and enter via the skin or the mouth [3], [4].

1. Workplace exposure

Due to the length and frequency of their contact with sewage and polluted soils, agricultural workers are one of the most impacted populations. For instance, in Haroonabad, Pakistan, farmers who use untreated wastewater have reported prevalence rates for hookworm infection as high as 80%. There is a lot of evidence, according to epidemiological studies of farmer groups utilizing wastewater, that helminth infections are quite likely. The rigorous WHO recommendation value of 1 egg per litre of irrigation water as a consequence. However, recent epidemiological research employing wastewater among Vietnamese rice farmers revealed much more evidence of increased diarrhea and skin issues than of helminth infection risk. There may be discrepancies between real and perceived hazards. According to Rutkowski et al, wastewater farmers seldom link illnesses and diseases to their irrigation practices, which might hamper attempts to get them to adopt risk-reduction measures. It also emphasizes how important it is to inform farmers about the dangers associated with irrigation with wastewater. According to certain arguments based on economic impact studies, farmers that use wastewater irrigation for agricultural productivity may be able to pay for helminth infection treatment with the money they save. Adding economic effect analysis to risk analysis.

Recent research from Vietnam and Cambodia has linked exposure with untreated wastewater to skin conditions such dermatitis in addition to helminth infections. According to a research done in the Kathmandu Valley of Nepal, more than half of 110 farmers utilizing wastewater who were surveyed reported having skin issues. Itching and blistering on the hands and feet were among the skin issues mentioned. Urban vegetable growers in Ghana utilizing wastewater and rice farmers near the Musi River in Hyderabad, India both reported experiencing similar issues. The development of nails may be damaged by iron deficiency, which is specifically linked to hookworm infections and causes koilonychias. Studies carried out in Vietnam did not discover a connection between the risk of eye conditions and wastewater-related exposure, but they did propose more research to see whether there is a connection between skin diseases and specific water contaminants.

DISCUSSION

The main issue with regard to consumption-related health concerns is related to vegetables consumed raw, such as in raw salad dishes. Increased Ascaris infections have been observed in both adults and children who consume uncooked vegetables that have been irrigated with sewage, according to a number of studies, including a prospective cohort study, an analytical descriptive study, and several descriptive studies, one of which was conducted in Jerusalem. Studies on the effects of consuming contaminated vegetables on diarrhoeal disorders have been widely reported and reviewed. In underdeveloped nations, enterotoxigenic E. coli, a strain of Escherichia coli, is often linked to diarrhea. The most often documented viral illnesses from vegetable eating are hepatitis A and viral enteritis, particularly norovirus and rotavirus. Vegetables irrigated with wastewater have been linked to a number of diarrheal epidemics. However, owing to additional contributing variables such inadequate hygiene, sanitation, and limited access to clean drinking water in impoverished countries, it is sometimes difficult to link diarrheal epidemics to specific exposure pathways.

Diseases Related To the Use of Wastewater in Agriculture

Not all risks will result in sickness, and various risks and exposure routes will produce various disease loads. Numerous variables affect how important health concerns are in spreading disease. According to Shuval et al., the virulence, tency periods, minimum infective dosage, and persistence in the environment all affect an infectious agent's capacity to spread illness. Therefore, pathogens with extended environmental persistence, low minimum infectious doses, little to no human immunity, and lengthy latency periods are more likely to cause infections than others. According to this, helminth diseases offer the biggest hazards related to wastewater irrigation in areas where they are prevalent. With the exception of specific locations where there is significant industrial wastewater output, most chemicals are regarded to pose little risks. Cancer is one of the more difficult illnesses to link to wastewater usage in agriculture. This is because it might be difficult to link a particular exposure route or causative factor to an illness due to the complex chemical mixes in wastewater and the lengthy latency periods before symptoms manifest.

The illnesses that matter the most vary from region to region based on the local degree of sanitation, hygiene, and wastewater treatment before use in agriculture. Examples of the burden of several illnesses that may be related to the usage of wastewater in agriculture are given. The majority of these excreta-related disorders affect children who live in underdeveloped nations. Disability-adjusted life years 3 are a crucial unit for comparing the outcomes of diseases caused by various exposures and are used to evaluate the disease burden. The next chapters provide further information on the application of DALYs. According to the WHO, diarrhea alone accounts for roughly 3% of all fatalities and 3.9% of DALYs globally. Diarrhea is an illness that may be mostly ascribed to environmental causes, including contaminated food and water, inadequate sanitation and hygiene, and drinking polluted water. It is still unclear how much of the illness burden may be attributable to subpar hygiene, dangerous drinking water, inadequate sanitation, and, in particular, consumption of vegetables irrigated with sewage. Comparative studies are rare, and the ones that do exist only include food- or water-borne routes. Both groups are connected by food that has been watered with waste water, but more crucially, many elements are interconnected and do not conflict. Any precise attribution to wastewater usage is challenging due to the many complicating variables. A microbiological risk assessment that takes into account exposures specific to a certain place is one approach to the problem [5]–[7].

Wastewater Irrigation Guidelines for Developing Countries

While some nations, particularly the more industrialized ones, have national regulations governing wastewater usage in agriculture, the UN, and particularly the WHO, are responsible for producing the most well-known worldwide regulations. The WHO published Reuse of Effluents: Methods of Wastewater Treatment and Public Health Safeguards in the early 1970s to promote the responsible use of wastewater and excreta in agriculture and aquaculture and to safeguard public health. This first WHO normative guideline on wastewater usage was created in the absence of high-quality epidemiological research and largely adopted a low-risk methodology from the USA. It was supplemented in 1976 by the FAO's Irrigation and Drainage Paper 29, which addressed the problems with salinity and specific ion toxicity in water quality. The WHO article included treatment recommendations based on best practices based on water thresholds, such as critical pathogen levels in irrigation water , which should not be exceeded. Many arid and semi-arid nations saw an increase in the use of wastewater in agriculture throughout the two decades that followed the release of these texts. Numerous epidemiological studies were conducted as a result of this trend and the health and safety concerns it raised. produced a comprehensive evaluation of epidemiological research. The first WHO report required to be changed, and the following new factors needed to be taken into account when epidemiological data was gathered.

1. In many situations, very rigorous water-quality criteria were difficult to meet, and as a result, they were often disregarded, making the Guidelines meaningless.
2. In order to lower health risks, guidelines required to incorporate risk-management techniques that would supplement existing treatment procedures or could be employed in the absence of wastewater treatment.

Based on these ideas, the WHO Guidelines' second version was released in 1989. Following the 1989 Guidelines, the FAO's Irrigation and Drainage Paper 47 addressed challenges specific to irrigation, such regulating salinity, while also expanding on the 1989 Guidelines. Both recommendations have had a significant impact, and many nations have followed them, often with modifications. Both papers underlined the necessity for suitable wastewater treatment before to use and for water-quality parameters that are simple to monitor in light of pathogenic concerns.

The WHO water-quality requirements were questioned in the FAO's "Water Report No. 10" in 1997 since appropriate treatment facilities to help reach these levels would not be available for another ten years or more. This article emphasized the need of extra, temporary measures, like crop limitations. The WHO teamed up with the FAO to begin another historic review of the WHO Guidelines in light of growing understanding of risk assessments and methods, the introduction of the DALY concept, and the growing focus on important control points to ensure food safety. With a deeper focus on local possibilities but also constraints to accomplish risk reduction, the updated version was to provide more information about how to define acceptable risks to society depending upon the real illness condition in each specific nation.

The switch from critical levels of microbiological contamination in irrigation water to health-based objectives was a significant move. Another weakness was that water quality-based thresholds did little to address food contamination that occurred from sources other than irrigation. This was especially problematic in countries where the burden of associated illness was highest. The recommended option was to minimize risk throughout the production and distribution chain, particularly for consumers of wastewater-irrigated crops. This might include the treatment of wastewater, the use of safer irrigation techniques, the cultivation of only completely cooked foodstuffs, and the washing of crops during the cooking process. By combining these preventative measures, it will be feasible to obtain close to the health goal values that are established at the point of consumption, at the end of the food supply chain. This goal, which may be stated in DALYs prevented, is computed based on the pathogen decrease from the original crop contamination level. According to Sperling and Fattal , the focus on "targets" suggests that these objectives should not be interpreted as absolute values but rather as goals to be accomplished in the short, medium, or long term depending on the technical, institutional, and financial circumstances of the nation [8], [9]. It was decided to offer the Guidelines in different volumes in order to properly package them for target audiences:

Volume 1: Aspects of policy and regulation;

Volume 2: Agriculture's usage of wastewater;

Volume 3: Aquaculture's utilization of wastewater and excrement;

Volume 4: Grey water and excrement utilization in agriculture.

Traditional solutions and their shortcomings in emerging nations

It has long been believed that wastewater treatment in specially constructed facilities or pond systems is the best way to lower the dangers associated with wastewater irrigation of agricultural land. This has led to extensive research and documentation on wastewater treatment as a risk-mitigation strategy in both developed and developing nations. However, concerns are being voiced about some emerging organic chemical compounds, such as pesticides and their residues, pharmaceutically active compounds, and endocrine disrupting substances, as well as the efficiency of conventional treatment systems in eliminating pathogens that are particularly problematic in many developing countries. In fact, the majority of conventional systems have two different types of treatment: primary treatment, which removes organic matter and suspended particles, and secondary treatment, which removes biodegradable organics. There may also be tertiary level therapy options, although that level's focus is on removing hazardous substances and nutrients. Therefore, human health hazards are not the major focus of traditional treatment methods; rather, environmental issues are. A study of more than 20 research completed for the WHO's third edition of its Guidelines further demonstrated this. The analysis revealed significant variability in the efficacy of several pathogens' log unit reductions by various conventional treatment techniques.

With the exception of stabilization ponds, many conventional treatment systems' processes are difficult and expensive to run in developing nations due to their high energy needs, labor requirements for skilled labor, and high installation, operation, and maintenance costs. This may account for the large number of inoperable treatment facilities and the low wastewater treatment rates overall in developing nations less than 1% in sub-Saharan Africa, roughly 35% in Asia, and 14% in South America. According to a study conducted in Ghana, for instance, just 10% of the estimated 70 treatment facilities and faecal sludge stabilization ponds are currently working according to schedule, with the majority of them being part of bigger hotels [10]–[12].

Therefore, for conventional wastewater treatment to be seen as a viable alternative for reducing health risks in poor nations, innovative innovations are required. As stated in Chapters 14 and 15, some of these modifications in recent years have included research towards re-engineering conventional wastewater treatment systems to make them more suited for irrigation. This has been done by optimizing the water and nutrient levels in treated wastewater effluents. Studies have also concentrated on creating systems that are more effective in removing pathogens and conserving nutrients. Here, as stated in Chapters 8 and 9, an emphasis on systems that utilise low-rate biological processes, such as pond systems, has been pushed. Additionally, biosolids are receiving more attention in research, particularly when it comes to creating risk-reduction strategies for faecal sludge usage in agriculture and outsourcing treatment to the farm level.

Alternative strategies and the multiple-barrier strategy

The third edition of the WHO Guidelines suggests using the "multiple-barrier approach" in light of the apparent constraints of currently being able to build conventional wastewater treatment facilities in many developing countries. The strategy is focused on targeted interventions at important control points throughout the food chain to accomplish a food-safety goal. It is inspired by the Hazard Analysis Critical Control Point concept established by the Codex Alimentarius project. From the creation of wastewater through the preparation of the vegetables provided for consumption, there are critical control points along the whole chain of events that may act as significant pathogen barriers. In order to achieve health goals for farmers or consumers alike, the strategy includes both conventional and non-traditional wastewater treatment procedures in addition to additional health-protection measures. The use of low-cost systems, such as on-farm ponds, sedimentation traps, and bio-sand filters, as well as improved irrigation techniques, like drip irrigation, the cessation of irrigation before harvesting, and produce-washing are examples of unconventional wastewater treatment methods. These various options are categorized in some sections of the 2006 edition of the Guidelines as "treatment" and "non-treatment" options, with "treatment" including all conventional wastewater treatment systems and "non-treatment" options including all other potential practices and measures, particularly on farms and in the post-harvest sector.

CONCLUSION

Wastewater from treated, untreated, or diluted forms is utilized to irrigate agricultural land in and around four out of every five cities in developing countries. Despite their tiny land sizes, these farms often specialize in growing extremely perishable cash commodities that account for a significant portion of the market. It is vital to understand that good wastewater treatment may not be accessible for many years in many circumstances where wastewater is utilized in agriculture. Therefore, international regulations must be realistic and provide workable risk-management solutions that will optimize health protection and enable the efficient use of limited resources. The third version of the WHO Guidelines offers tools, techniques, and processes for setting health-based objectives that may be fulfilled with various pathogen barriers from the wastewater source to the consumption of food that has been irrigated with wastewater. This multiple-barrier strategy should be used in conjunction with other health initiatives including health promotion, hygiene education, and the provision of access to clean, safe water and toilets. A few of the numerous unanswered research and application-related issues are listed in the last chapter of this book. A broad-based policy approach is necessary to appropriately interpret and implement the recommendations in a way that is suited to local circumstances. This approach will include legislation as well as favorable and unfavorable incentives to encourage the adoption of excellent non-treatment or post-treatment behaviors. The expansion of wastewater treatment is crucial, and progress in this area has to be made quickly. The current WHO Guidelines may aid regional, governmental, and international standard-setting organizations in their attempts to create their own methods and protocols for achieving the suggested health-based aims. Depending on the technical, institutional, and financial constraints in each location, the methods will vary. As the nation climbs the sanitation ladder, local standards and real execution should advance but the health-based objectives will always be a given in any given situation.

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CHAPTER 4

GUIDELINES FOR THE HARMLESS USE OF WASTEWATER IN AGRICULTURE

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ABSTRACT:

The 2006 WHO Guidelines for the Safe Use of Wastewater, Excreta, and Grey water in Agriculture, which are based on a tolerable extra burden of illness of 10-6 Disability-Adjusted Life Year DALY loss per person per year, are reviewed in this chapter. These guidelines also prescribe certain pathogen reductions that must be made. Here, the quantitative microbial risk-analysis method and 10,000-trial Monte Carlo risk simulations are described. The estimations of the median risk for exposure through limited and uncontrolled irrigation at different degrees of pathogen reduction are also provided. In order to ensure that the added burden of illness does not exceed 10-6 DALY loss per person per year, it is now possible to choose the most appropriate combinations of pathogen reduction methods wastewater treatment and post-treatment health-protection measures.

KEYWORDS:

Agriculture, Wastewater, Water, World Health Organization (WHO).

INTRODUCTION

In September 2006, the World Health Organization released the third version of its guidelines for the safe use of wastewater in agriculture. These were primarily different from the WHO's 1989 Second Edition of the Guidelines in the following ways:

1. Calculating the necessary reductions in viral, bacterial, and protozoan infections using a risk-based methodology.
2. The specified pathogen reductions are to be accomplished solely via wastewater treatment in order to safeguard the health of individuals working in or otherwise exposed to wastewater-irrigated fields i.e., limited irrigation.
3. The required pathogen reductions can be achieved by a suitable combination of wastewater treatment typically to the level required for restricted irrigation and post-treatment health-protection control measures, such as those described below, in order to protect the health of those consuming wastewater-irrigated food crops i.e., unrestricted irrigation [1], [2].

The 2006 Guidelines are basically a set of best management practices to make sure that wastewater is utilized in agriculture safely and with the fewest health hazards possible mostly for irrigating crops, particularly food crops that are or may be consumed uncooked. They consequently represent much more than just a collection of ideals. However, in order to design wastewater reuse systems that do not negatively impact public health, wastewater treatment and reuse engineers need to know how to employ the Guidelines' suggestions. To ensure the safety of the wastewater reuse systems they develop, they must fully comprehend the principles behind the Guidelines. The Guidelines and this chapter both take into account two major categories of wastewater-related illnesses that are pertinent to the use of wastewater in agriculture.

1. Illnesses caused by viruses, bacteria, and protozoa, for which quantitative microbial risk assessment QMRA determines the health hazards;
2. Helminthic illnesses, for which the Guidelines established a reference value based on epidemiological research.

The Guidelines' foundation for protecting human health states that the additional disease burden brought on by viral, bacterial, and protozoan diseases that results from working in or consuming crops that have been irrigated with wastewater should not exceed 10-6 DALY loss per person per year . The health risks associated with wastewater use in agriculture are therefore the same as those associated with drinking fully treated drinking water, which is essentially what consumers want because they expect the food they eat to be as safe as the water they drink. This level of health protection was used by the WHO in its 2004 Guidelines on drinking-water quality [3], [4].

DISCUSSION

The exposure scenario outlined in the Guidelines for Restricted Irrigation is the unintentional intake of soil by people working in or small children playing in fields that have been watered with wastewater. This is a possible situation since the employees' or kids' fingers would be contaminated by wastewater-saturated dirt, which might then spread certain bacteria to their mouths and be consumed. The amount of dirt unintentionally consumed in this method has been estimated to reach up to 100mg per person per day of exposure . Investigations focused on heavily automated agricultural and labor-intensive agriculture, two sub-scenarios. The former describes exposure in industrialized nations where agricultural workers frequently use tractors and related equipment to till, sow, and harvest while also being required to wear gloves and practice good hygiene while working in fields that are irrigated with wastewater. The latter illustrates agricultural methods utilized in underdeveloped nations where tractors are not used, gloves are not worn, and cleanliness is frequently not emphasized.

1. Labor-intensive farming

The results of the Monte Carlo-QMRA risk simulations are provided for 300 days of exposure per year and for different wastewater quality. As can be shown, a wastewater quality of 103–104 E. coli per 100 ml entails a median risk of rotavirus infection of 10-3 pppy. This means that a 4 log unit drop, or going from 107-108 to 103-104 E. coli per 100ml, is required to meet the acceptable rotavirus infection risk of 10-3 pppy. The data also demonstrates that the chances of infection with Campylobacter and Cryptosporidium are all lower than those associated with rotavirus.

2. Agriculture Mechanism

Table 3.6, which presents the simulated hazards for different wastewater quality and for 100 days of exposure annually, demonstrates that a 3 log unit drop in E. coli concentration—from 107–108 to 104–105 per 100 mL is necessary to reach the acceptable rotavirus infection risk of 10–3 pppy.

Unrestricted Irrigation

Consumption of wastewater-irrigated lettuce and consumption of wastewater-irrigated onions are the exposure scenarios utilized in the Guidelines for unrestricted irrigation.

1. Simulations of risk

Unrestricted irrigation required a somewhat different strategy, which was used. The needed log rotavirus reductions for different tolerated rotavirus yearly infection risk levels were calculated using the QMRA- Monte Carlo tool. According to the data, root crops must have pathogen reductions of 6 log units for non-root crops and 7 log units for root crops in order to achieve the acceptable rotavirus infection risk of 10-3 pppy. The table also demonstrates how the needed pathogen reductions vary by an order of magnitude with each order of magnitude change in the tolerated risk and that the consumption of root crops needs a 1 log unit pathogen reduction larger than the consumption of non-root crops. For unrestricted irrigation, this 6-7 log unit reduction is best accomplished by a 3-4 log unit reduction from wastewater treatment, as needed for limited irrigation, plus a 2-4 log unit reduction from post-treatment health-protection control measures. These post-treatment health protection controls are quite trustworthy since they essentially always take place. There have been a number of important advancements in risk analysis methods and the interpretation of the resultant hazards since the release of the 2006 WHO Guidelines for the safe use of treated wastewater in agriculture. These consist of:

1. Understanding that in many developing-country contexts, a tolerable extra disease burden of 10-6 Disability- Adjusted Life Year loss per person per year may be excessively strict and that a DALY loss of 10-5 or even 10-4 pppy may be adequate to preserve human health.
2. A compelling case for utilizing single-event infection risks rather than yearly risks alone as a gauge of "outbreak potential" when assessing risk tolerance.
3. An approach to predicting yearly risks that is more exact.
4. The accessibility of norovirus dose-response data.
5. Using QMRA to calculate the risks of contracting Ascaris.
6. An assessment of the pathogen reductions brought about by produce washing and disinfection.
7. Less severe, tolerable disease burden

Setting a 10-6 DALY loss per person per year annual risk from waterborne exposure will have little effect on the overall disease burden in locations or situations where the overall burden of disease from microbial, chemical, or radiological exposures by all exposure routes is very high, according to WHO in Levels of Protection, one of the documents in the rolling revision of its drinking-water quality guidelines. Because of this, establishing a less strict limit of acceptable risk, such as 10-5 or 10-4 DALY [loss] per person per year, from waterborne exposure may be more practical while still being compatible with the objective of providing high-quality, safer water and promoting gradual improvement of water quality. The Stockholm Framework's guiding principles may be modified and used to wastewater utilization in agriculture. Therefore, setting a tolerable additional burden of disease of 10-6 DALY loss pppy for communities with high diarrhoeal disease rates is likely unrealistic; a more realistic level might be 10-5 DALY loss pppy for consumers of uncooked food crops irrigated with wastewater and 10-4 DALY loss pppy for those who work in fields irrigated with wastewater. If the latter are given the chance to make an informed decision about their working conditions and, consequently, their occupational health risks, a less strict level may be set for them [5]–[7].

