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Treatment and Use of Sewage Effluent and Sludge for Irrigation: A Review

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Abstract:- Irrigation with sewage effluent has potential benefits to farmers which cannot be over emphasised. But continual irrigation with wastewater over a long period results to accumulation of heavy metals which perils the growth of plants and overtime affect the groundwater as well quality, and also impact human health through the transfer of diseases pathogens when used to irrigate vegetable crops. This paper reviewed the treatment and use of sewage effluent for irrigation to sustain agricultural production. The research indicated that there are two sources of sewage effluent; point and non-point sources and there are three basic methods of treatment technology which includes wetland method, treatment plant method and land application method. It further noted that in the treatment of sewage sludge and effluent, the following irrigation water quality should be taken into consideration; pH, salinity level, SAR, CEC level, BOD, COD, TSS, TKN, TP and other heavy metals concentration in the water to minimize the environmental and health impacts imposed by the use of sewage effluent and sludge for irrigation.

Keywords:- *Sewage Effluent, Sources, Treatment, Irrigation Introduction.*

I. INTRODUCTION

Rain-fed agriculture has been the major practices carried out around the world with the aim of increasing food, fuel, and fibre production, but its focus tends to fail during dry season [1]. This failure in archiving the rain-fed agriculture is perhaps augmented by irrigation practices. Research has indicated that just about 1% of the total freshwater on the globe is used by human and for enterprises and the rest percentages are accounted by irrigation of agricultural land. Irrigation of Agricultural land being the major consumer of the global asset, [2], [3] reported that it accounts for four fifth of the total freshwater set aside for human use. Another researcher reported categorically that irrigation is accounting for 70% withdrawn freshwater and 90% consumptive use of the water [4].Therefore, irrigation has improved the economic and standard of living in semiarid and arid regions via increase in income and providing sundry new opportunities for economies development [3]. However, irrigation done with only freshwater reduces the resource as other uses compete alongside due to increase in human and animal population, and enterprises that require the use of water. This dwindling rate has caused farmers to search for alternative sources such as the use of wastewater due to its availability (see Fig. 1) and the nutrient found in it.

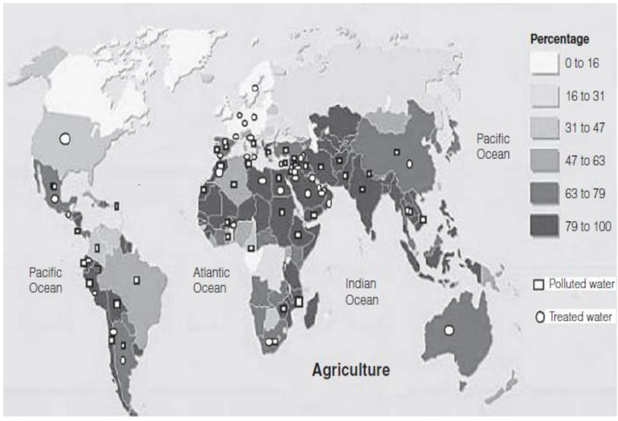

Fig 1: Freshwater extractions for agricultural use in the year 2000 and countries reporting the use of wastewater for irrigation [5]

As the freshwater get scarcer, world health organisation in 2004 reported that an estimation of more than 10% of the world population consumes foods irrigated with wastewater [2] and projected global water demand from 2000 to 2050 as presented in Fig. 2. The Figure indicates that out of the total global water demand, irrigation consumes approximately half of the demand. Also taking into consideration the trend of irrigation water used as presented by Siebert & Doll, [7] in the past decades (Fig.3), the demand for irrigation water increases as time goes on. Therefore, need for additional sources is global concern.

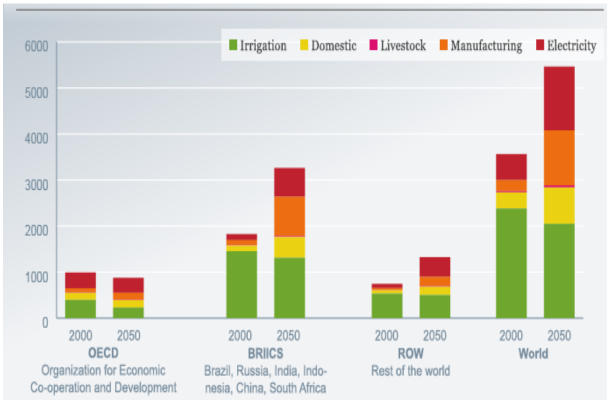

Fig **Error! No text of specified style in document.**2:- Global water demand in 2000 and 2050 [6]

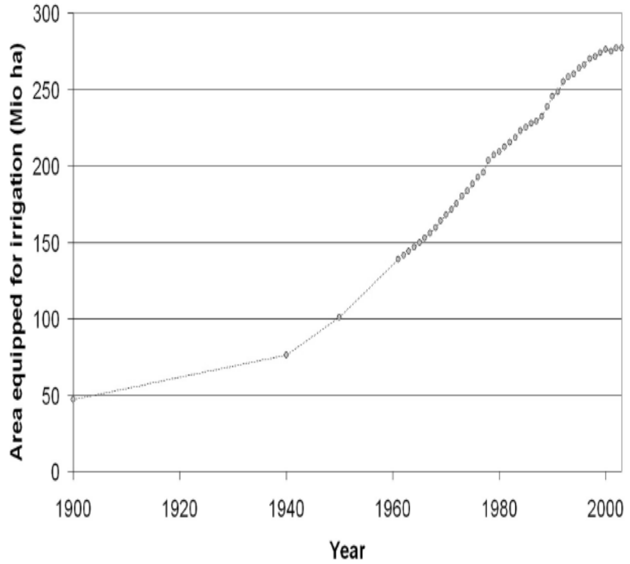

Fig 3:- Global trend of Irrigation water used **[7]**

Further research indicated that approximately 330 km^3yr^{-1} of municipal wastewater is globally generated. This would hypothetical findings can be sufficient to irrigate and fertilize millions of hectares of land for crop production and biogas to stream energy for millions of households [8]. Wastewater has over the years been of benefit to farmers, most especially in integrated fish farming where the water containing ammonia in fish pond is passed through cowpea farm and resent back to the pond for continual usage [9]. Wastewater reuse for irrigation have been in existence since before the antiquity development (3200-1100 BC), that is, the Bronze Age [10]. It is therefore not a new concern. Other benefits of wastewater recycle in agriculture includes alleviating freshwater lack, provision of a drought resisting source