Therefore, wastewater treatment that produces a pathogen reduction of two orders of magnitude lower than that for 10-6 DALY loss pppy, which is a decrease of just 1-2 log units, will protect fieldworkers, at least in part. Similar to how consumers would be safeguarded, a total pathogen reduction one order of magnitude lower than that for 10-6 DALY loss pppy, which is a reduction of just 1-2 log units by wastewater treatment augmented by 4-5 log units accomplished by post-treatment health-protection management methods, would protect consumers. This book goes into further detail about it. The annualized probability of infection is often used as a benchmark for acceptability, when separate exposure episodes occur throughout the year to determine the yearly risk. Although disease outbreaks are often linked with shorter-duration periods of heightened risk, the amount of immediate infection risk to the exposed population varies throughout the year. In order to evaluate, report, and benchmark risks, Signor and Ashbolt argue in favor of the widespread use of shorter-duration reference periods for infection probability objectives. They contend that doing so would open up possibilities for enhanced risk management of diseases associated with water, with an incentive to lessen the incidence and effects of event-driven peaks. For a design or operational target of an annual disease risk of 10-4 per person, Signor and Ashbolt propose that a daily or single-exposure disease probability of 10-6 per person would achieve the original target's objectives and encourage the implementation of measures to reduce the severity of short-term adverse risk fluctuations. For an acceptable yearly illness risk of 10-x per person, this may be extrapolated to a single-exposure disease risk of 10- pppy, where the value of y depends on the frequency of exposure. Naturally, the chances of infection would be decreased [8], [9].

A More Strict Process for Estimating Annual Risks

An improved technique for calculating yearly infection risks using QMRA-Monte Carlo simulations is suggested by Karavarsamis and Hamilton. Approach A, which is the name of this procedure, is detailed in Box 5.1. In a nutshell, it accurately accounts for daily variation in infection risk when determining annual risk, as opposed to the usual approach, which extrapolates an unreliable estimate of annual risk from infection risk for any given day of exposure. The flaws in the latter technique are not fixed by repeated simulation calculations, according to Karavarsamis and Hamilton; instead, they just produce a dispersion of inaccurate estimations. While the median risks from the two methods are comparable, the Karavarsamis and Hamilton method produces 95-percentile risks, which are sometimes used as conservative estimates of annual risk, up to an order of magnitude lower than the WHO method. These estimates of risk from the application of both methods to five wastewater irrigation scenarios.

Urbanization Of Agriculture in Cities That Are Developing

Different consumption habits lead to different levels of exposure, which must be taken into consideration when calculating risk. For instance, according to Seidu et al., individuals in metropolitan Ghana often eat 10–12g of lettuce in 'fast food' four days a week. It is substantially less than the 100g of lettuce ingested on alternate days by Shuval et al. to reflect the situation in Israel. This speaks to a unique circumstance in one underdeveloped nation, and this may or may not be indicative of what occurs elsewhere. A computer program based on the Karavarsamis and Hamilton approach presented in this chapter, QMRA-Monte Carlo, was used to model the infection risks for this Ghanaian population's lettuce intake. A reduction of 4 log units results in a risk of norovirus infection of 3.6 10-2 pppy, which is only slightly higher than the tolerable norovirus infection risk determined in the section for a tolerable DALY loss of 10-5 pppy. For example, a 1 log unit reduction in wastewater treatment and a 3 log unit reduction in produce disinfection could achieve the required 4 log unit reduction [10], [11].

Treatment of wastewater implications

In the aforementioned scenario, wastewater treatment is only necessary to achieve one log unit pathogen decrease. Simple treatment methods like an anaerobic pond, a three-tank system, or a three-pond system, together with nighttime settling, may easily accomplish this. The three-tank or three-pond system is run as a sequential batch-fed operation, with one tank or pond being filled with wastewater on any given day, another's contents settling, and the third's contents being utilized for irrigation. This system is very trustworthy—almost impregnable. Contrary to large-scale farming, small-scale urban agriculture often only requires one tank, which is also more cost-effective. The tank's contents are used to water crops every morning, after which the tank is refilled and its contents are left to settle until the next morning [12]–[14].

If it is estimated that untreated wastewater in places where ascariasis is prevalent contains 100 Ascaris eggs per litre, a 3 log unit egg reduction is necessary to obtain 0.1 eggs per litre for helminth eggs. For root vegetables consumed raw, wastewater treatment is necessary to achieve a decrease of 1 log unit from 100 to 10 eggs per litre, assuming a 2 log unit reduction occurs via product peeling prior to consumption. All three of the aforementioned strategies may be used to reduce this amount. This might be accomplished by washing the peeled food in a mild detergent solution and then rinsing with clean water in hyperendemic locations.

CONCLUSION

A viable and sustainable answer to the urgent problems of water shortage and food security is the safe use of wastewater in agriculture. When carried out properly and in accordance with safety regulations, this procedure provides a number of advantages. In order to increase agricultural output and lessen dependence on dwindling groundwater supplies, it first and foremost increases farmers' access to irrigation, especially in areas with little freshwater resources. Additionally, wastewater includes beneficial elements that may act as an economical fertilizer to increase agricultural productivity and soil fertility. Additionally, by avoiding untreated discharges into rivers and lakes, the proper use of treated wastewater reduces environmental contamination while safeguarding aquatic ecosystems and public health. Due to its efficient water resource recycling, it also complies with the principles of the circular economy. However, it is essential to stress that effective treatment procedures to get rid of toxins and pathogens, as well as thorough monitoring and regulation, are necessary for the success of harmless wastewater usage in agriculture. To guarantee safe procedures, public awareness and education are equally important. The use of treated wastewater in agricultural activities has the potential to significantly improve food production, decrease environmental impact, and address water shortages. But in order to execute and manage this technique properly for the benefit of present and future generations, it requires a coordinated effort by governments, farmers, and stakeholders.

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CHAPTER 5

ANALYZING THE POTENTIAL HEALTH CONCERNS OF REUSING WASTEWATER

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ABSTRACT:

When evaluating the potential health concerns of reusing wastewater, sludge, or excreta in the cultivation of food crops, knowledge of the dose-response relationships of waterborne and foodborne enteric pathogens is crucial. Human challenge trials, animal research, and epidemic investigations are the three primary sources of data on dose-response connections. The use of quantitative microbiological risk assessment to investigate the possible health concerns connected to the consumption of food crops irrigated with wastewater or fertilized with biosolids needs information on a number of parameters in addition to dose-response data. These include routes of transmission, the frequency and concentration of pathogens in biosolids and wastewater, the persistence of pathogen viability or infectivity in the environment and on food crops, and the quantity and frequency of crop consumption. In several scenarios, assessments of the risks of Giardia and Ascaris infection associated with food crops are presented. These assessments show how pathogen reduction strategies like produce washing and WHO guidelines may significantly or insignificantly affect the risks of infection associated with food crops irrigated or fertilized with wastewater and bio solids.

KEYWORDS:

Biosolids, Pathogen, Sludge, Wastewater.

INTRODUCTION

In order to achieve a particular degree of health protection in a population that is exposed, the WHO Guidelines for the Safe application of Wastewater, Excreta, and Grey water are based on the formulation and application of health-based objectives. Then, to accomplish this degree of health protection, a variety of risk-management measures may be used. Sometimes the intended degree of protection cannot be completely implemented at a particular moment. The WHO Guidelines advise creating policies that permit gradual adoption because of this. Depending on the conditions and resources of any specific nation or area, this may be accomplished over time in an orderly way. Each nation should make an effort to create a risk-management strategy based on the local environment in order to accomplish this. For instance, the WHO Guidelines employ a safe performance objective for unrestricted irrigation of 6-7 log units for general pathogen reduction [1], [2].

Quantitative microbial risk assessment may be utilized as one potential strategy to adapt the goal to locally relevant pathogens and wastewater application methods. The availability of dose-response data has a significant impact on the quality of the QMRA study. This data shows the association between exposure to certain dosages of a virus and the likelihood that the exposed host would get infected or exhibit symptoms. The virulence of the virus and the susceptibility factors of the host both have a role in dose-response interactions. Estimating the likelihood of infection, contingent upon exposure, as well as the likelihood of sickness, contingent upon infection, is required for risk prediction. Infection cannot happen without exposure, just as illness cannot happen without infection. This seemingly unimportant assertion has significant ramifications for quantitative risk assessment: if exposure assessment shows that the chance of exposure is below a certain threshold, the probabilities of infection and sickness typically cannot surpass that threshold. Some microbes, like the Norwalk virus example discussed later in this chapter, are very contagious. A significant risk of infection and sickness may be linked with exposure to even small amounts of highly infectious pathogens.

Any assessment of the potential health concerns of wastewater, sludge, and excreta irrigation or reuse for crop production must take into account information on the dose-response relationships of waterborne and foodborne pathogens. Human challenge studies, animal challenge studies, and outbreak investigations are the three primary sources of knowledge on the dose-response for enteric infections. In this chapter, many forms of potentially dangerous microorganisms will be taken into account as we investigate these sources of data and the factors to be taken into account when using them for risk assessment. Four relevant enteric pathogens will be used as examples to provide dose-response data. Because the WHO technique may be used to provide recommendations to lower the risks of pathogen exposure regardless of the kind of pathogen, only its application to helminth eggs is discussed in this chapter [3].

Studies on Human Challenges

Human challenge experiments, where both the exposure and reaction can be adequately described, may provide the most accurate dose-response data. These experiments use different pathogen solution dilutions to regulate exposure. This inoculum must pass stringent safety tests to guarantee that it only contains the intended pathogen and nothing else hazardous. Additionally, the suspension must be titrated using a variety of methods, including polymerase chain reaction for certain viruses and bacteria, or microscopic counts or particle counts of cysts, oocysts, or eggs. Although the precise quantity of the target pathogen that is consumed in each dosage is unknown, it may be inferred from knowledge of the suspension's titre and its dilution. The evaluation of the dose-response includes the estimate of exposure as a result. Two dose-response relationships that may be built from physiologically acceptable assumptions about the infection process are the exponential and beta-Poisson models. Haas and Eisenberg compiled the best-fit dose-response parameters for these models for a variety of human diseases.

DISCUSSION

The use of human volunteers restricts the variety of infections that may be used in human challenge experiments to relatively mild pathogens that produce modest symptoms that can either go away on their own or be treated to resolve them and are not linked to any long-term detrimental health consequences. Therefore, ethics committees carefully analyze these research to make sure that the participants' health, privacy, and human rights are completely respected. These studies typically only include healthy adults who are able to comprehend the research procedure and provide informed permission to participate in the study. This is done for ethical considerations. Before being accepted into the research, all prospective volunteers undergo a health and immunological competency check to make sure there won't be any negative effects on them. The volunteers who get the pathogen inoculum are often brought into a clinical research facility so that their symptoms may be closely monitored, documented, and treated as necessary if necessary. To check for signs of infection, regular samples of feces, sera, whole blood, saliva, vomitus, and sometimes intestinal biopsies are obtained before and after. A increase in pathogen-specific serum or salivary antibodies, signs of a cellular immune response, or excretion of the challenge pathogen as shown in stool and vomitus samples are all indications of infection [4]–[6].

Immunity's function

The effect of prior exposure and potentially protective immunity in human challenge tests must be taken into account in both quantitative microbiological risk assessment and the data from infectious agent dose-response investigations. Many potential volunteers may have already had infections with common intestinal pathogens like norovirus and Cryptosporidium, and this prior exposure to/infection with these pathogens may have an effect on the host's reaction to challenge. The presence of norovirus-specific antibodies in sera proved to be a measure of vulnerability to norovirus infection in investigations of norovirus infectivity but did not seem to provide protection. In tests of the infectivity of Cryptosporidium, volunteers who were serologically naïve for the organism had a much greater chance of contracting the infection after being exposed to it than participants with higher quantifiable titres of serum antibodies against it.

If the particular pathogen exposure is significantly different between industrialized and underdeveloped nations, the problem of protective immunity restricts the transfer of dose-response models. As an example, estimates based on external dose-response models for the hepatitis A virus are likely to overstate the risk for large portions of the local population who may have had hepatitis A infection during infancy and are no longer vulnerable to infection. This problem can be solved using the QMRA's computations.

Host susceptibility and strain virulence heterogeneity

According to studies, there is a significant variance in infectivity across various isolates from the same pathogen species. Similar to animal hosts, human hosts may vary greatly in their susceptibility to infection and disease. Blood group O participants in Norwalk virus challenge research were significantly more vulnerable to infection than other blood types, although blood group A volunteers seemed to be less susceptible. Additionally, it was shown that certain volunteers were entirely immune to Norwalk virus infection and sickness. This immunity was linked to genetic elements that may have encoded for the viral binding site. Last but not least, it is important to remember that the majority of pathogens are first discovered during disease outbreaks, when the most virulent strains are often found and the most vulnerable hosts are frequently sickened. In contrast, the hosts are screened and chosen for their health in human challenge research, and the challenge organisms are often less contagious and virulent. As a result, information from epidemics and human challenge studies which, regrettably, are often conducted in industrialized nations tends to represent opposing ends of the dose-response continuum [7], [8].

Additional Sources of Information on Dose-Reaction

Risk assessors are now considering using surrogate data, such as substitute hosts or substitute infections, since it is difficult to get reliable dose-response data, even for hazardous diseases.

1. **Study on animal challenges**

According to Teunis et al, a human disease may often be adapted to its host, resulting in a reaction in a surrogate host species that is markedly different from its 'normal' behavior. Animal challenge experiments are not especially well adapted to offer information on dose-response in humans since quantitative risk assessment aims to quantify the relationship between exposure and health effects in addition to connecting causes and consequences. Furthermore, there doesn't appear to be consensus in a few cases when there is evidence on both animal and human infectivity. For instance, data from rabbits and human outbreaks of pathogenic E. coli revealed very little consistency, but data from immunodeficient mice and human volunteers for Cryptosporidium showed striking parallels.

2. Data from outbreak-related investigations

Recent research have sought to utilize epidemic investigations as a source of dose-response information. Few outbreaks have been well recorded enough to permit such research since not only does the population need to be known who was exposed and who was impacted , but also there has to be some understanding of exposure. This data is accessible for a small fraction of all reported outbreaks, enabling a unique kind of meta-analysis. A single epidemic alone could provide insightful data. Additional degrees of heterogeneity between outbreaks must be included in a dose-response analysis employing multiple distinct outbreaks. For explaining such data, a multi-level dose-response model is most appropriate since it can take into account variations in exposure circumstances as well as variations in the inherent characteristics of pathogens and hosts.

3. Norovirus

Noroviruses may spread via feces-contaminated food, drink, surfaces, and hands and are likely the most prevalent non-bacterial epidemic acute gastroenteritis cause. Noroviruses are diseases that pose a particular threat to the quality of vegetables. Norovirus outbreaks affecting many nations have been linked to raspberries from China or Eastern Europe that were irrigated with tainted agricultural fluids. Salads and cut fruits have been linked to several norovirus outbreaks. However, it's also plausible that some of these outbreaks may have been caused by produce that got contaminated in the field or during harvest and transportation. The majority of these outbreaks have been linked to produce contamination via contact with sick food-handlers. These viruses seem to be relatively persistent in the environment and quite contagious, according to evidence from outbreaks [9].

In a series of human challenge trials, the infectivity of the Norwalk virus, a prototype norovirus, was investigated. A dose-response model was created using the information from these investigations. By conducting a combined analysis of challenge tests with aggregated and disaggregated viral inocula, a single hit model for microbial infection was modified for virus aggregation. The Norwalk virus is the most contagious agent ever identified, according to the model parameters, which define a beta distribution of the infectivity of a single unit. According to quantitative real-time reverse transcription-polymerase chain reaction analysis, the median infectious dose was calculated to be 18 virus genome copies. The virus was also highly contagious at low doses, with an average probability of infection of about 50% for a single virus genome, which is particularly important for produce contamination from the environment. These challenge trials further revealed variations in host vulnerability and potential protective immunity through a mucosal immune response. The infection rate tended to plateau at about 75% at the highest dosages examined, indicating that some percentage of the population may be immune to infection.

Giardia and Cryptosporidium infection models that have been used in developed nations include those in Rose et al. and Teunis et al. In developed countries, the incidence of giardiasis normally varies from 2 to 5% of the population. Giardiasis prevalence in underdeveloped nations might be as high as 20–30%, and little research have been done to estimate its hazards, especially when compared to Cryptosporidium. Therefore, taking into account the significance of Giardia in public health for developing countries, QMRA applications are illustrated, taking into account that: exposure to pathogens can vary significantly at a local level, therefore exposure may be noticeably different between industrialized and developing countries; the health response in each country may be different as some infections may be endemic and people can develop immunity.

Risks from protozoa and recommended reuse

Because of their high infectiousness and resilience to chemical disinfection, Giardia and Cryptosporidium have both been implicated in several outbreaks of waterborne infections recorded in various parts of the globe. Giardia cysts and Cryptosporidium oocysts are reported to be reduced by conventional wastewater treatment by an average of 99.950 percent and 99.993 percent, respectively. But even in tertiary-treated effluents, these protozoan parasites are often found. For this reason, risk assessments concentrate on analyzing the prevalence of Giardia and Cryptosporidium in source waters in order to decide the proper treatment required to achieve certain safety standards for drinking water. Both infections are also often acknowledged sources of recreational waterborne illness. The majority of outbreaks in recreational waters are caused by faecal mishaps or cross-connections in swimming pools. However, it is not commonly known or established that animal wastes may contaminate natural recreational waterways. In addition, outbreaks of Cryptosporidium and foodborne giardiasis have been documented.

Reclaimed water has historically been utilized for agricultural purposes, such as pasture irrigation or the watering of non-food crops, and is often thought of as a way to dispose of wastewater. According to the United States Environmental Protection Agency, 2004 the trend has changed to unconventional recovered water applications include indirect potable reuse, toilet and urinal flushing, commercial and industrial uses, and urban horticultural irrigation. Reclaimed water may be used widely, however there are issues with its microbiological purity and possible health problems. No direct evidence of disease transmission was discovered for exposed groups of consumers, according to a review of the health risks associated with the use of wastewater in irrigation. However, there was evidence of the presence of protozoa on wastewater-irrigated vegetable surfaces. The risk of Giardia intestinalis infection for agricultural workers and their families was shown to be negligible for contact with both untreated and treated wastewater, however there was a higher risk of amoebiasis linked with contact with untreated wastewater. No information on the spread of protozoan diseases from sprinkler irrigation with wastewater existed for adjacent areas, making it impossible to assess the risk.

In industrialized nations, drinking water has been linked to infection risks with Giardia spp. and Cryptosporidium parvum, but never with the use of recycled water. The Jordan Valley, Asnara, Eritrea, and a population of agricultural workers in Mexico are just a few examples of developing nations where there is evidence of an increased risk of Giardia infection. There is not enough information available to estimate the dangers posed by Cryptosporidium oocysts and Giardia cysts in reclaimed water. Although significant efforts are being made to enhance risk assessment for Cryptosporidium, limited information on risk assessment for Giardia is accessible because to the well-established risks for immuno-compromised people.

The exponential dose-response model for giardiasis has been used most often in the definition of water treatment requirements for QMRA for drinking water. Giardiasis concerns associated with the reuse of wastewater, sludge, or feces may be less common. Instead of in poor nations, the majority of these were carried out in industrialized ones. The dose-response function derived from epidemiological data was consistent with estimates of infectious risks predicted by the dose-response curve established by Rendtorff, to cite one example from an epidemiology and microbial risk assessment study conducted in southeast France. A different study provides a thorough explanation of how risk assessment can be used as a method for figuring out what degree of water treatment and Giardia reduction is required to guarantee that the risk of Giardia from treated drinking water is less than 1 infection per 10,000 people per year.

The study by Teunis et al. is another example of attempts to enhance risk assessment for Giardia infection. Every element that affected the quantitative risk assessment for Giardia lamblia was considered as a stochastic variable, and an appropriate distribution was provided to examine the degree of uncertainty in risk of infection estimates. The concentration of cysts in raw water, the recovery effectiveness of the detection technique, the vitality of recovered cysts, the elimination of organisms during the treatment process, and daily tap water use were determined to be the main contributing variables. The risk of infection due to exposure to Giardia cysts in drinking water from a surface-water supply in The Netherlands was calculated in this study, and the results revealed that the estimated removal efficiency of the treatment process's uncertainty dominates the uncertainties due to other contributing factors [10].

Another example is the work of a Canadian research program, which calculated the danger of Giardia and Cryptosporidium in 45 drinking water treatment facilities. As previously stated, a Monte Carlo model was created using a distribution of r parameter values that was created using 1000 bootstrap replications of the original data from Rendtorff et al. Ryu et al. evaluated the possible risk of Giardia related with the use of reclaimed wastewater for three exposure scenarios: playgrounds, recreational complexes, and landscape irrigation for golf courses. In this study, a comparatively low risk of Giardia infection was calculated from exposure to the tertiary-treated effluents from seven reclaimed water treatment plants in the southwest of the United States, where dual disinfection practices chlorination and ultraviolet disinfection demonstrated better reduction of this parasite.

A wastewater tertiary treatment facility in the Swedish city of Hässleholm served as a case study for the use of QMRA and HACCP. Before being reused on agricultural land, primary and biological sludge is held outside the wastewater treatment facility. In a larger list of pathogens chosen for control, the risk of infection from Giardia was assessed. Human exposure scenarios taken into account included treatment, handling, soil application, ingestion of raw crops, and water exposure from a wetland region and recreational swimming. It was shown that eating vegetables produced in soil treated with sludge provided a lower risk than anticipated and led to fewer annual illnesses. However, the authors noted that if the organisms were found in greater concentrations inside sludge lumps as opposed to being evenly dispersed as predicted, the danger would be much higher. The ten-month gap between sludge fertilization and crop harvest for raw consumption is mandated by current Swedish rules, which must be taken into account. However, a worst-case scenario applying to just a one-month timeframe was used in this investigation.

Problems with dose-response

Since 1990, several risk-assessment studies have used the Giardia dose-response relationship established by Rendtorff. These studies demonstrate the range of expertise obtained from the exponential dose-response model's use for risk assessment by using it to predict the risks of giardiasis from a number of various exposure pathways. One issue is the proportion of asymptomatic to symptomatic Giardia infections, since Rendtorff's tests indicated positive response by cyst excretion but did not identify disease. Giardia infection is often asymptomatic in humans, with no symptoms present in around 39% of infections in children under the age of five and 76% of infections in adults. However, rates of symptomatic infections have ranged from 50–67% to as high as 90%, and chronic giardiasis may manifest in as many as 58% of infected individuals. Additionally, there is data that suggests exposure to Giardia cysts in drinking water may result in some level of community immunity. As a result, assessments of risk using infection as an endpoint may overstate the number of sickness cases.

Giardia's existing dose-response data is based on healthy adult hosts. From the standpoint of public health, this is not the most significant category. The projected risks of infection using these data may be underestimated for several sections of the population when compared to infants, the elderly, and other risk groups. Other variables that affect susceptibility to infection and the course of an infection include nutritional state, illnesses that predispose to infection, and prior exposure.

CONCLUSION

It is possible to use a QMRA technique to investigate the potential hazards of infection linked to consuming food crops that are fertilized with biosolids or irrigated with wastewater. Information on pathogen dose-infection relationships, transmission routes, the frequency and concentration of pathogens in wastewater and biosolids, the persistence of pathogen viability or infectivity in the environment, and information on food crops and crop consumption are all necessary for the application of QMRA to this situation. Through this method, several "what if" scenarios may be explored, some of which may include measures to lower exposure, such as the treatment of wastewater or biosolids or the washing of produce. However, local context of possible exposure pathways, pathogen prevalence and concentration in wastewater and biosolids, and endemic disease rates should be taken into account when assessing the hazards associated with consumption of food crops irrigated or fertilized with wastewater, biosolids, or faecal sludge. Particularly in developing nations, the availability of local data for these inputs to the risk-assessment model may be severely limited or nonexistent. Due to the extensive laboratory resources needed for these studies, pathogens are seldom evaluated in environmental samples wastewater, biosolids, faecal sludge, soils, and crops. Similar to this, the assessment of microbiological indicator species may also provide details on the degree of microbial decrease brought on by certain interventions, such cleaning produce or altering irrigation techniques. The National Research Council conducted a thorough evaluation of the usage and selection of microbiological markers for waterborne diseases. However, there is no substitute indication for helminths.

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CHAPTER 6

IRRIGATION OF WASTEWATER WITH NON-PATHOGENIC TRADE-OFFS: A COMPREHENSIVE REVIEW

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ABSTRACT:

With a rise in population, urbanization, industrialization, bettering living standards, and economic growth, urban wastewater production has expanded in volume and scope due to home, industrial, and commercial water usage. The majority of governments in underdeveloped nations lack the funding necessary to clean wastewater. Therefore, farmers in many poor nations utilize wastewater in diluted, untreated, or partially treated forms with a wide variety of related benefits despite official prohibitions and possible health risks. In addition to microbiological risks, the practice can also result in an excessive and frequently unbalanced addition of nutrients to the soil, the accumulation of salts in the soil depending on the source water, particularly sodium salts, elevated concentrations of metals and metalloids particularly where industries are present, which can eventually reach phytotoxic levels, and the accumulation of emerging contaminants, such as residual pharmaceuticals. It is vital to closely monitor wastewater quality, its sources, and its usage for location-specific risk assessment and risk reduction since these potential trade-offs of wastewater use vary significantly across sites and regions.

KEYWORDS:

Crops, Industrialization, Urbanization, Water, Wastewater.

INTRODUCTION

The production of wastewater by the home, industrial, and commercial sectors has grown due to population growth, urbanization, better living circumstances, and economic development. The majority of developing nations have urban drainage and disposal systems that combine home and industrial wastewater. Although managing water quality is said to be a top priority and a key issue for governments in developing countries, the majority of them lack the means to treat wastewater. Only 24% of the wastewater produced by homes and businesses in India is treated before it is used in agriculture or dumped into rivers. Only 2% of the wastewater in Pakistan is treated. Other regions of Asia, Africa, and Latin America have comparable difficulties. Most communities in underdeveloped nations lack wastewater treatment facilities or have subpar operations. As a result, urban and peri-urban farmers divert wastewater in partly treated, diluted, or untreated form and utilize it to cultivate a variety of crops. Contrary to how most poor nations handle their wastewater, more Middle Eastern and North African, Mediterranean, American, Latin American, and Australian nations have increased their usage of recycled wastewater in recent years [1], [2]. Farmers in many poor nations utilize diluted, untreated, or partially treated wastewater despite official limits and possible health effects because:

1. Wastewater provides a dependable water supply for irrigation throughout the year, and is sometimes the only one.
2. Since wastewater irrigation is a source of nutrients, it often minimizes the requirement for fertilizer application.

3. If the clean water supply option is deep underground, using wastewater requires less energy even when pumping, which lowers expenses.
4. Wastewater also produces other advantages, such as increased revenue from the production and distribution of high-value crops like vegetables, which support year-round employment.

With regard to wastewater irrigation, research and decision-making have a tendency to concentrate on the effects on the health of food producers and consumers, the financial ramifications for farmers' lives, and the variety, quality, and cost of the food supply. However, very little attention has been paid to the biophysical effects of wastewater usage and management in agricultural ecosystems. This chapter considers the following constituents and processes: levels of macro- and micronutrients; concentrations of total salts and specific species; levels of heavy metals; and the presence and intensity of organic constituents. It also discusses environmental quality in wastewater source and use areas, including natural water bodies that receive wastewater. This chapter focuses on environmental quality and the benefits and drawbacks of various components and processes [3], [4].

Sources of Wastewater and Possible Repercussions

Any water whose quality has been negatively impacted by human activity is referred to as wastewater. Urban wastewater may include a mix of rainfall that does not infiltrate into the soil and other urban runoff, commercial building water, industrial effluent, and part or all home effluent. Before wastewater may be utilized in agriculture to produce a variety of crops, it must first undergo adequate treatment to eliminate the wide range of toxins it carries from various sources. 50 to 80 percent of domestic wastewater is made up of greywater. It is a specific word that refers to water produced by household activities like dishwashing, laundry, and bathing; blackwater, on the other hand, refers to effluent from toilets. In terms of the quantity and make-up of its chemical and biological pollutants, greywater differs from blackwater. Its foggy look and the fact that it is neither freshwater nor badly polluted are the reasons for its moniker.

DISCUSSION

Depending on the source from which it is created and the degree of its treatment, wastewater comprises a variety of unwanted elements in varying forms and concentrations. Industrial wastewater generally requires more treatment before disposal or use since it has higher amounts of pollutants, such as metals and metalloids, volatiles, and semi-volatiles, than household wastewater. On the other hand, household wastewater has greater pathogen concentrations. Domestic wastewater is often alkaline owing to the presence of detergent and soap residues, unless it is combined with certain acidic industrial components. The composition of raw wastewater in the case of mixed domestic-industrial wastewater a condition that is typical in developing nations depends on the kinds and quantities of industrial units and the properties of the residual elements.

Depending on the kind of organic materials present, the presence of organic matter in wastewater may have good or detrimental effects, similar to the delivery of nutrients via wastewater irrigation. Positive effects of organic matter addition through wastewater include better soil structure, storage of vital nutrients for crop growth, and enhancement of charge characteristics of irrigated soils, such as cation exchange capacity, which may hold undesirable metal ions on the cation exchange sites making them less available for plants. An increase in CEC increases the likelihood of cations being adsorbed on the exchange sites of the soil because heavy metals in ionic form are positively charged cations [5]–[7].

According to studies done in India, aggregate stability, water-holding capacity, hydraulic conductivity, and total porosity all improve during the course of wastewater irrigation . With the length of the wastewater irrigation, these soil characteristics virtually always increased. For instance, the soil's hydraulic conductivity rose by 24% after 15 years of wastewater irrigation from 19.1 cm h-1 of freshwater irrigation to 23.6 cm h-1 of wastewater irrigation. After 25 years of wastewater irrigation, it further grew to 26.6 cm h-1, a 39 percent increase over freshwater-irrigated soil. According to research on the steady rise in soil hydraulic conductivity in wastewater-irrigated soils, the rate of increase is roughly 1.5% annually. The important soil physical characteristic known as soil hydraulic conductivity provides information on how easily water may travel through the soil profile. Increases in other soil physical characteristics, such as aggregate stability, water-holding capacity, and total porosity, help the soil store more water, which increases productivity and efficiency of water usage. This is especially crucial when there are limited water resources available for agriculture.

Along with improving soil physical characteristics, soil organic matter also raises the organic carbon status of wastewater-irrigated soils regardless of the soil and agro-climatic circumstances. In India, using wastewater for irrigation caused an increase in the organic carbon content of the top 0.3 meters of soil, according to Baddesha et al. According to Minhas and Samra , groundwater-irrigated sandy loam soils contained lower amounts of organic carbon than wastewater-irrigated soils did. Studies on the long-term impacts of wastewater irrigation show that after 15 years of wastewater irrigation, soil organic carbon increases by 80%. In freshwater-irrigated soil, the amount of soil organic carbon was 1.42 percent, rising to 2.56 percent. According to the organic carbon status of soil irrigated with wastewater for 25 years, this trend persisted as the percentage of organic carbon increased to 4.63 percent, indicating a 226 percent increase over the soil that had been watered with freshwater and an 81 percent increase over the soil that had been watered with wastewater for 15 years. Despite the low quantities of organic carbon found in dry and semi-arid soils , this soil carbon pool is crucial for the soil's productivity and environmental functions as well as for the global carbon cycle . Wastewater irrigation helps to mitigate the enhanced greenhouse effects by raising soil organic carbon, a critical indicator of soil quality, in addition to supplying necessary nutrients and enhancing soil physical qualities.

Salts in Solution and Calcium

According to the majority of wastewater has high dissolved solids contents, which might generally have detrimental effects on its usage as irrigation. However, the presence of inorganic electrolytes in wastewater, especially those brought on by Ca salts, enhances hydraulic characteristics for certain sodic and saline-sodic soils with poor permeability. These soils are distinguished by the presence of excess sodium at concentrations that may harm soil structure. These soils may have structural issues that affect water and air flow, run-off and erosion, sowing operations, seedling emergence, root penetration, and crop development. These issues can be caused by certain physical processes as well as particular conditions. Therefore, it is not necessary to apply a calcium-supplying amendment when using high-electrolyte wastewater that contains a suitable amount of divalent cations, such as $Ca2+$, to improve sodic and saline-sodic soil.

Harmless Trade-Offs

Due to the potential consequences of adding too many nutrients to wastewater-irrigated soils, maintaining optimum amounts of nutrients in wastewater is a difficult undertaking. There are three potential effect routes for macronutrients like N and P:

1. Excess N added by wastewater application may result in excessive vegetative growth, a delay in maturation, lodging, and a poor economic yield.
2. Eutrophication is the unwanted development of algae, periphyton-attached algae, and weeds in irrigation systems and natural water bodies caused by excess N and P.
3. Leaching of nitrogen may lead to groundwater contamination and methaemoglobinemia if N-rich groundwater is consumed.

Due to their high solubility, nitrates may quickly flow through soil that has been watered with wastewater. It follows that nutrients and other toxins from wastewater that are retained in soil do not enter aquatic bodies where wastewater would otherwise be dumped [8], [9]. But there is a big problem with how wastewater discharge affects receiving waterways. Two biophysical phenomena that have been seen in many settings across the globe are the irrigation withdrawal of wastewater-dominated river flows and the return flow of drainage, particularly in arid and semi-arid areas. First, wastewater applied to the soil and agricultural products that retain both P and N may help reduce areas with high nutrient concentrations. Fodder grass works to retain N and P applied in wastewater and is particularly well adapted to wastewater irrigation.

Excessive Levels of Salts and Sodium

Because salts are added to wastewater from various sources, as was already mentioned, it has a higher salinity than freshwater. The procedures, such as cation exchange resins or reverse osmosis membranes, which are exclusively used to generate high-quality recycled water, are prohibitively costly, therefore there are no economically feasible ways to remove the salts once they enter wastewater. While sodic water is characterized by high amounts of Na+, saline wastewater includes excess quantities of soluble salts. Saline-sodic wastewater is produced when both salts and Na+ are present in excess amounts. Wastewater from two major factories contains salts and other inorganic pollutants. Industries that produce wastes with significant salt content fall under the first group. Examples include manufacturing facilities for rayon and the production of chemicals. The second group of industries includes those that produce various amounts of hazardous waste, such as those that produce pesticides, fertilizers, medicines, and garbage that is high in chromium. The quantity, kind, and treatment of salts used in a given industry have an impact on the effluent quality. The consequences are further complicated when commercial or industrial brine waste streams are dumped into major urban sewers instead of separate waste sewers that transport wastewater to treatment facilities or to disposal channels that flow to agricultural fields. According to Lazarova and Bahri, there are no limitations on the amount of salt that may be found in industrial effluent that is released into urban sewers. Therefore, salt concentrations and the proportion of industrial to residential wastewater volume determine the salinity and sodicity levels in mixed domestic and industrial wastewater.

While sodicity values were between 3.2 and 20.8, salinity levels varied from 1.9 to 4.0 dS m1. Simmons et al. observed that wastewater-irrigated soils had salinity and sodicity levels that were 51% and 63% higher, respectively, than freshwater-irrigated fields in terms of salt buildup in irrigated soils in Faisalabad, Pakistan. Additionally, compared to irrigation with canal water, wastewater irrigation caused a little increase in soil alkalinity. Crops, soils, and groundwater are adversely affected by excessive salts introduced by wastewater irrigation. Ionic imbalance, osmotic effects, and ion-specific effects all have an impact on plant development. Plants have limited access to water due to osmotic effects, which lower the external water potential. Increased concentrations of certain ions, such as Na+ and chloride, may induce toxicity or nutritional deficiencies in plants. According to Qadir and Minhas, in the case of sodic wastewater irrigation, the excess levels of Na+ and bicarbonate cause the slow development of a sodicity problem in soils, displaying structural issues brought on by certain physical processes. Saline and/or sodic wastewater irrigation may have an effect on groundwater quality. It is possible for salts and other pollutants to flow through the soil profile into unconfined aquifers in well-drained soils. The key determinants of how much salts in wastewater affect groundwater quality are the quality of the wastewater, the properties of the soil, and the beginning quality of the receiving groundwater [10], [11]. Chemicals have an impact on soil, agricultural, and human health. The 'soil-plant barrier' for certain heavy metals shields the food chain from these substances, although bioaccumulation may still happen. The behavior of the chemical parameters, the anticipated reuse uses of the water, and site-specific considerations, such as the degree of dilution with water from other sources, all affect acceptable levels of chemical parameters. Essentially the same informational components are required to derive numerical limitations of pollutant loading rates in the land application of wastes in general. The dangerous compounds that need to be taken into consideration are identified:

1. Dose-response assessment and risk characterization based on the dose-response characteristics linked to a preset acceptable risk level, the maximum permitted exposure level in the exposed participants is established for each chemical.
2. Exposure analysis identifies the topics of exposures by developing plausible exposure scenarios that show the pollutant transport channels.

Where dose-response correlations between water quality, soil quality, plant development, and human health have been well established, analyzing wastewater quality as a risk indicator is suitable. This is true, for instance, of the majority of macro- and micronutrients and salinity indicators, which have an impact on crop and soil health yet continue to pose a challenging problem for human health. In this situation, data from epidemiological research, extrapolations from animal studies, or toxicity tests on mammalian or bacterial cells may be used to develop dose-response correlations. The most accurate cause-effect connections can be determined using epidemiological data, however these data are only accessible for a relatively small number of substances. The necessary investment in analytical laboratory capability is another difficulty, particularly in developing nations. Because it is difficult to determine the impacts of many environmental toxicants, such as cancer, due to their extended latency periods, the quality of the data is decreased. Models for risk assessment are necessary.

An acceptable daily intake for any particular chemical may be proposed after dose-response correlations have been determined. The process quantitatively backtracks the pollutant transport through the food chain to arrive at an acceptable pollutant concentration for the receiving soil to arrive at the 'predicted no-effect concentration', which is used to derive the numerical limits for pollutant input in land application. Its value must be higher than the assessed or "predicted environmental concentration" in order to show an acceptable danger to health or the environment. Excess or deficiency of nutrients and heavy metals in crops depends not only on their absolute individual concentrations but also on the balance of the elements, the type of organic matter present that may bind them, and the soil conditions, which can affect their solubility and uptake by roots. Wastewater analysis in these circumstances may only provide a preliminary indication; soil analysis may be more relevant. This holds true for organic contaminants found in soil that are susceptible to various biotic and abiotic processes.

The study of the crops on the individual farms is an often-overlooked approach for metals and metalloids, particularly when transmission via the food chain is of importance. Compared to soil or water analysis, plant analysis often offers a far more accurate evaluation of potential absorption. However, it also takes into account the absorption from all locally accessible sources of nutrients or toxins in the soil, such as irrigation water, chemical farm inputs, or even traffic exhaust, which is especially important in urban farming. In such a case, a comparison investigation would be necessary before generalizations about a specific source could be made.

In all circumstances, sampling and analysis must take into account regional and temporal fluctuations in water quality as well as the gradual buildup of pollutants in the soil or plants. Long-term monitoring is suitable for this, or a system that enables comparing locations with various exposures. While the examination of nutrients often needs laboratory equipment, the evaluation of soil and water salinity may be done in the field using an electrode. Moving from macronutrients to micronutrients or heavy metals often results in more sophisticated and costly equipment depending on the concentration of the components in the sample. Although many universities and research centers in underdeveloped nations have labs to analyze the majority of macronutrients and certain micronutrients, additional assistance is sometimes needed due to the presence of heavy metals or organic pollutants. Predicting the risk using environmental variables and application methods is a low-cost option. One such tool is the Pesticide Impact Rating Index, a free software program created by the CSIRO in Australia.

CONCLUSION

The chemical composition of wastewater presents a more complex situation with both positive and negative impacts on soils, crops, and water bodies, which are important considerations not only for the farmer but also for managing wastewater treatment and discharge. While wastewater is seen from a microbiological perspective more as a biophysical hazard. Nutrient contents in wastewater may vary greatly. Maintaining adequate levels of nutrients in wastewater is a difficult task due to the potential negative effects of their excessive addition to soils, even though reliable availability for irrigation and nutrient-supplying capacity are considered to be major drivers for untreated wastewater use in agriculture. There are no cost-effective ways to remove salts from wastewater after they have entered it due to the high cost of the processes, which are exclusively utilized to generate high-quality recycled water. However, calcium-deficient soils like sodic and saline-sodic soils may benefit from the addition of wastewater that has a suitable number of divalent cations, such as calcium. Although they are harmful at high concentrations, several metals and metalloids given by wastewater irrigation are actually necessary for proper plant development. The majority of companies in developing nations release untreated wastewater with varying metal and metalloid contents. The wastewater channels may contain a mixture of industrial and household effluent since there is often no separation of the two types of wastewater. The precise metals and metalloids released and their concentrations vary greatly depending on the amount of industrialization and the kind of industry. Impacts may only be seen locally in many developing nations, but the situation still has to be carefully monitored, particularly in transitional economies. The quality of chemical risk evaluations, however, differs greatly across various dangers. There is little knowledge about other aspects, such as the fate and consequences of organic pollutants in irrigation water with reference to human health. While the effects of excess nutrients or heavy metal levels on soil productivity or crop health have been researched for some time, this is not the case for other factors. Computer-based models comparable to those used for microbiological risk evaluations are much needed.

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CHAPTER 7

CHALLENGES TO CONVENTIONAL WASTEWATER MANAGEMENT PRACTICES IN AGRICULTURE

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ABSTRACT:

Urban wastewater management in emerging nations often struggles to keep up with rising wastewater production. Authorities are forced to release substantial volumes of untreated or just partly treated effluent into surface waterways due to institutional, technological, and financial constraints. As a result, unrestricted usage of contaminated water is becoming more prevalent in the peri-urban regions downstream. Although using wastewater poses a serious threat to human health, it is also beneficial and productive for many. The transmission of a waterborne risk from the wastewater disposal system to the food chain that results from agricultural wastewater usage is a notable example of the urban-rural link and calls for a paradigm change in the methods used to reduce risk. Traditional methods for the management and treatment of urban wastewater are based on top-down, technically oriented approaches that either ignore or inadequately take into account the connections between the social, economic, and health elements. Although this scenario is acceptable from a historical and technical standpoint, it does not provide creative answers to the present issues facing cities in emerging nations. It is necessary to adopt an alternative strategy and reevaluate traditional wastewater system design and management. One may learn about the connections between many stakeholders who handle and utilize or misuse water, the effects on total production, and the hazards by using a systems approach to analyze both the water and food chains. Decentralization must be included into governance structures to control wastewater usage in agriculture in order to accommodate bottom-up thinking, promote stakeholder participation, and offer coordination and policy coherence for managing risks from both the water and food chains.

KEYWORDS:

Management, Surface Water, Wastewater, Water Pollution.

INTRODUCTION

In developing nations, rising wastewater flows surpass current capacity for management, treatment, and appropriate handling due to population increase, urbanization, and economic development. According to Davis, the rate of growth in many cities in developing nations is unprecedented, outpacing the capacity of city managers to keep up. Ujang and Henze contend that 95% of the wastewater produced does not receive the proper treatment before entering the environment. It is clear that surface water contamination near urban areas affects agricultural regions downstream. More than 10% of the global population now consumes food that has been irrigated with wastewater of different quality as a consequence of this. Urban wastewater and dirty water in general provide a difficulty for agriculture since they not only have negative environmental effects but also directly affect the food chain. This condition is certain to continue, and it will surely spread to new places that are experiencing urban expansion. It is essential to address health hazards related to both water pollution and food poisoning at the same time for greater health protection. In reality, this is how we believe the 2006 World Health

Organization Guidelines for the safe use of wastewater in agriculture should be used in poor countries [1], [2].

According to research compiled by the UN, the traditional approach to wastewater collection, treatment, and discharge frequently fails because of high costs, limited financial resources, issues with governance, and an overemphasis on technologically driven processes . These technologically driven, centralized or decentralized systems strive for quality standards that are sufficient to safeguard the environment. This suggests that developed-country norms are often implemented in poor nations, regardless of whether they have the institutional and financial means to maintain systems that comply with these standards. Even if the new WHO Guidelines for the Safe Use of Wastewater in Agriculture provide the possibility to customize standards to local needs, developing country institutional structures have difficulty implementing them. Few wastewater-management systems also take into account agricultural effluent usage from the standpoint of recovering water and nutrient resources, which is crucial when addressing environmental and financial viability. An alternative paradigm is presented and discussed in our study as a solution to this issue.

According to our hypothesis, traditional wastewater management models fail because they do not adequately assess the social, economic, and health consequences of wastewater flows or account for the effluent's downstream consumers. Decentralized water services that focus on integration, prevention, and resource recovery rather than treatment and disposal may thus have a greater chance of success. Examples include closed-loop, source separation, and other ecological sanitation systems. It is significant to note that the Australian Senate has taken the position that decentralized service supply models, especially those connected to water recycling, ought to be given more serious consideration when replacing aging urban infrastructure. By defining which upstream and downstream problems are involved and how they are connected, a water-chain approach based on systems management principles aids in identifying how responsibility is divided among different stakeholders. In order to handle the sequence of events from the point at which water is obtained through the many uses , to the point at which it is disposed of, which is typically the environment, it is necessary to conceptualize water and wastewater using a systems approach. Therefore, we argue that such an analytical strategy may enhance management by enabling users to decide how best to manage the resource. Such a management plan aims to meet user demands for water and nutrients in addition to improving water quality via sustainable waste treatment [3], [4].

DISCUSSION

Using a water-chain perspective also demonstrates how pollution may have an impact on the food that people eat. The simultaneous improvement of water quality and food quality would be made easier with an understanding of the parallel food chain along the different contamination paths that exist from the farm through the various transportation and marketing channels to the consumer. Applying the multiple-barrier approach, which is supported by the WHO, to risk reduction indicates that interventions may be done partially along the water chain and partially along the food chain in order to reduce cumulative risk. Therefore, risk management would combine better irrigation and agricultural methods with post-harvest food safety procedures, which call for institutional setups distinct from what is now the case in the majority of nations. This has been amply shown even in affluent nations, where stakeholder involvement has been known to make or fail a project. Safe and acceptable wastewater utilization would need stakeholder engagement.

Application of the Reverse Water-Chain Design

A water-chain approach to link upstream and downstream needs and issues is suggested by Huibers and van Lier as well as Huibers and Raschid-Sally as a useful platform for negotiating and allocating responsibilities of various stakeholders along the chain. There is a significant advantage to connecting the usage of wastewater to how it is managed upstream, notwithstanding issues with current governance systems for wastewater. We further contend that in order to achieve sustainability, one must develop connections with the food-contamination cycle, since it is directly connected to the wastewater chain via agricultural usage. There are a number of stakeholders in both chains whose activities utilize water and may either improve or degrade the quality of the water or food product. It is helpful to understand the connections and interconnections between stakeholders and the processes they are engaged in in order to enhance decision-making and build optimal management practices. The design and administration of the traditional wastewater system are mostly top-down. Farmers often lack knowledge about the water's composition and are excluded from system decisions and negotiations, making them passive recipients of dirty water. As a result, they have little influence over how the wastewater is managed. According to the reverse water-chain concept, end users may choose their preferred amounts and quality in relation to the intended usage, prices, and benefits. In this approach, wastewater is seen as a resource as opposed to a waste material [5]–[7].

The flexibility of this strategy is a crucial component. The design of centralized systems is often quite strict and pays little attention to the specific environment. Policy frameworks commonly include standards for end-of-pipe quality without necessarily taking end usage into account. Flexibility would provide the local government greater latitude in determining the regulations that apply to the use of wastewater for various crops both now and in the future. The water chain is conceptually similar to an actor-heavy production chain. According to supply-chain management ideas, a production chain may be managed more effectively by coordinating the activities of the several independent actors as a single, cohesive unit. These traits of supply-chain management are present:

1. It is a systems-based strategy that controls the movement of products from the supplier to the final client and considers the supply chain as a whole.
2. It encourages the joining of efforts that realize the best use of resources and culminate in the creation of a product by two or more organizations in a manufacturing process.
3. It puts the needs of the customer first to provide distinctive and personal sources of customer value that result in customer happiness.

The interactions and strategic choices of the various supply chain players are described by Peterson et al. Stakeholders might position themselves as spot market buyers or sellers at one end of the supply chain, acting independently from the other participants. Vertical integration is the opposite extreme, when all parties see a shared benefit when they work together inside the supply chain to provide the end user with a satisfying product. Coordination and control intensity ranges from low to high on a continuum. When agencies are working toward a common objective, mutual trust is important to improve collaboration. According to Evers et al. these principles enable analysis of the system and the governance needs from a distinct viewpoint when applied to the wastewater production and effluent use process. Applying these guidelines to a case study of Hanoi, Vietnam's peri-urban use of contaminated water for agriculture leads to the conclusion that Hanoi is typical of the situation in many developing cities where spontaneous wastewater use occurs within a management system in which each actor acts in a spot market with very few connections to the other actors.

Urban wastewater sources' users should be identified in connection to their intended uses, and requirements for wastewater delivery, such as location, storage options, and quality control, should be defined. In a supply-chain strategy, this would result in a negotiation process that involves cost sharing among the many parties. Such a method makes it easier to accept the idea of wastewater exchanges, resulting in more integrated water management. As specific challenges may be resolved differently and/or at various points along the chain, whether in technical design or in the system's intended operation, an integrated approach also introduces additional flexibility. The incorporation of downstream user viewpoints is fundamental to the design process' success. Utilizing user viewpoints in wastewater management aligns with current service delivery trends to increase the influence of service receivers in various fields. For instance, participatory budgeting is being utilized in several cities as a tool to manage investments, while citizen report cards are used in Bangalore, India, to check service quality. Only when there is political intent for their acceptance can such instances function. Additionally, proper cost-recovery techniques should be used in conjunction with the reverse water-chain strategy. The responsible authorities must be given the authority by the central government to create means of collecting money from those who use wastewater and take advantage of these services, for instance, if users are to decide, design, and collaborate with local authorities on the appropriate ways to harness the wastewater. User-centric design has little chance of becoming sustainable without such a compromise.

Decentralization of the Service Provision for Wastewater

The evidence supporting decentralization of waste-water management is mostly based on the following:

1. Centralized systems in underdeveloped cities are vulnerable to poor management and dysfunction, which eventually results in failure.
2. The cost of centralized transportation and care is high.
3. Due to emerging cities' fast urbanization, it is highly challenging to provide enough administrative and sanitary facilities.

In addition to these reasons, a policy to increase the use of wastewater for agriculture would also be in favor of decentralized systems. While a wastewater treatment plant's location is typically determined by its position in relation to the wastewater producers, its ideal location from the standpoint of effluent use would be at a higher level to maximize the irrigation command area downstream of the treatment plant. Therefore, it is reasonable to assume that choosing where to locate decentralized systems would depend on making the most use of the irrigable land. Additionally, this would make it possible to choose the ideal places for regulating the characteristics of wastewater inflow and excluding harmful waste streams from the sewerage. Due to declining cost-efficiency and administrative/fiscal boundaries, small towns and peri-urban regions are often excluded from centralized services. They are also sufficiently 'rural' to allow for or support agricultural activity. Decentralized service delivery that enables the recovery of water and nutrient resources may have the most effect here. Decentralizing wastewater's physical infrastructure has undergone multiple pilot projects, often with the goal of maximizing water recovery. Low-tech options that show potential include collective biological treatment systems, home wastewater treatment, artificial wetlands, and even bigger systems like waste stabilization ponds. These solutions may enhance water quality and, ultimately, lower food safety issues. These systems' relatively straightforward design and operation result in operational, financial, and management benefits.

Decentralization of management and operational responsibility and authority to lower-level authorities experienced a sharp rise in supporters throughout the 1990s. The major goals were to make these authorities more receptive and to "democratize" administration by fostering more public involvement. Decentralization policies that are carefully thought out and implemented may provide better services at lower costs and over time, enhance water quality. Decentralization is generally seen as a wise policy. By handing over certain operations and administration to user organizations and the commercial sector, Argentina and Chile have achieved modest success. According to Litvack and Seddon, user groups in Mexico who operate irrigation systems have boosted cost recovery from 30% to 80%. The Community Water and Sanitation Project in Ghana enables local governments to control and manage their own water and sewage infrastructure. According to the project's managing organization, 78% of the target groups report an improvement in their water services , but the majority of decentralized wastewater treatment facilities deteriorated. There are other instances as well where decentralization of service delivery has not been supported by adequate fiscal reforms, budgeting, or capacity-building that permit local tax collection and tariff setting [8], [9].

Who is accountable and who is responsible for funding such services are often unclear. Municipal administrations have sometimes been given responsibilities without the management skills or legal authority to raise money. This has often resulted in a breakdown in the relationship of trust between local government and the people it serves. Increasing public participation in decision-making in the context of decentralization is one strategy to address this issue. A rising number of communities are implementing participatory budgeting, for instance, which gives citizens some control over how services are delivered. Better policy coordination across the federal, state, and local levels of government may lead to more solutions.

Attributes and Costs, Policy Coherence and Coordination is Required

Given these significant obstacles, securing the proper legal protection for local governments' administration of services like wastewater supply is a crucial first step in ensuring user-centric wastewater management is successful. This would replace the motivation behind existing regulation, which is focused on health concerns, with a more logical strategy for reducing risks and maximizing the benefits to wastewater users. It is feasible to alter the distribution of project financing and expenditures by negotiating the terms of wastewater usage. Instead of attempting to support several activities from a single pool of cash, which is vulnerable to political influence and ad hoc expenditure, segregated budgets that distribute funding for certain programs are a useful tool. A similar approach would enable utilities to collect fees from various pollutants and end customers in order to offset the expenses of the services they supply. In most OECD nations, the 'polluter pays' notion is generally recognized. For instance, in Brussels, 30% of service expenses are covered by waste-related pollution fees. In order to raise money to pay for service expenses, Mexico charges for wastewater discharge licenses.

Other methods, like the often used growing block tariff, provide progressive financing by allowing for various cost-recovery strategies for high-income domestic homes that generate significant volumes of wastewater vs low-income households, as well as for big- and small-scale industries. Reclaimed water is now utilized in Tunisia to irrigate grapevines, citrus and other fruit trees, fodder crops, and cereals over an area of 8000 hectares. The rules permit the use of secondary treated effluent for a limited list of crops, and the regional agricultural departments are in charge of monitoring the water reuse order and fee collection. Farmers spend roughly $0.01 per m3 for irrigation using reused water. An institutional partnership between the local water management stakeholders, the urban water consumers, and the farmers' water user organization was developed in Drarga, Morocco as a result of a public involvement initiative. An extra charge for household water delivery was imposed, and other cost-recovery strategies were under discussion, in order to strengthen the sustainability of the new facilities.

Due to its sensitivity and status as a public good, water is frequently regulated at the national level in terms of planning and rights, leaving municipal and public utilities to manage infrastructure services and conduct local planning. This presents another challenge for user-centered wastewater management. To properly implement the 2006 WHO Guidelines, two governance conditions must be met. The first is the urgent need for sectoral and vertical coordination across levels of government, and the second is the connection between food and water quality. Numerous national governments have established numerous organizations with a variety of water-related functions and responsibilities, but they often suffer from a lack of efficient coordination. Water is often within the jurisdiction of the national ministries in charge of agriculture, environment, natural resources, urban development, and health. Coordination of law, planning, and resource management may sometimes fall within the purview of national agencies. The management of essential services is often split among three levels of government: the national, state, and local, which only serves to muddle matters further. The responsibility for ensuring proper pricing and adherence to environmental standards often falls within the purview of an independent regulatory body. If adequately supported and given access to the required skills, this complicated network of players would function well; unfortunately, in actuality, these circumstances are seldom realized. Setting up a coordinating organization among the relevant agencies that connects levels and sectors would be a first-level solution in such circumstances.

Agriculture and sanitation have long been distinct industries. This reflects the contrast between rural and urban activities and management domains. In the new paradigm, governance for agriculture must better coordinate with governance for drinking water and sanitation; it is crucial to comprehend what incentives are required for this collaboration to succeed. In wastewater swaps, for instance, water that was formerly used for agricultural but is now used for urban purposes is recycled back into farmland as wastewater. A suitable legal and managerial structure is necessary for such a system in order to encourage dialogue between various user groups. Because regulatory responsibility for water management might be conflicting or divided among many authorities, integrated methods are sometimes rejected. These organizations sometimes even operate in opposition to one another. The WHO multiple-barrier approach to wastewater usage in agriculture makes it even more necessary to build a link between water quality and food safety [10]–[12].

Thus, there are two separate sets of institutions engaged. The jurisdiction over water quality may fall within the purview of the irrigation authority, the water authority, or the environmental authority. The public-health authorities, who may not always be answerable to the ministry of health but instead to a local authority if there has been a devolution of power, are in charge of overseeing food quality. At the national level, ministries and organizations in charge of agriculture, urban development, water, health, and the environment must acknowledge that managing wastewater and pollution calls for a cross-sectoral strategy. Vertical cohesiveness between the national, state, and local levels of government must be created, nevertheless.

Stakeholder Participation

The pre-existing circumstances for a paradigm shift include a large and dispersed collection of stakeholders and the inability of any one organization or individual to adopt and scale up the "technology" needed for sustainable wastewater usage. Depending on whether wastewater use is spontaneous or planned, the stakeholders vary, but in general they include: water users, farmers, consumers, national and local level authorities, local level planning authorities where the technology will be put in place, and various other stakeholder actors. Water service providers must take into account participatory planning as the need for better stakeholder engagement becomes more widely understood, shifting the focus away from public acceptance of predetermined technological options and toward strategies for successfully institutionalizing public participation. Participatory institutions foster the creation of common values across many stakeholder groups and provide ground-breaking approaches to managing water resources.

CONCLUSION

A paradigm change in how we think about risk is necessary to prevent the transmission of dangers that are only waterborne from the wastewater disposal system to the food chain via the use of wastewater in agriculture. It also necessitates a thorough reevaluation of the effective governance structures that may be used to enhance risk assessment and management techniques. We believe that the integrated water and food chain strategy should be backed by an efficient decentralization of technical planning and management as well as financial and operational supervision. It will be necessary to restructure local government, provide assistance with clear instructions for its use, and change the budget in a way that involves more stakeholders. Thus, rather than only being implementers, municipalities may also act as enablers and facilitators. Another effect is the close connection between urban and rural areas created by such usage. This connection may be handled by using supply-chain management theories, which aim to manage a production chain as efficiently as possible by coordinating the activities of the many independent players into a cohesive whole. It implies that a key necessity for efficient wastewater management would be policy consistency across various sectors and levels of government. In order to better understand the demands, possibilities, and restrictions that users experience and to better involve them in better wastewater management, planners might utilize the reverse water-chain technique to determine the intended applications of wastewater. Flexible but robust institutional frameworks are made possible by acknowledging users and the part they may play in monitoring for optimal service delivery and financial responsibility.

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CHAPTER 8

SERVICE PLANNING APPROACH FOR REUSE-ORIENTED SANITATION INFRASTRUCTURE

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ABSTRACT:

In the realm of sanitation, it is commonly known that a vital element of total sanitation is the reuse or usage of wastewater, feces, and their associated resources. Reuse is often thought of as a way to reduce water shortages or water pollution in agriculture and other industries. We argue that reuse-oriented sanitation may also be used to increase the treatment plan's long-term effectiveness by offering more concrete and quantifiable rewards for proper operation and maintenance than those involved with operating a disposal plant. The requirements that must be fulfilled for agricultural reuse compared to those needed for discharge into an aquatic environment. This distinction necessitates a shift in design philosophy and has the potential to reduce costs associated with the kind of treatment procedure, the energy need, and the operational skills required. Therefore, wastewater treatment intended for agricultural reuse may provide a more suitable plant for poor nations looking to expand access to better sanitation as opposed to a more sophisticated system. This chapter presents Design for Service, a five-step planning technique that encourages a culture of creating site-specific and reuse-oriented systems from the beginning of the planning process.

KEYWORDS:

Agriculture, Infrastructure, Technology, Wastewater.

INTRODUCTION

DFS views wastewater as a resource, and decisions on its repurposing influence the design of the infrastructure, including the choice of location, technology, and plant size. We utilize South African reuse schemes that are in different levels of implementation as an example of the challenges encountered when there are no readily available planning frameworks. We present projects that are now under progress in Ghana and China, respectively, to show how DFS may be utilized for the rehabilitation of schemes that have fallen into disrepair and for the design of new reuse-oriented sanitation systems. Comprehensive sanitation, whose main objectives are to safeguard public health and the environment, is increasingly seen to require the productive use of wastewater, feces, and its embodied resources. Reuse is sometimes fueled by a lack of resources, such as water or landfill space, which encourages non-disposal end uses. In other instances, recycling or resource capture is done more for environmental considerations. For instance, anaerobic digestion and the collection of biogas may be used to minimize the demand for non-renewable energy sources at a treatment facility. Sludge may also be used to agriculture to replace or supplement the usage of chemical fertilizers.

Reuse should, in our opinion, not just be seen as an alternative that follows wastewater treatment, but as a way of fulfilling the fundamental objectives of comprehensive sanitation. The aforementioned drivers of reuse are not only reasonable but legitimate [1], [2]. Wastewater and faecal sludge are viewed as environmental and public health issues in conventional sanitation and waste disposal methods; as a result, management solutions involve expensive methods of preparing them for unproductive disposal, which will happen regardless of what, if any, treatment they receive. It is understandable why governments with little resources don't prioritize cleanliness very highly. However, the effects of poor sanitation are severe, as Jiménez et al. make apparent in Chapter 8. Reuse has the potential to be used to inspire effective sanitation solutions that consistently safeguard public health and the environment in the face of the challenging job of increasing worldwide access to better sanitation, especially given the history and current record of unsuccessful waste-disposal projects. Reuse-oriented sanitation successfully changes the focus from maximizing the amount of embodied resources that are securely gathered and distributed to increasing the degree to which trash may be properly disposed of. The first step toward reuse-oriented sanitation is to see wastewater and feces as resources, but putting this theory into practice is difficult since most engineers and planners are educated to "design for disposal." They are taught to create plans that transport sewage to a centralized treatment facility, often as far away from populated areas as geography allows, where it is mechanically, biologically, and sometimes chemically purified before being released into an ocean outfall or surface water. Reuse is often considered after the fact during the planning stage, to the degree that it is included in a treatment scheme.

Although there are many instances of planned reuse throughout the world, designing for reuse at the outset of a waste-management planning process is frequently viewed from both a technical and institutional perspective as a burden and unnecessary complication. Planning for reuse from the start may make the system more sustainable. When reuse programs fail, it is often because they were developed without enough consideration of the local institutions, market demand, and supply chains essential for them to succeed. Conventional waste-disposal plans also have the disadvantage of being very expensive and labor-intensive, which contributes to inadequate sanitation in many developing cities. The energy required to treat wastewater and the solids generated, which must subsequently be processed and disposed of, are additional environmental externalities of popular technologies like activated sludge. On the other hand, it becomes desirable to maintain the embodied nutrients in the water when designing a treatment plan for reuse in agriculture. This can significantly lower the capital and operating costs of a treatment system in comparison to those needed for direct discharge to the aquatic environment [3]–[5].

DISCUSSION

This chapter takes the stance that resource recovery makes treatment plans intended for reuse more ecologically and financially viable. Reuse-oriented waste-management systems may effectively support the local economy and way of life while simultaneously providing the public and environmental health benefits associated with appropriate sanitation. To that end, the chapter aims to provide the reader with a methodical method of putting into practice sanitation plans that make the most use of the resources contained in waste given the local environment. A transition from the design-for-disposal to the design-for-reuse paradigm is facilitated by the five-step planning process known as "Design for Service," which is used to renovate existing structures or create brand-new ones that may be used again. We demonstrate the sorts of challenges experienced by projects that retroactively include reuse using case studies from South Africa, and we make the point that these challenges are made worse by the absence of planning tools for reuse-oriented sanitation design. We argue that DFS may be used to promote a thoughtful and coherent decision-making process, and we illustrate how one can utilize the tool in the context of renovating existing wastewater treatment facilities and building new ones via scenarios in Ghana and China.

Advantages of Reuse-Oriented Sanitation Planning and Difficulties

To illustrate the difficulties in designing for retroactive reuse in the absence of systematic planning methodologies, we offer three instances of endeavors to build reuse-oriented sanitation solutions in the eThekwini Municipality, South Africa. E Thekwini, like many other developing nations where population development has outpaced conscious planning procedures, is faced with managing a wide range of sanitization systems. Undoubtedly, the eThekwini Municipality takes a highly forward-thinking approach to sanitation, both in terms of the technology that are being used by the administration and their search for useful applications for locally generated faecal sludge. In order to demonstrate that practitioners lack the necessary planning skills, even when local decision-makers are willing to adopt reuse-oriented sanitation, we look at programs that have had varied degrees of success.

The first scenario involves the emptying of 60,000 vented improved pit latrines and the ongoing search for a practical strategy to get rid of or make use of the feces sludge. Every five years, the pits must be filled, which may be quite expensive. The municipality is responsible for paying these expenditures. The municipality's strategy for proper disposal or usage is best characterized by action-based research. Authorities have adopted a strategy of burying the pit contents on site in less densely inhabited regions. However, there isn't enough space for burial in densely populated areas, therefore the sludge must be transported somewhere. The municipality experimented with several other disposal methods after determining that discharge into the sewer networks was too disruptive to the wastewater treatment plants. These included trials using chemical or biological additives to enhance the degradation of the pit contents, mixing with lime, and limited discharge in a domestic landfill. Deep trenching with tree planting in the trenches looks to be the most practical approach so far. Trials are now being conducted to evaluate the threat of groundwater contamination, various tree and plant species' capacity to absorb nutrients from VIP sludge, plant growth rates, and pathogen die-off rates. The whole pit emptying and disposal process has been intended to generate employment, using teams from the areas it serves, and the majority of the municipality's expenses for the pit emptying are recovered from the user community [6], [7].

On the one hand, it is reassuring that local authorities are committed to finding a sensible alternative to the VIP materials' careless disposal. On the other hand, a methodical planning approach for developing reuse plans that are locally adapted will enhance the coherence of the design process and provide a methodology for including a wider range of local stakeholders in this process. Right now, choices regarding the final use of feces in eThekwini are determined separately from the region's overall planning goals. For instance, a similar citywide project is promoting woodlots on unoccupied property to support locals' livelihoods. The trees are meant to be used for a variety of purposes, including orchards, papermaking, firewood, and input into natural and therapeutic goods. The final end-users of the faeces sludge should be considered as main woodlot stakeholders in the co-design of these woodlots for faecal sludge land application. The use of faecal sludge on these trees won't be investigated until after the woodlots have been installed and shown to be effective without it due to the absence of precedence for such integrated planning.

The second case study concerns wastewater that was treated in a pond system before being discharged to the Ngane River from a sewered region in Mnini, a part of the eThekwini Municipality. Due to insufficient treatment, the natural ecosystem of the river was harmed, which had an adverse effect on the river's users. Two ideas were put out in 2002, one of which included using the ponds' runoff for agriculture. An irrigation system was created by a specialist and put in place by January 2003. On a 2ha plot of land, 10,000 banana plants in all had been acquired, and 75% of them had been planted by 2005. Over 2 hectares of mango plantations are planned, and two plots for vegetables and cash crops have also been created. Despite the system's technological feasibility, institutional obstacles have prevented it from being put into practice. For instance, the irrigation system was set up without the consent of all the role-players and stakeholders. The people behind the reuse project did not receive permission to use the land from the local traditional leader, from local households to install an irrigation system and use the land for agriculture, from the Department of Agriculture to break virgin ground, or from the Departments of Trade and Industry or Water Affairs and Forestry to issue the necessary permits.

Although well-intentioned, the Mnini reuse scheme's failure may be attributable to the haphazard and top-down methods used in its design and implementation. Mnini is just another example of the need for a methodical planning strategy that leads practitioners through a process of involving the proper stakeholders, both institutional and individual, and asking the proper questions in order to avoid unsuccessful results. If a reuse program is to be continued, it must also be socially, economically, and institutionally sound. It must also provide incentives for the proper operation and upkeep of the sanitation program itself. The majority of practitioners are discouraged from designing for reuse at the start of a sanitation project due to the complexity and delays that these extra aspects bring to the planning process. This tendency is seen in our third case study.

The eThekwini Municipality has chosen to construct twin vault urine- diverting toilets in rural locations where there is at least 250m2 of unoccupied land available for the householder's exclusive usage because to the expense and challenges connected with servicing the VIPs previously outlined. A free toilet, free water supply, and hygiene instruction are all included in the introduction of this sanitation alternative to the previously underserved. The homeowner is also in charge of system maintenance. Reusing feces and pee is not currently supported by the government. It was believed that since the introduction of urine diversion is sufficiently distinct from standard practice, implementing reuse of the urine and solids at the same time would be too disruptive to the objectives of enhancing sanitation and eliminating open defecation. The municipality also took into account the fact that this sanitation system would be more environmentally friendly than any of the other options [8]–[10].

The social stigma associated with using UD toilets along the boundary between a sewered region and a UD toilet-serviced area is one issue that has arisen since diffusion started. From the viewpoint of the rural residents, their UD toilets have just one function—containing human waste just like the watery toilets linked to the sewage system. However, consumers nearly universally view UD toilets as being less sophisticated and higher class than their waterborne counterparts. If profitable and beneficial reuse had been integrated into the project from the beginning, the societal resistance to UD toilets may have been lessened. Let's do a mental exercise. What if the endeavor was encouraged to develop new income possibilities for rural homes rather just distributing UD toilets in the name of sanitation? By conceptualizing the initiative in this way, better sanitation would be a byproduct rather than the project's main objective, and UD toilets would provide homes a way to profitably utilize the resource value of human waste. When the UD toilets are introduced as a new and better sanitation option, every other sanitation option nearby is automatically put into comparison, which often results in the unfavorable opinions mentioned above. In contrast, if financial incentives were the main focus of the project, UD toilets might not be viewed as inferior by households, but rather as entirely different systems with entirely different purposes. In order to simultaneously increase food security and access to sufficient sanitation, it is crucial to leverage the economic and agronomic advantages of reuse-oriented sanitation on a wide scale. Once again, adopting an end-use and profit-oriented strategy for what is normally the overt aim of increasing hygiene and sanitation necessitates a change in practitioners' mindsets and planning methods. Additionally, the notion has to be explained to end users and institutional stakeholders in a clear and persuasive manner.

Leading the way in sustainable sanitation innovation is the eThekwini Municipality. The great majority of underserved areas have given rise to several environmental and health issues, necessitating their vigorous quest for remedies. To promote a culture of reuse-oriented sanitation in other parts of the world and to make reuse easier to implement in areas where it is already on the agenda, we have identified three key issues that an effective planning tool could and must address from the cases we have discussed here. An effective planning structure will:

1. Promote a method for methodically evaluating and removing a comprehensive list of reuse choices as quickly and effectively as feasible via a coordinated effort amongst all agencies that might be engaged in the reuse project;
2. Encourage an inclusive planning process where decisions are made that are acceptable to all other stakeholders and customized to the final consumers of waste and treatment byproducts;
3. Should be readily available to practitioners and dispel hesitation to include reuse at the commencement of a sanitation project.

DFS Application for New Sanitation Schemes Design

When DFS is used to direct the planning and design process of a new treatment plant, its full potential is best achieved. Results are much better when collection, treatment, and reuse are combined into a single planning process, according to experiences from a number of reuse initiatives. When DFS is used from the beginning, the exact location and size of a treatment plant may be optimized for the anticipated end uses of the effluent and treatment byproducts. Designing for reuse is meant to assist stakeholders in navigating the more challenging planning and design process, even while it introduces extra variables to the traditional design for the disposal planning method, which are likely to need more time and resources to handle. We think that a reuse-oriented design will have long-term advantages that much surpass the initial expenditures. An example of how DFS was used in China to construct an irrigation-focused wastewater treatment plan for the Pixian peri-urban region [11], [12].

The tool and findings might also be used by local planners and decision-makers to modify wastewater treatment plans to meet social, environmental, and economic concerns. The example DFS applications in Ghana and China demonstrate how the technique may be used for the renovation of existing facilities or for the construction of new treatment plants after these obstacles have been addressed. However, decision-makers are urged to include reuse from the commencement of a planning process wherever feasible to optimize the effectiveness and advantages of reuse.

CONCLUSION

The thesis of this chapter is that reuse-oriented sanitation may have more positive effects on the environment and the economy than traditional, disposal-focused wastewater/faecal sludge management. However, due to institutional limitations, local knowledge, conventions, and normative frameworks, developing and executing such systems successfully is often challenging. In particular, the three studies from South Africa showed that a reuse strategy was used despite the need to address some of these issues right away. Due to a lack of systematic design procedures for establishing wastewater/faecal sludge management systems that involve reuse for agriculture, this was made even more challenging. However, if well run, such plans may generate income from the profitable use of the treated trash in addition to employment. Urban planners, sanitation specialists, and agricultural extension workers must work closely together and understand one another from the very beginning of the planning process for these programs to be successful. For the purpose of determining the viability of and designing a reuse plan, it may not be sufficient to depend just on assumptions about market demand and cost sensitivity for new materials. The introduction of the DFS planning technique served as a rational and approachable planning framework for reuse-oriented system design and execution. By utilizing the resource potential of human waste in ways that have the greatest local benefit, working through DFS should produce a plan for urban wastewater and faecal sludge management that contributes to local sustainability by reducing the risks to public and environmental health associated with indiscriminate discharge. One-size-fits-all effluent regulations and the lack of incentives or platforms for multi-stakeholder communication and collaboration are two major institutional and monetary impediments that might prevent the successful application of DFS.

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CHAPTER 9

USE OF FOOD SAFETY MEASURES ON FARMS AND IN STREET FOOD INDUSTRY: A REVIEW STUDY

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ABSTRACT:

The implementation difficulties of the WHO Guidelines on Safe Wastewater Use are discussed in this chapter with regard to the use of so-called "post-treatment" or "non-treatment" solutions, such as safer irrigation techniques or proper vegetable washing in kitchens. It is doubtful that widespread adoption of suggested methods would immediately follow amended rules or any educational campaign and training due to the low risk awareness and quick advantages of wastewater irrigation. The majority of the suggested procedures not only call for behavior modification but also have the potential to raise operating expenses. Exploring how traditional and/or social marketing might promote the intended behavior-change toward the adoption of safety procedures in such a setting would need substantial work. New strategic alliances and a new section of the WHO Guidelines will be needed for this. This chapter discusses the methods and factors to be taken to increase the likelihood of adoption and proposes a framework based on a mix of social marketing, incentive systems, awareness-raising and education efforts, and the implementation of legislation. An important finding is that these phases need thorough target group research that heavily involves social sciences and should not be undervalued in related efforts.

KEYWORDS:

Food, Industry, Sanitation, Water, Wastewater.

INTRODUCTION

African cities confront development issues and cultural shifts as a result of urbanization and globalization. For instance, eating habits are changing away from traditional dishes and toward fast food, which frequently consists of rice, poultry, and salad and is supplied by a thriving but largely unregulated street food industry that gives urban residents jobs and affordable food. The issues with development are related to the delayed rate of sanitization facility construction, which leads to significant environmental contamination. The street food industry is particularly impacted by unhygienic working conditions as well as the quality of vegetables grown in heavily polluted surface water. Farmers and consumers will require some time before they can completely depend on wastewater treatment to maintain water quality since the growth of the sanitation industry in developing nations still confronts a number of problems. The WHO acknowledged that alternative measures, such as on-farm water treatment, better irrigation techniques, or meticulous vegetable washing, may significantly contribute to reducing health risks as a stopgap measure [1], [2].

Through more diversified health-risk reduction control points, this emphasis on extra non- or post-treatment choices may actually boost security. In this system, which is founded on the concepts of hazard analysis and critical control points, farmers who use contaminated water, dealers who purchase and sell contaminated products, and commercial or residential kitchens that prepare raw salads all play important roles. The system's biggest issue is effectively implementing in low-income, low-resource, and low-education environments like those commonly seen in sub-Saharan Africa, which exhibits the biggest gap between what is required and what is actually experienced.

Bridging the gap between academic techniques and their practical relevance in the field is the major difficulty facing the food safety industry. The two main areas of intervention that are often needed are infrastructure development and behavior modification among the stakeholders of the key control points identified for health-risk reduction. Despite the fact that behavior-change concepts are well developed and are increasingly being used in the sanitation and hygiene sector, farmers, traders, and consumers still represent a pristine research field in the context of "wastewater irrigation," whereas the provision of infrastructure offers a promising intervention area.

Using studies conducted by the International Water Management Institute and its partners in Ghana as examples, this chapter attempts to lay out a potential route for facilitating behavior-change toward safer food handling and irrigation practices. Literature reviews, expert interviews, street surveys, focus group discussions, observations, training sessions, and a range of knowledge-sharing activities are among the techniques used to analyze choices for causing a behavior change. The method was very iterative and combined intellectual and empirical viewpoints. Farmers and restaurants, particularly street food establishments where more than 90% of the wastewater-irrigated salad crops are served, were the groups in Ghana targeted for behavior change [3], [4].

DISCUSSION

Many health promotion efforts in the past centered on informing individuals about the dangers of illness in an effort to influence their behavior. But there isn't much proof that health education-based strategies have had the desired effect, especially in poor nations. According to certain program assessments, knowledge has grown but hasn't changed behavior. The causes might be several, including the fact that "old habits die hard," particularly if the advantages are not immediately apparent or just indirectly relevant. Additionally, the way in which an educational message is delivered may determine whether it is successful or unsuccessful, particularly if it does not align with local beliefs and knowledge. For instance, food safety signs created in the USA included words like "fight back" and symbols for bacteria that the focus groups studied in Ghana could not comprehend. New practices may not always follow new information because they can be excessively costly, time-consuming, difficult, or controversial. Prior research on the target groups' knowledge and views is crucial for the effectiveness of treatments, and this goes for their promotion as well.

Conceptions of Safe, Clean, and Dirty

The need of acknowledging the significant social aspects of hygiene in developing nations has been emphasized by Curtis. Thus, hygiene and associated risk assessment are seen as social phenomena based on culturally predetermined concepts. Hygiene is not only about getting rid of germs since it was a desirable behavior even before the discovery of bacterial disease transmission. Similar findings are reported in the work of van der Geest, an anthropologist who discovered that in Ghana, cleanliness stands for physical and moral attractiveness while dirt stands for potential health risks. In Ghanaian English, cleanliness is frequently referred to as "neatness," a term that does appear frequently in local street-food surveys. Farmers and employees of street eateries were the focus of perception studies conducted in Ghana to better understand the potential and barriers to behavior change. Such target group participation studies are crucial for figuring out what can make innovations more likely to be adopted.

Setting Off Behavior-Change

If changing behavior, or adopting suggested practices, is the goal, it is important to know what internal or external variables exist in the local environment that can encourage or inhibit this change. An internal component that might promote this is greater health risk awareness. A credit program or restrictions and regulations that are implemented are examples of supportive external factors. It is difficult to break old behaviors, which is undoubtedly a huge internal obstacle. The needed investments or prospective losses represent additional obstacles. Crop yields and crop densities may be decreased by certain safer irrigation techniques like drip or furrow irrigation. Similar to this, ceasing irrigation, even for only two or three days, may lower production since Ghana's hot climate need daily watering. There could be a budget constraint as more efficient vegetable washing in kitchens would necessitate purchases of items like bleach or chlorine tablets. In summary, a number of the non-treatment or post-treatment procedures suggested to improve the safety of wastewater-irrigated vegetables entail more work or resources without clearly visible immediate benefits unless customers are willing to pay more for safe product. Although there is a broad need for safe food, there isn't enough risk knowledge to generate much of a willingness to pay [5], [6].

To spur behavior change in such a circumstance, social marketing strategies should be investigated. Social marketing aims to persuade a target audience to freely adopt, change, or reject behavior for the benefit of people, organizations, or society as a whole. In contrast to commercial marketing, which ultimately tries to make money for a private interest. The social marketing strategy incorporates elements of commercial marketing, such as customer focus, market research, and the marketing mix. Both the sanitation industry and public health have tested the idea. In general, marketing strategies are seen as a viable alternative to conventional techniques to changing people's behavior since they encourage a demand-driven change rather than being supply driven , making them more consumer-oriented.

In the case of Ghana, farmers may ultimately alter their behavior in response to other, similarly illusory incentives, such as a reduction in pressure from authorities and the media that their existing methods are detrimental to public health. Additionally, more tenure security could make investments easier, such those in on-farm treatment ponds. In Vietnam, farmers who wanted to raise secure veggies may request for financial assistance. When they made a profit and repaid it, they were required to pay back 80%. Supporting a desired behavior change alone is often insufficient since the present alternative to the recommended practice has to be actively opposed at the same time. Therefore, the best strategy could be a combination of incentives and disincentives.

Applied Research Is Required

Finding the circumstances that allow one or both of social marketing and commercial marketing to succeed is crucial. Analyzing: In the context of wastewater and food safety, this entails:

1. If adopting safer methods would immediately result in increased output or lower production costs;
2. If adopting safer procedures would ultimately pay off because consumers and merchants would be more ready to pay;
3. Whether there are any additional incentives or triggers that could alter behavior, and if so, how to effectively implement and capitalize on them while avoiding change obstacles.

The third study pushes most projects even farther outside of their comfort zones whereas the first two studies call for traditional economic analysis. It necessitates a thorough sociological study of the target group's possibilities and limits as well as perceptions, desires, and attitudes. Tradition, family pressure, community norms, time constraints, inconvenience, and other factors can all play a role in a person's decision to stick with their current behavior. This does not always mean that they are unaware of the social or health benefits of adopting the practice that is being promoted. This analysis should be based on participatory research principles and involves strong listening abilities. Analyzing what could drive behavior change will need different effort than comprehending the factors that might prevent it. Different demographic groupings as well as the social and cultural contexts in which individuals behave must be taken into account in trigger studies. According to Grier and Bryant, this data is utilized to make strategic marketing choices concerning target group categories, including what advantages to give and how to position, price, and promote items [7]–[9]. The following phases may be used to describe the planning process based on results from applied research:

a. Examine present practices for handling food in relation to the problem of concern.
b. Find workable solutions to change that lower health risks.
c. Identify the target group as well as any potential obstacles and enabling variables for a relevant behavior change.
d. Research the best outreach messaging and communication methods.
e. Give careful thought to which stakeholders and policymakers will be essential in creating, promoting, and putting into practice successful change initiatives.

Although it is ideal to promote all areas of food safety and cleanliness, it is understood that programs for promoting hygiene are most effective when they concentrate on a limited number of activities and messages that are simple to remember. However, it is important to keep in mind that by advocating a specific activity, such as washing vegetables, people may believe that this practice may stop the spread of illness by itself, creating a "illusion of risk-control" . Further, it is doubtful if a program can have any appreciable or measurable influence on health if the focus is just on handwashing or cross-contamination and proper vegetable washing is overlooked. Effective vegetable washing as well as other fundamental food safety procedures should ideally be included in a comprehensive behavior-change effort.1 The expenses of marketing a package of maybe two to three excellent practices may only be somewhat greater than for one practice, while doubling its potential effect, even if not all of its components are embraced. Finding the best break-even point while taking cost effectiveness and the target group's capacity for message absorption into consideration is undoubtedly difficult. A variety of internal and external behavior variables for adopting improved food-safety procedures were identified by the Ghanaian street food study. To aid in developing potential intervention methods, obstacles and enabling variables were categorized in accordance with distinct categories, following the example from Favin et al.

Framework for a Campaign

A strategy for implementing a nationwide campaign on food safety with a focus on wastewater-irrigated vegetables was developed as a result of the research carried out in Ghana. This campaign has not yet received funding. The framework included many components or tactics thought to be crucial for altering farmer and street food industry behavior. It makes use of Tables 16.1 and 16.2, as well as the 'Receptivity Model' outlined by Jeffrey and Seaton, and it highlights the equal relevance of many metrics in order to encourage behavior changes and raise food safety. The framework also takes into account the advantages of combining incentives and disincentives, for instance via the imposition of rules and taxes. The framework's components are:

1. Education (given the poor level of education);
2. Social marketing (since altering behavior has no financial motive);
3. Incentives (turning the target group's requirements into opportunities);
4. Regulations (to stop unethical behavior and institutionalize right behavior).

Education

As previously indicated, education and information transfer alone may not influence behavior, but they are nevertheless essential parts of any multi-strategy approach, particularly if they avoid top-down lecturing. It is vital to understand that there are two sorts of information when thinking about knowledge as a motivator for behavioral change or lack of knowledge as a barrier to change. For changing behaviors, practical or logistical information is crucial for example, how to make the right chlorine solution to disinfect produce. According to the Ghana hand-washing campaign, the second sort of knowledge a scientific explanation of why behavior change is crucial such as how chlorine works might not be necessary to effect behavior change.

Social marketing

In cases when economic justifications are ineffective, social marketing is a crucial instrument. Social marketing research may assist to find linked benefits that are appreciated, such as indirect commercial advantages, better self-esteem, a sense of comfort, or respect for others, even if health issues are not highly valued in the target population. So, according to Siegel and Doner Lotenberg (2007), studies must seek for "positive values" that the main target audience identifies with or may link with the invention. For instance, social marketing messaging and communication techniques could support the perception that utilizing a drip kit for safer irrigation makes one feel "technologically advanced" [10]–[12].

Incentives

When the benefits are indirect, such as when personal behavior benefits society more than the actor, incentives are crucial. In the instance of hand washing, the benefit was for both the individual and the family, which is a much tighter link than for a farmer who does not sell his or her products to consumers. Additional incentives may be required in the farmer's situation. Interactions between customers and vendors have been identified as a significant factor influencing food safety concerns, both as a barrier to maintaining the existing state and as a possible source of change.

Regulations

To institutionalize new food safety guidelines, regulations are needed. When they are followed, they provide the legal foundation for both fees and certificates, which serve as disincentives. Normal capacity building requirements accompany new regulations. Inspection forms may be updated, inspectors/extension officers can be taught, and pressure can be put on caterers in the form of fines and, in the worst case scenario, company closure in order to incorporate better food-handling procedures into institutional frameworks. However, laws shouldn't be created based on imported standards but rather on locally practicable criteria, since doing so would render them useless in real-world applications and increase the risk of corruption. In contrast to promotional and instructional initiatives, which are often time-bound, regulation and institutionalization may help ensure the long-term sustainability of behavior change [13], [14].

Application

specific campaign elements may be more appropriate for specific people or groups than others depending on their stage of behavior change, from initial awareness through association, acquisition, and finally application, although they generally work best together. The recommended campaign framework's potential and cost-effectiveness were shown by a study that used varied adoption rates. It has to be investigated if the framework offers benefits over other potential behavior-change techniques for better food safety.

CONCLUSION

Inter-sectoral cooperation, policy discourse, and policy development are encouraged as essential components for their implementation, according to the WHO Guidelines for safe wastewater irrigation. While this is vital, it is not adequate to protect public health when wastewater treatment alone cannot do so. In order to put the recommendations into practice in this case, a few key players along the pathogen route must first alter their behavior. Though they may be landmarks, improved regulations and accompanying education often fail to influence behavior. In order to solve major adoption hurdles, this scenario requires for a greater integration of social scientific research in the domains of engineering and epidemiology. In most situations, suggested actions to improve food safety don't result in a direct financial benefit or lower production costs they could even be more costly. Education levels in underdeveloped nations are too low to comprehend public health dangers and the responsibilities that go along with them. Safety standards often lack local applicability and are too theoretical. Although neither paradigm is without difficulties, conventional and social marketing may play a significant role in understanding and encouraging behavior-change in addition to educational and regulatory initiatives. The requirements, goals, values, and daily lives of the target audiences, as well as their views of the elements that can encourage or dissuade them from adopting suggested technologies, must be understood for social marketing to be effective. The results of this study will be very beneficial in developing a well-targeted food safety campaign for any policy that supports the WHO guidelines in the agricultural and post-harvest sectors.

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CHAPTER 10

UTILIZING FARMERS' KNOWLEDGE AND PERCEPTIONS FOR WASTEWATER-IRRIGATED AGRICULTURE HEALTH RISK REDUCTION

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ABSTRACT:

The creation of risk-management solutions that are mutually acceptable requires an awareness of farmers' knowledge of health risks and risk-reduction measures, as well as their perceptions of those risks. The chapter demonstrates that expecting high risk awareness is not practical by drawing on research from various nations. When farmers are aware of health hazards, they evaluate mitigation strategies based on how they will affect total productivity and crop output as opposed to only the possible health benefits. The chapter makes the claim that considering farmers' requirements and limits when developing suggested practices is important for the effectiveness of on-farm risk-reduction methods. The development of risk reduction strategies by farmers and scientists working together may assist indigenous processes that may take place in this regard. Finding generally acknowledged issue signs is a crucial first step. It is necessary to identify additional triggers as well as suitable communication methods for successful outreach in cases when the health benefits for farmers and consumers are insufficient justifications for the adoption of safer practices.

KEYWORDS:

Agriculture, Farmers, Water, Wastewater.

INTRODUCTION

There are several ways to lessen the health dangers associated with using human excreta and wastewater in agriculture. Farmers may contribute significantly to the multiple-barrier strategy in addition to traditional wastewater treatment. Some of the on-farm health risk reduction strategies are discussed. Farmers must be made aware of the hazards in order to achieve widespread adoption and full health protection for both farmers and consumers. It will be exceedingly difficult to encourage a behavior shift toward safer behaviors without raising risk awareness. Additionally, incentives could be required, particularly in the area of health concerns where immediate benefits would not be apparent. Furthermore, the suggested actions might possibly call for extra funding or significantly lower agricultural yields. Projects aimed at conserving soil often confront comparable difficulties [1], [2].

Few'standard' advice for risk-management strategies on farms can be applied directly to the farmer's field. Drip kits and suggested cessation times won't always work for local factors like crop density, wastewater quality, or crop water needs. Many technologies need analytical monitoring and assessment techniques that, especially in developing nations, are much above the technical and financial capabilities of the majority of farmers. Therefore, it is crucial that farmers be actively involved in the creation of risk assessments and risk-mitigation techniques. In order for farmers to perceive the advantages, risk-reduction techniques and performance evaluation should ideally work hand in hand. The simplest way to do this is, for instance, to use indications that both parties agree upon. Numerous studies have shown that farm-based interventions, particularly in countries with limited resources, have mostly failed as a result of the absence of farmer engagement.

Risk awareness and knowledge have a significant impact on how risks are seen and handled. While practical experience may serve as a foundation for awareness, farmers also add fresh knowledge and ideas to their knowledge base from other farmers, agricultural extension agents, field schools, input suppliers, the media, development workers, and other sources. This chapter examines what farmers know and believe about the health dangers associated with human excreta and wastewater through several case studies, with a focus on Ghana. It also goes over how this information may be used to influence behavior such that health risk reduction actions are adopted.

Farmers' Perceptions of Health Risks and Scientific Evidence

The utilization of wastewater and excreta poses serious health concerns when done without using proper risk-management techniques, according to reams of epidemiological data. According to many research, intestinal worm infections in farm workers and bacterial illness infections in food consumers pose the largest risks in wastewater-irrigated agriculture. However, research on farmers' perceptions reveal that they are typically happy with their wastewater supplies and do not believe wastewater irrigation constitutes a serious health concern. According to many studies, a variety of other agricultural restrictions are often rated higher than any health concern. Accordingly, even when quantitative microbial risk assessments anticipate obvious disparities, there are often no appreciable changes in risk perception across farmers utilizing various water sources, as seen in Accra and Ouagadougou. Farmers who are aware of the potential health risks associated with using polluted water sources seem to believe that these risks are minimal and that they are willing to accept them because using polluted water has economic benefits and other water sources are not readily available [3], [4].

DISCUSSION

The likelihood of dangers to customers is often questioned as well, albeit it may be difficult to get objective responses. Occupational dangers that have an impact on farmers' ability to execute their job are regarded higher by farmers than the consumption of food grown using wastewater as irrigation. However, precautionary actions are seldom adopted as a result of this understanding. Given the low degree of perceived danger, protective apparel is often seen to be inappropriate in hot weather and unnecessary. By contrasting the perceived danger between urban farmers utilizing wastewater and rural farmers using clean water, Bayrau et al. provided an intriguing research. The findings revealed the exact opposite of what was anticipated, which highlights the difficulties such perception research encounter. The need to understand the farmer in his or her situation is the cause in this instance, as it is in many others. According to Bayrau et al, the wastewater irrigators were more urban-based, seemed more educated, had a greater degree of cleanliness, and had better living conditions in terms of access to piped water, sanitary facilities, and the number of occupants per room.

According to studies conducted in Nairobi, wastewater farmers were worried about the water's purity and ability to spread illness. However, there were a variety of views among farmers about the connection between wastewater usage and enteric infections. Some farmers disputed the idea that handling wastewater or ingesting crops cultivated with it may have a harmful impact on one's health and instead cited other food safety precautions including boiling. Additionally, the majority of farmers said that they often wash their vegetables before eating it, but researchers on the ground found that this was not the case. Some believed that years of exposure had given them an immunity. According to the farmers' perspective on enteric illness, their incidence was common and not always connected to their usage of wastewater. It is significant that the majority of farmers surveyed around 80% did not believe that wastewater usage made them more susceptible to gastrointestinal infections. However, research into specific diseases revealed that the majority of farmers' top health concerns were skin rashes. Farmers continued to utilize wastewater despite knowing that it may have a harmful impact on their health since there was no alternative water available for farming.

Farmers in Pikine, Senegal, identified the top four ailments they had suffered in the preceding year as being weariness, dermatitis, parasite infection, and malaria. According to 70% of the farmers, they had not personally experienced any ailments brought on by wastewater. In contrast, the top six ailments for all ages according to Pikine's district health data were malaria, dermatitis, parasitic infections, arterial hypertension, diarrhea, and anemia. It's interesting that the farmers did not include diarrhea as a health issue, maybe because children experience it more often and severely. Cultural taboos may also contribute to under-reporting of diarrheal occurrences since a loose stool may no longer be considered notable [5]–[7].

In a previous research, Niang discovered that farmers utilizing wastewater had a much greater incidence of Ascaris than farmers using shallow groundwater, whereas about the same proportion in both groups did not see an association with wastewater usage. This implies that many of these farmers may have been parasitized without being aware of it. In terms of risk awareness, this scenario paints a bleak image, but things may change. For instance, many wastewater-related programs and efforts to mitigate associated risks had a significant impact on farmers' awareness in Ghana, while various media notified decision-makers to take action. Farmers were pressured to react, at the very least to avoid conflict and risk losing business, whether or not they perceived their own danger. The absence of a link between symptoms of probable diseases and exposure and the invisibility of infections demonstrate the necessity for mutually agreed-upon risk indicators. More study is required to determine the relationship between skin infections and specific water contaminants, even though the majority of research has been on helminth infections and diarrhoeal disorders as occupational health concerns in wastewater agriculture. According to studies conducted in Nepal, Cambodia, India, Pakistan, and Vietnam, exposure with untreated wastewater is highly linked to skin conditions.

According to Cofie et al. farmers requested that septic truck drivers drop their cargoes into the fields. The majority of farmers believed that using excreta would boost crop output. Excreta's unpleasant smell was cited by users as a significant issue and the primary reason why non-users were hesitant to employ excreta on their properties. The strong negative index value of -0.93 for users, which differs significantly from the weighted average index of -0.26 for non-users, suggests that users of excreta believed it did not contaminate food. Farmers made a valid point, however; at the research area, excreta is mostly utilized for corn rather than vegetables. Before planting, dried excrement that has been exposed to the sun is worked into the soil. However, only health risk and revenue loss revealed as negative influences on the likelihood of excreta usage out of the 11 defined factors that may influence farmers' decisions to utilize excreta.

Farmers who used human excreta in northern Ghana, where the practice has a longer history, connected it to skin illnesses, diarrhea, foot rot, and vomiting. Farmers associated skin infections with handling relatively moist sludge and vomiting episodes with the pungent smell of raw excrement. Farmers, however, believed that odorless sludge and dried excreta, regardless of the length of treatment, posed no health risks. Even the cakes that had just recently dried out were OK to handle with bare hands. According to a QMRA of this "cake sludge" conducted at 40 Tamale faecal sludge drying sites, farmers are at high risk of contracting viral and Ascaris infections, which is beyond the WHO-tolerated infection risk of one infection per 10,000 people per year.

Factors Influencing Farmers' Perceptions of Health Risk

Farmers and public health risk specialists see hazards differently, which is commonly recognized and acknowledged. The creation and promotion of best practices and technologies need an understanding of these distinctions. What factors lead to these variations, and how may they be reduced to encourage the adoption of safe practices? Several factors, including ones connected to the process, were discovered in risk perception tests carried out in Ghana:

1. Farmers' utilization of waste experience

According to studies, the length of time farmers has worked in their industry might affect their awareness of and perceptions of health concerns. Farmers in northern Ghana with more expertise applying human excreta than those with less experience were better able to identify illnesses linked to improperly handle human excreta. In Kumasi and Accra, farmers with more expertise in wastewater farming judged dangers as being lower than those with less experience.

2. Degree of familiarity with risks

Given the average level of education in agricultural areas, the majority of farmers lacked in-depth understanding of the causes of health issues and health-risk factors. 'Invisible' health threats like infections are particularly affected by this deficit. Due to the informal character of this practice and its low national relevance, training on the health dangers of wastewater irrigation has not been integrated into educational curricula, including those of agricultural extension officers. Nevertheless, when farmers were exposed to the topic, mostly via research initiatives, there was a noticeable rise in knowledge, awareness, and interest in health-risk concerns and risk mitigation [8], [9].

3. Source of information

Perceptions are influenced by how individuals learn things. Different sources are available for considering health concerns, but not all of them are acceptable. One of the primary information sources for farmers in Ghana has been the media, which has also greatly influenced how they perceive danger. The Ghanaian media, for instance, essentially denounced the activities and amplified the hazards, which is in line with previous research' observations that the media may construct complex messages about risks but can also magnify or attenuate risks. Complex signals and magnifying dangers should be avoided, but dangerous behaviors should also not be promoted. In order to guarantee that farmers are assessed adequately to prompt adjustment to safer practices that are required for health protection, there should essentially be a balance when communicating risk alerts to them.

4. A farmer's quality of living

Many farmers live in unhygienic impoverished settlement areas with no access to clean drinking water. As shown in the case study from Ethiopia, in such situations, the local environment affects perceptions, developing attitudes, and standards with which people live on a daily basis. In these situations, wastewater irrigation may not get much attention. Researchers who may have grown up with varied hygienic standards and are now faced with the issue of conducting objective interviews are affected equally by common standards. Additionally, due to the fact that they are subjected to varying degrees of sanitary standards, scientists and farmers may find it difficult to come to an agreement on common indications for illnesses that may be linked to exposure to wastewater or excreta on farms. In-depth epidemiological research will be required to demonstrate the percentage that may be ascribed to certain risk variables.

5. Defending techniques

If farmers feel the need to establish defensive methods to demonstrate the safety of their activities so that their businesses are not imperiled or so that they are not seen as promoters of public-health concerns in the community, the findings of the interviews may be skewed. Farmers may create defensive methods to intentionally understate the health hazards connected with their profession in order to avoid negative views from the interviewer, the general public, or harassment from authorities and the media. Brazilian pesticide users have been shown to have similar results. The transmission of risks may be severely hampered by such denial and defensive tactics, which are also difficult to disentangle from the low-risk impression connected to unhygienic living circumstances. Building trust among community members and suppliers is consequently essential for any risk-factor communication. This was also shown in a separate research on street food vending, which found that consumers' decisions to buy the food were mostly dependent on their faith in the seller since there was no valid way to assess the meal's safety. As a result, in situations when no other assessment criterion is available, trust also becomes essential. Farmers who anticipate outside help and so exaggerate their issues are using the opposite of a defensive approach [10], [11].

Knowledge and perceptions of health risk reduction strategies among farmers

It need good listening skills and impartial approaches to evaluate farmer perspectives. These must be carefully considered in various social and cultural contexts, taking into account the environment and any informational access that farmers may have. It is crucial to comprehend farmers' understanding of and attitudes about risk-reduction strategies, especially the criteria they use to decide if a technology is suitable for them. This evaluation of a measure's appropriateness may not always result in a definitive "yes" or "no." Typically, it entails rating the measures according to several criteria, going from more acceptable to less appropriate. A talent that the researcher must acquire is the ability to gather these impressions, transform them into criteria for assessing risk-reduction strategies, and evaluate them against other approaches.

In Ghana, wastewater farmers were engaged in choosing their own appropriate risk-reduction strategies. These actions differed greatly from those recommended in the WHO Guidelines, which included conventional wastewater treatment, agricultural limits, implementing health programs, and human exposure management. The reason for this was that while farmers were more concerned with business-related risk factors like loss of yields or income, level of investment, and land-tenure issues, WHO's proposed measures were based solely on health targets, i.e., the effectiveness of reducing levels of pathogens in irrigation water or on crops. In general, farmers favored modifications that needed little or no investment to their present methods. Similar results have been found in previous research conducted in resource-limited communities; and from participatory on-farm trials generally. To be in line with farmers' decision-making, scientists should examine specific risk variables from an integrated multi-risk approach.

Knudsen et al. in a study in Hanoi highlighted another crucial aspect in research on risk perception. The authors demonstrated how gender affected the choice of protective apparel. It was discovered that women used protective gloves and boots more often and consistently than males. The gender-specific labor separation on farms, where males wander about the fields a lot more than women, was primarily blamed for the discrepancies. However, both groups believed that wearing protective clothes limited their ability to work. These findings have also been found in studies of farmers in Ethiopia and Ghana who use wastewater or human excreta.

Only 19% of the 138 vegetable producers in Accra who participated in the Ghana research who used wastewater for irrigation wore protective apparel, mostly boots and gloves. In certain instances, it was discovered that farmers were using protective clothes to ward off the cold and physical harm rather than to safeguard their health.

The Trouble with Visualizing Risks

Educating farmers about the health dangers associated with 'invisible' pollution, such as parasites or toxins in water and soil, is one of the most difficult aspects of safe waste reuse. Getting farmers to keep tabs on the results of minimizing unseen dangers is another difficulty. The Ghana hand-washing program, which was discussed in Chapter 16, had a similar obstacle but eventually had great success. The ad chose to focus on "disgust," which seems to be a strong enough trigger to safeguard the family, rather than on the health risks connected with contaminated hands. On the other hand, given the majority of health hazards are for customers much farther down the market chain, encouraging behavior change among farmers is more difficult. The farmers virtually ever hear any complaints regarding the food. The farm family only sometimes eats the veggies they grow themselves since exotic vegetables, which are really those eaten fresh, are uncommon in conventional diets. Therefore, it is crucial to research other potential indicators in order to raise farmers' knowledge of water contamination and the associated health risk.

As shown in Ghana and Sri Lanka, low-cost test kits for water-quality monitoring may assist to visualize unseen danger. The absence of certain indicator species, such as frogs, toads, or insects exclusively found in clean water, might be another sign of contamination. Rashes on the skin might be a sign of how unhealthy water impacts people's health. Farmers often use physical and sensory indications to determine the degree of pollution in water, such as color, odor, and the presence of solid debris. For instance, some farmers in Kano, Nigeria, utilize untreated industrial effluents from breweries and tanneries to detect unfavorable or undesired circumstances by color, smell, and the creation of foam. A farmer may say, as an example: There are three undesirable water colors that appear at various periods. We instantly shut off our pumps when we see the oily red and the green colors in the channel because they will destroy the crops. When the blue water comes into touch with the skin, it is corrosive and results in a red rash. Whenever we come into touch with the blue water, we immediately wash our hands.

Researchers will be able to confirm the extent to which farmers' physical indicators match microbiological reality via participatory on-farm research. Studies, for instance, have shown that although shallow wells used for irrigation were thought to be "physically clean" because they had clear water and no unpleasant odor, they actually contained high levels of coliform bacteria, just like the water from nearby streams that was thought to be "physically dirty". The next problem is to convince farmers that the suggested methods will have a beneficial influence throughout the food chain, where further indications are needed to depict the decreased health risk, once consensus has been reached on a risk indicator for the water or sludge. Whatever the indications may be, they should raise risk awareness and facilitate communication between scientists and farmers. However, in many circumstances, only raising knowledge won't be enough to influence behavior. Economic incentives, access to financing or tenure security, as well as favorable media coverage, are additional incentives that are required.

CONCLUSION

In general, farmers who use wastewater and human excreta are unaware of the hazards they face or do not place a high priority on such concerns. Farmers and scientists must collaborate in order to find common ground and utilize information to alter attitudes and behavior.

However, the absence of tools and indicators that farmers may use to evaluate and track health hazards is problematic since the physical indications that farmers use to evaluate wastewater and human excreta for reuse may not always agree with laboratory evaluations. It could still be suitable for researchers to incorporate farmer-identified indicators in their broader set of indicators. These might include issue indicators, as well as input and output indicators, which focus largely on agricultural yields. To maintain minimal effort and high outputs, recommended methods may need to be modified. Although they may not be the best strategies for lowering health risks, these actions are probably more long-lasting. Since many indigenous remedies actually lower health hazards, even if they do so unintentionally, it is crucial to encourage farmers to find answers on their own.

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CHAPTER 11

MULTIPLE STAKEHOLDERS TO MANAGE WASTEWATER USE IN AGRICULTURE: AN OVERVIEW

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ABSTRACT:

Since it crosses traditional sectoral and regional policy and planning borders and is influenced by perceptions and views, wastewater usage in agriculture is a complicated topic. Researchers, community organizations, the commercial sector, and various government agencies responsible for water, sanitation, agriculture, and irrigation must all be involved in planning for wastewater utilization. How can these stakeholders work together to enhance the management of the system when wastewater usage is currently occurring erratically and illegally in order to maximize benefits to livelihoods while reducing effects on health and the environment? One option is the creation of multi-stakeholder platforms, which provide a forum for stakeholders to exchange ideas and look for negotiated solutions in an open and 'equal' atmosphere. Questions remain about how successful they are, what results may be anticipated, and how they might be made better. In three case studies, multi-stakeholder approaches were used to enhance wastewater management for urban agriculture in this chapter. Despite the distinctions, there were a number of universal teachings. The beginning point, which includes an accepted definition of the issue that needs to be solved, negotiated objectives, and a management structure that is acceptable to all stakeholders, is crucial. Project goals must be in line with local priorities when multi-stakeholder procedures, like those covered here, are externally launched.

KEYWORDS:

Agriculture, Irrigation, Multiple Stakeholders, Sanitation, Wastewater.

INTRODUCTION

Long-term sustainability may be increased by finding an institutional home and anchor organization, but caution must be used when evaluating the effects on current power systems. The success of the process is significantly influenced by participation and representation, and additional work may need to be done to promote this, for as through bolstering local community organizations. Possessing real results that show stakeholders the potential of multi-stakeholder platforms is one aspect that seems to significantly boost involvement and engagement. A well-accepted definition of multi-stakeholder platforms and processes is that they are "a decision-making body comprising different stakeholders who perceive the same resource management problem, realize their interdependence for solving it, and come together to agree on actions for solving the problem" . Multi-stakeholder platforms and processes have a variety of definitions and even names. Those who have been engaged, including those from the scientific community and those in the places where multi-stakeholder procedures take place, may contest this definition.

Perhaps it would be more correct to state that multi-stakeholder processes should strive to achieve this definition. Critical examination of current multi-stakeholder procedures, including self-evaluation by the researchers participating, is required to support this ambition [1], [2]. This chapter examines how multi-stakeholder platforms are used to manage wastewater for agricultural use. These applications are not new, but it is important to recognize the differences between two unique situations of agricultural wastewater usage since they affect the goals of these platforms. The first is reuse, which occurs in nations where wastewater is processed before being used to the production of food crops. Cost, farmer willingness to pay, farmer and public worry about effects on crops and health, and resistance due to the "yuck factor" are the main issues in this scenario. Multi-stakeholder procedures are put into place to win over users, develop reciprocity and trust; and to create an environment conducive to negotiation and conflict resolution.

The second scenario is the impromptu or spontaneous use of untreated wastewater for irrigation. In this instance, farmers already appreciate it as a resource, but there are health risks that they may not be aware. Such circumstances often arise in low-income nations where inadequate sanitation and wastewater management methods are the norm for institutional and economic reasons; they call for creative solutions to lower hazards and water pollution. In this circumstance, multi-stakeholder procedures must strive to incrementally improve the current situation, including both regulatory reforms and the implementation of straightforward, creative risk-reduction strategies that incorporate farmers and consumers. Such platforms must include innovation and education as core components [3], [4].

The literature has addressed the topic of gaining stakeholder support for planned reuse rather effectively, but less has been written on spontaneous reuse and the function of multi-stakeholder procedures in these circumstances. Three instances of multi-stakeholder procedures being used in several nations are shown in this chapter, mostly to answer the second case. The assignments under evaluation are:

1. WASPA project ;
2. Sustainable Water Management Enhances the Health of Tomorrow's Cities;
3. The Resource Centers on Urban Agriculture and Food Security's Cities Farming for the Future Program.

DISCUSSION

These multi-stakeholder approaches have been established to address the difficulties involved with managing wastewater in urban areas and in peri-urban and urban agriculture, where a major worry is the health risk posed by wastewater pollution. According to an explanation provided later in the chapter, each has a slightly different focus. For example, WASPA focuses on the transition from wastewater production to use in agriculture, RUAF primarily works to improve urban and peri-urban agriculture, which includes wastewater use, and SWITCH addresses integrated urban water management, which in some cities includes reuse. All of the procedures were started from the outside, but they have had varied degrees of acceptability and success, with some having a long-lasting effect on policy. All of the procedures increased knowledge and inspired the stakeholders to create shared goals and strategies. Here, these multi-stakeholder approaches are examined to see if they have the potential to enhance wastewater management and reuse, resulting in enhanced irrigation-water quality overall, benefits to livelihoods, and improvements to public health. The accomplishments and shortcomings, as well as the way ahead, are also covered, as well as how stakeholders have been and may be engaged in addressing all of these.

Processes with many stakeholders and participation

Partnerships and participation have been a staple of development work for decades, evolving from applied anthropology and activist participatory research. According to Reed, this process began with raising awareness in the 1960s, progressed to the inclusion of local perspectives in data collection and planning in the 1970s, led to the development of techniques that value local knowledge and "put the last first" in the 1980s, such as farming systems research and rapid and participatory rural appraisal, and culminated in the increasing use of participation as the norm in the sustainable development agenda in the 1990s. A developing "post-participation" consensus on best practices emerged as a result of the following criticism of participation and disappointment over its shortcomings, with significant lessons drawn from both the failures and accomplishments of this lengthy period. These advances have occurred concurrently in different disciplinary and geographic settings. They have played a crucial role in the advancements in the management of natural resources and resources that belong to everyone, such as community forestry and integrated catchment management, and more recently in the water and sanitation sector as well as the agriculture and irrigation sectors.

Stakeholder1 participation in issue characterization and action planning emerged in reaction to the public's and civil society's increased expectation and need to be meaningfully involved and not only accept "expert" advice or efforts from government agencies . The need to find techniques that addressed this complexity developed from an increased knowledge that issues are complex and affects straddle numerous disciplines and administrative borders. This awareness led to a rise in stakeholder participation. The problem, which is more specifically related to wastewater reuse, is how the stakeholders can better understand the various frames of reference regarding risk and sustainable natural resource management. In this context, sustainability refers to benefits to livelihood, decreased health risks, and resource recovery.

The partnerships of the 1990s have developed into the multi-stakeholder processes of today, which acknowledge that accommodating multiple interests in resource management is unavoidable and that communication and negotiation are necessary not only among the local community and state agencies but also among all actors with a stake. This is especially true when it comes to wastewater agriculture in resource-poor nations, where a lack of institutional structure and unclear planning procedures force actors to interact, collaborate, learn from one another, try to take into account all points of view, and implement creative solutions. Traditional ideas and current institutional structures are unable to handle the cooperation and agreement required to achieve sustainability. It is crucial for the success of such platforms to take into account the basic reason for including stakeholders and to define precise goals and results [5]–[7].

Although multi-stakeholder platforms and processes take many different forms and are often thought to have a number of elements that enable collaborative planning and interventions as well as shared learning, not all of them can be claimed to accomplish true mutual planning and action. It will be easier to replicate and enhance multi-stakeholder processes if you are aware of the general categories and what seems to be an "effective" multi-stakeholder process. In this regard, it is helpful to take into account Arnstein’s categories based on the relative power held by stakeholders and Warner’s classifications based on the degree of power-sharing. It should be observed that although Warner's categories vary along a spectrum between the categories presented in the table and should truly be understood to be overlapping, Arnstein's categories are more clearly defined.

Warner describes multi-stakeholder platforms as a "multi-legged beast, often mentioned in tales, but as yet rarely spotted in broad daylight" and believes it is important to understand why they are promoted, whether they actually emerge, and how they work. In keeping with Warner's analogy, many of us have seen multi-stakeholder platforms and processes, but we are not always certain what'species' they really belong to or if they are just another beast in disguise. Although we may not need to know the precise species, it is helpful to understand how they function and what they do in order to attempt to nurture positive features, such as equity and power-sharing. Multi-stakeholder procedures may be divided into Learning Alliances and other types of Participatory Action Planning. These are briefly detailed here to provide an introduction to the case studies and were utilized in the instances examined in this chapter. As previously said, the processes' lessons are relevant to a variety of multi-stakeholder processes and platforms and will aid in identifying the features that have to be cultivated or eliminated.

Learning Partnerships and Active Participation Planning

The goal of learning alliances, which are cutting-edge participatory methods, is to increase the influence of research on results and policy. Since the 1980s, the term has been used in the business world. It is derived from research on innovation systems, where innovation is connected to the commercialization of concepts, tools, and procedures with an emphasis on modifying existing knowledge rather than producing new knowledge. In the literature on development, Lundy et al. define a Learning Alliance as process by which good practices in research and development are identified, shared, adapted, and used to strengthen capacities, improve practices, produce and document development outcomes, identify future research needs and potential areas for collaboration, and inform both public and private policy decisions. It is jointly undertaken by research organizations, donor and development agencies, policy-makers, and the private sector.

Other definitions include the ideas of innovation identification, development, scaling up, and multi-stakeholder platforms at many levels, including local, regional, and national. The International Water and Sanitation Centre has been promoting the concept in recent years, particularly as part of an all-encompassing strategy for managing urban water resources. All three of the examples have utilized participatory action planning and the multi-stakeholder process for policy formulation and action planning in different ways, with WASPA and SWITCH referencing the planning cycles of "Participatory Action Plan Development" and the Euro-Med Participatory Water Resources Scenarios project. Both processes included a number of iterative elements, including scenario and stakeholder analysis, participatory planning, visioning, evaluating, reaching an agreement, strategizing, reviewing, reflecting, and implementing. In order to solve some of the most urgent and widely felt issues, stakeholders are given the chance to identify obstacles, make suitable suggestions for solutions, create plans of action, and start putting those plans into practice. Similar to this, the RUAF MPAP strategy calls for substantial engagement from all stakeholders. It brings together all key participants in urban agriculture into a new mode of interaction, information sharing, discussion, situation analysis, action planning, decision-making, and implementation with consideration for gender, and monitoring and evaluation [8], [9].

Wastewater Use Examples of Multi-Stakeholder Processes

Although the three examples used in this chapter are different, they have several characteristics, such as:

1. All three were started as parts of initiatives supported by donations.
2. As a result, the convening organizations were always external, even if there may have been early stakeholder involvement to make sure the projects and the multi-stakeholder platforms were required or acceptable to the stakeholders.
3. They are all facilitated by a lead organization that is certain—and can persuade others—that multi-stakeholder procedures will result in more relevant and demand-driven research, interventions, and policies.

4. Every one of them entailed the involvement of both governmental and non-governmental parties in collaborative scenario analysis, identification, and prioritizing of policy concerns in a way that was as open and transparent as feasible.
5. All use comparable strategies.

The information offered here is a result of a mix of internal reviews, first-hand observations from the writers, interviews, and literature reviews. The conclusions concerning WASPA, for instance, are based on the authors' experience as well as data from an internal review and process monitoring. The SWITCH project's findings are mostly based on literature, but they also draw on the authors' own experiences in Accra, one of the research cities. Similar to this, RUAF is based on the writers' experiences in West Africa and on documentation that summarize the program as a whole.

Project on Wastewater Agriculture and Sanitation to Reduce Poverty

Between 2005 and 2008, a group of domestic and foreign partners carried out the WASPA project in Rajshahi, Bangladesh, and Kurunegala, Sri Lanka, with support from the EU Asia Pro Eco II Programme. The project's background was the use of untreated wastewater in agriculture as a consequence of subpar upstream sanitation and waste disposal practices. In order to address this, a group of researchers believed that involving wastewater producers, managers, and end users in the process as well as applying holistic and sustainable wastewater-management principles through interventions in the entire wastewater continuum would increase the sustainability of agricultural wastewater use. The project's main focus was involving stakeholders in the development and implementation of PAP. Therefore, its goals were to:

1. Identify creative regional answers via collaborative learning;
2. Promote communication between the community, NGOs, and local government;
3. Guarantee that all stakeholders support sustainability;
4. Expanding the reach of solutions to new areas.

The project went through a number of interconnected and iterative processes, the most of which were chosen and directed by the organizing group:

1. Initial stakeholder identification to identify the primary stakeholders, their functions, issues, connections, and conflicts.
2. Establishing Learning Alliances by letting all interested parties know about the initiative via private meetings at different organizations and public gatherings, and by enticing them to join together to talk about wastewater management.
3. Assessment, information sharing, and consensus building a quick assessment of the issue, essential elements of which were done with stakeholders, in order to provide a fact-based framework for debate.
4. Prioritizing and visioning when the stakeholders had identified the issues, they were able to picture the ideal future state, create a vision statement, and specify tactics to get there. Plans for implementation were created after prioritizing the tactics.
5. Planning and execution are handled by the WASPA team with the assistance of working groups chosen by the Learning Alliance. To speed up its execution, a core group of three to four members chosen by the Learning Alliance authorized specific choices relevant to the actions outlined in the action plan [10]–[12].

Goal-clarity and effective management

All multi-stakeholder processes begin with a set of objectives, particularly when they are externally begun as projects. It is ideal to set common objectives early on, as the SWITCH project revealed, but it is difficult to start the process without some established targets. Participatory goal-setting may not be incompatible with this if the objectives are not exclusive and operate at multiple levels. The multi-stakeholder platform goal, for instance, might be vision-based, while the project goal might be, for example, "to encourage multiple stakeholders to engage in knowledge sharing and collaborative planning for improved wastewater management." Goals must be agreed upon in order for the platform to function, therefore if this is not possible, there is a basic issue that suggests that either the platform has been formed around an unsuitable topic or that more preparation was required in order to exchange perspectives and find the proper challenge. Although these scenarios are uncommon and parties are often eager to talk and seek practical solutions, in some of these instances conflict resolution and negotiating skills may be required. The WASPA project team came to the conclusion that visioning, planning, and execution would have gone much more smoothly if there had been even more education and collaborative efforts to comprehend the problems with wastewater agriculture from the beginning.

To prevent disappointment if expectations are set too high, the objectives must be attainable. The projects under consideration tended to have high expectations, aiming for policy changes, demand-driven research, and the execution of action plans. Only a few of these expectations were realized, but stakeholders consistently noted that the multi-stakeholder platforms had improved their knowledge and capabilities, which is an important result. Additionally, they connected groups and people who had never or seldom met before. Arnstein noted that this may be seen as a type of tokenism, but if it is a valid process intended to foster awareness, capacity, and eventually cooperation, in which case it is a required initial step, then it won't be.

Goals must have a deadline and be supported by a framework of agreed-upon roles and duties in order to be realized. The RUAF experiment discovered that if there is bad management, insufficient preparation, and a lack of openness, the process's outcomes might be unsatisfactory. However, there needs to be a balance struck between being "well organized" and being "overly prescriptive," as the latter can make the process very laborious and resource-intensive and alienate stakeholders by giving them the impression that everything has already been decided and they are merely being used as pawns in the effort to validate predetermined ideas and actions. The ideal scenario is one in which the platform or process is given a minimal set of requirements that ensures it goes beyond platitudes and token gestures. One of the first things that should be determined by the stakeholders themselves is the specific organization, mandate, and terms and conditions.

Participation and representation of stakeholders

Stakeholder analysis, inclusion, and selection are crucial components of a successful multi-stakeholder process. In all three initiatives, the goal was to include as many stakeholders as possible, but it was inevitable that some would be forgotten and others would opt out. Encouragement of active participation by stakeholders is one strategy, but it could be more effective to work with people who see the advantages and want to participate. Stakeholder groups who are typically excluded from decision-making processes but who are significantly impacted by choices run the risk of excluding themselves for a variety of reasons, necessitating the use of particular methods to address the issue.

It is not always guaranteed that the delegate is appropriately representing his or her community, even when the platform seems to be representative. As the RUAF project discovered, it may be difficult to distinguish between an individual's and an organization's engagement, and it can be challenging to ascertain whose viewpoints they represent without meeting the whole group. Therefore, multi-stakeholder platforms tend to 'federate' often conflicting local interests and do not provide a comprehensive knowledge of individual motives. This is particularly true if there is no system in place for choosing representatives and facilitating dialogue between the stakeholder group and its spokesman.

CONCLUSION

In less developed nations, wastewater management and reuse generally take place spontaneously and with little planning. In these circumstances, multi-stakeholder platforms serve the function of bringing together diverse players to request their feedback in the conviction that such collective action and dedication are vital components for resolving particular wastewater concerns. The hazards and advantages that stakeholders believe wastewater has as a resource have a variety of effects on how they see wastewater management and reuse. Thus, it is essential that all views be heard, and multi-stakeholder forums are essential for this goal. However, there is no manual for the ideal operation of a multi-stakeholder platform or process; it depends on the local socio-economic and cultural circumstances, and in order to be effective, the platform must be integrated into the current institutional framework. Future multi-stakeholder processes will have the greatest impact if they are understood as the metaphorical "beast" Warner compares them to and their positive features are bred into them. This prevents the processes from becoming nothing more than the rhetoric of projects and programs seeking to justify their activities. The use of multi-stakeholder procedures in the wastewater-agriculture sector is still relatively new. Some successes are noted in the three case studies presented here WASPA, RUAF, and SWITCH, but practitioners still need to learn how to operationalize and sustain such platforms in a way that is less time- and resource-intensive, realistic in its objectives, and inclusive. If such platforms can record and use the information, expertise, and wishes of all pertinent stakeholders, solutions would be easier to identify and more successfully executed.

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CHAPTER 12

WASTEWATER IRRIGATION AND HEALTH: RISK REDUCTION OBSTACLES AND PROSPECTS IN LOW-INCOME COUNTRIES

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ABSTRACT:

There are many levels of danger associated with the common and expanding occurrence of wastewater irrigation. Food and fodder production utilizing untreated sewage or treated effluent may have major environmental and human health consequences for farmers and consumers, whether it is done haphazardly in urban and peri-urban agriculture or planned as part of water reuse programs. Poor wastewater collection, treatment, and unintentional discharge into receiving water bodies are common causes of water pollution in low-income nations. It takes a location-specific mix of various pathogen barriers, including, where available, adequate wastewater treatment, to make wastewater irrigation safer. The shared approach to wastewater management for disposal has to undergo a multi-sectoral paradigm change in order for these solutions to function cohesively and mutually supportively. Additionally, it is essential to keep researching the types and severity of risk, locally applicable mitigation options, the cost-effectiveness of safer wastewater irrigation practices in comparison to other interventions against diarrhoea, and how to make "non-" or "post-treatment" options more widely adopted.

KEYWORDS:

Income, Irrigation, Wastewater, WHO, Water.

INTRODUCTION

With a focus on the WHO Guidelines, this closing chapter integrates the primary findings of the current volume, synthesizes important aspects of the current global state and difficulties of sanitation, and provides a forecast for wastewater irrigation. Additionally, it emphasizes options for wastewater governance that have the most potential to enable safe wastewater irrigation while simultaneously addressing the issues brought on by the global water, sanitation, and food crises. The current increase in food costs has rekindled public interest in safe food production in and around cities, with the water and sanitation crises serving as the primary drivers of planned and unplanned wastewater irrigation, respectively. As cities expand, so do the problems with access to clean water, sanitary conditions, and wholesome food. According to the Comprehensive Assessment of Water Management in Agriculture, urban and peri-urban agriculture suffers the most from poor water quality. As of right now, urban farmers in four out of five cities in the developing world are forced to use polluted water sources for irrigation [1], [2].

There have been several articles and studies on the advantages for livelihood and food supply over the last 10 years as there has been an increase in interest in understanding the use of untreated wastewater for irrigation. Furthermore, it has been made clearly evident that attempting to outlaw this largely unregulated activity would not be successful. Making wastewater use safe while increasing its value as a resource to meet physical or economic water shortages is the main problem in maximizing the benefits of wastewater usage while safeguarding human health and the environment.

Urban and peri-urban agriculture thrives in low-income nations when rural migrants relocate to urban areas where they may take advantage of vacant plots and waste materials to meet urban demand for conventional as well as non-traditional cash crops, including irrigated exotic veggies used in salad. The increased spending power of the urban middle class and the expansion of urban markets on the demand side are paired with these demographic and production trends on the food supply side. In the end, water contamination and wastewater irrigation may lead to an extension of health-risk transmission channels. Common paths may be different in urban populations than in rural ones. While exotic veggies and fresh salads may be unfamiliar in rural regions and access to good drinking water remains a significant concern, the situation might be quite different for city inhabitants [3]–[5].

Although urban populations may benefit from better diets, access to water, and health care, distress migration, an increase in immunocompromised people, consumption of street food, and rising population densities of people living in urban slums without adequate sanitation present a new set of risk factors, "hotspots," and potential pathways for epidemics. The countries and regions where wastewater treatment, specifically purchasing and operating treatment plants, remains beyond the capacity of governments, as well as those where diffuse exposure pathways exist for wastewater irrigators, as well as particularly for consumers along the food chain, are the global hotspots for health risks related to wastewater irrigation as well as other health risks linked to inadequate sanitation and waste disposal. In such circumstances, it is crucial to educate local administration about the many choices that are now available and that may be pursued in order to reduce health hazards.

DISCUSSION

In this last chapter, we synthesize what is currently known about wastewater irrigation. We do this by significantly referencing earlier chapters in this book, which are not explicitly acknowledged here. The reader is urged to read the full book, which outlines the existing situation, goes into depth about risk assessment and mitigation, and then considers governance and policy issues and potential solutions before making the case for safe wastewater irrigation. We want to provide a comprehensive perspective on wastewater irrigation and the reduction of related health hazards in underdeveloped nations. We refer to the definitions to describe the practice's multifaceted nature, but to convey to the reader the two types of wastewater use that are most prevalent but fundamentally distinct in terms of their geographic significance, motivators, and difficulties, two are highlighted here and mentioned throughout this chapter:

1. Unintentional wastewater use in agriculture is a highly prevalent and pervasive practice in and around urban centers in developing countries, mostly as a consequence of poor sanitation and extensive surface-water contamination. As a consequence, crops are watered with highly contaminated water that may be wastewater that has been diluted or that has only been partly cleaned. Such usage, which happens in both wet and dry locations, will increase as long as expenditures in wastewater treatment do not keep up with urbanization and population expansion, resulting in unchecked contamination of water sources.
2. The use of planned wastewater is more prevalent in arid areas where wastewater streams are often channeled, after at least partial treatment, for controlled reuse in farmland to make up for water shortages. Given the current context of water shortage, this technique is gaining root steadily.

We predict that the planned irrigation of wastewater will cover a smaller area globally than the former. Contrary to popular belief, unplanned wastewater irrigation places authorities in need of immediate action to address potential risks arising from informal plots throughout urban and peri-urban spaces. This is because unplanned wastewater irrigation makes it more difficult to design and implement safe wastewater irrigation schemes. It takes a framework for risk assessment and risk mitigation to prioritize and execute well-targeted and locally suitable risk-management solutions, even if this could simply lead to "damage control." The World Health Organization's 2006 Guidelines for the Safe usage of Wastewater, Excreta, and Greywater in Agriculture, which placed a strong focus on unforeseen wastewater usage, served as the foundation for this idea.

In fact, this attention was required. Authorities in many developing nations are ill-prepared to deal with point pollution and are becoming more disoriented in light of dispersed threats. There are no local statistics on the impact of existing mitigation strategies in terms of safety, risk-reduction potential, economic viability, or cultural acceptance. Risk assessment methodologies have never been employed. The WHO Guidelines make a distinction between situations/countries where treatment alone can break the cycle of pathogens and those lower on the "sanitation ladder," where only alternative approaches or a combination of treatment and non-treatment practices can achieve an acceptable risk reduction. This in no way implies that different standards ought to apply to other nations. Contrarily, all nations should strive towards the same acceptable illness burden per person per year in accordance with the WHO Guidelines. However, the country's present circumstances, environment, and potential for advancement in terms of management and human resources will all play a role in how quickly this goal may be met. It is advised to use a step-by-step approach since any risk reduction is preferable than none, while keeping in mind that the path selected may alter as the nation moves from more technologically based to more humane solutions [6], [7].

Assessment of risk, mitigation of risk, and WHO guidelines

The two most significant "at risk" populations are food consumers, particularly when irrigated products are consumed fresh, and farmers or fieldworkers and their families. Communities that are located near to planned or unplanned wastewater irrigation zones, where contamination may occur accidentally, are referred to as a third category. Farmers who are aware of occupational health risks frequently accept them as a necessary part of their business, whereas consumers are typically unaware of the source or treatment of their food and would choose a different source if they were. In most cases, these groups have varying levels of knowledge about the risks they may encounter. Additionally, customers in many underdeveloped nations lack enough understanding about "germs" and their transmission.

The WHO's shift in emphasis from essential pathogen levels in irrigation water, or water-quality thresholds, to health-based objectives recognizes the requirements of poor nations who are still unable to pay for expensive large-scale wastewater treatment systems. Although certain treatment facilities and associated wastewater reuse plans may be able to meet effluent-quality standards, this is far from the norm when unplanned wastewater usage along generally contaminated streams occurs. Local health-risk managers now have the necessary flexibility to respond to situations involving unauthorized usage thanks to the increased emphasis on health-based goals and different pathogen barriers. In order to react similarly to all nations, from those at the bottom of the sanitation food chain to those at the top, the new Guidelines were developed.

Unplanned and planned wastewater usage, however, call for distinct risk-management strategies and accompanying recommendations for the same health-based aim. This raises the issue of whether the WHO Guidelines should create a stronger distinction between various circumstances so that stakeholders in various groups can comprehend them more easily. The WHO Guidelines are now global in character, which makes them needlessly complicated, which is hindering their readability and acceptance, particularly for policy makers. The number of real-world examples, like those in this book, demonstrating that the new WHO Guidelines are doable but that additional capacity building on their local adaptation is needed is growing. Local risk reduction can make use of a range of strategies, including wastewater treatment, post-treatment options like post-harvest pathogen die-off, and safer methods of wastewater retrieval, application, and produce processing, with the goal of producing healthy fieldworkers and consumers. Combining these steps is possible to bring the increased burden of illness brought on by wastewater usage in agriculture to acceptable levels rather than a single action having the intended impact [8], [9].

To calculate the needed pathogen reduction through a locally acceptable mix of health-protection control measures, the 2006 WHO Guidelines recommend combining quantitative microbial risk assessment with Monte Carlo simulations. To protect consumers, it is reasonable to aim for a pathogen reduction of 5–6 log units on the irrigated produce even when the available data do not permit the application of QMRA. This can be done by combining different treatment and post-treatment options, depending on their availability and implementation potential, which must be locally determined. Two log units via treatment, three log units through safer irrigation and pathogen die-off, and one log unit from washing product in clean water are feasible combinations. In this case, understanding the theory behind the Guidelines, QMRA, and the idea of disability-adjusted life years is not strictly necessary; rather, it is simply necessary to have the laboratory capability to analyze, for instance, E. coli as the most prevalent pathogen indicator. However, if the real risk is smaller and less effort are needed to protect health, the benefit of the QMRA would become clear.

Implications for governance and policy

The history of expensive and unsuccessful sanitation measures proves that the "one size fits all" risk-mitigation strategy is no longer suitable for many nations. Based on this experience, which is reflected in the assessments presented in this volume, WHO encourages a methodical progression to the following stage of wastewater management and associated risk management, where each step not only reduces risk but also strengthens institutions' capacity to do so. The steady physical extension of a sewage system, as well as growing political support for ongoing investments in the health and sanitation sector, may make the incremental attainment of health-based objectives obvious.

However, in light of the constantly shifting urban population and poverty, the return on investment in wastewater treatment has so far only had a modest effect. Due to poorly designed, poorly administered, and poorly managed facilities, underfunded institutions, a lack of human resource capability, and serious financial difficulties, investments in technologically complicated treatment methods and policies have failed. For instance, an examination of roughly 200 wastewater treatment facilities in Brazil, a country with a reasonably developed economy, revealed that the majority of them are unreliable and prone to breakdowns. The situation is worse in sub-Saharan Africa. Less than 10% of the urban wastewater would be treated even if all of Ghana's roughly 70 wastewater and faecal sludge treatment plants were operational. Only 10% of these facilities still operated as intended. It is also obvious that poor sanitation has an impact on both costs and health. Research from the World Bank's Water and Sanitation Program shows that poor sanitation costs the Philippines, Vietnam, Cambodia, and Indonesia an estimated $9 billion yearly. According to the Water and Sanitation Program's 2007 report, this represents 2% of their total GNP [10], [11].

Health-risk reduction will need a mix of treatment and post-treatment solutions, as was previously mentioned in the context of beneficial wastewater management and usage. The best option is treatment when it is possible, but this calls for careful preparation and the choice of the right technological choices. Examples of middle-income nations that have started planned reuse initiatives based on treatment include Mexico, Jordan, and Tunisia. Intensive, commercially focused agricultural economies like California, which has made significant financial investments in creating, running, and maintaining a network of wastewater treatment facilities, eventually set the pace, though unintentionally. Furthermore, it is projected that US$20 billion, or 210 times the amount now allocated for the purpose, would be needed over the course of the next 20 years to cover that state's anticipated infrastructure construction expenses and maintain the existing network. When compared to telecommunications, electricity, etc., water infrastructure and treatment is among the least financially autonomous of all infrastructures, while financial studies on the full benefits of water and wastewater infrastructure have not yet been conducted.

To maximize the benefits to public health, calls for funding and expanding treatment in low-income nations must be balanced against the realities on the ground. A more progressive, systematic strategy that incorporates new participants in the wastewater management process, from the treatment plant to the farm and the consumer, is necessary for effective risk management. The goal still is to find the best mix of risk-management techniques and wastewater treatment processes. We acknowledge that in many resource-stressed countries, achieving high sewerage coverage and related wastewater treatment is challenging, at least in the short term. Nonetheless, this goal should be maintained unless alternate strategies, like water-saving ecological sanitation technologies, become more widely applicable and lower the overall demand for sewerage and pressure on treatment [12], [13].

This would have a number of advantages since the world's unsettling economic reality is probably going to make matters worse when it comes to pollution management in low-income nations. Stress on wastewater management in rapidly expanding cities throughout the globe will rise as a result of reduced credit for bank loans for capital investments, an unstable bond market for governments, and the predicted fall in donor monies available. We also acknowledge that the cost of sanitation, which the UN Development Programme estimates for low-income countries to range from 3 to 15% of gross national product, is extremely high and, in many cases, will not be feasible. Under these conditions, the implementation of an integrated multiple-barrier risk-reduction strategy, such as that described in the WHO Guidelines and further refined in this book, remains the most economically viable method to significantly minimize the hazards associated with wastewater irrigation.

Another development in the way we think about wastewater management is the recognition of consumers, dealers, food caterers, and farmers as major players in wastewater management. At every point, behavior modification is going to be needed for this additional human contribution to be successful. While new study on the value of wastewater will increase our understanding of how economic incentives may change behavior, it is a truth that those along the "wastewater chain" will have to adopt safer methods without any evident personal or professional benefit. This may be more challenging to adopt and maintain from a national planning standpoint than using wastewater treatment as the main technique to reduce health risk in this region. The difficulty is in using incentives and restrictions effectively to raise awareness. This suggests that more study on risk perceptions and the factors that influence the adoption of suitable technology is still necessary [14]–[16].

The methods discussed in this book, such as altering irrigation techniques, product washing, and other behavioral changes, call for coordinated effort, but they are less costly than a sophisticated treatment infrastructure and do significantly reduce risk. The WHO Guidelines' gradual approach is crucial for these reasons, and post-treatment alternatives will continue to be helpful. It goes without saying that a phased approach to bettering risk management would need large expenditures in capacity development. One agency or ministry should be given sole responsibility for regulating wastewater management, coordinating reuse operations with the other relevant departments or ministries, and managing investments in the sector.

CONCLUSION

This is a minimal commonsense requirement but one that is uncommon given the numerous jurisdictional overlaps that are frequently observed. One should not overestimate the capacity of national and local governments in low-income countries to react to the WHO Guidelines given the absence of sufficient governance measures at the time. In the next years of growth in this area, a renewed effort to connect the WHO Guidelines to practice and current wastewater governance systems will be essential. We now have the best and most complete knowledge of how wastewater is used in agriculture. The Accra Consensus illustrates how the need of a comprehensive approach to addressing the difficulties of water contamination and its effects on food production and consumption is being more recognized. To decrease the effects of wastewater-related health hazards as effectively as possible and to find win-win solutions to the sanitation, water, and food crises triad, a mix of biophysical research, social, economic, and policy analyses, and excellent politics and governance are needed.

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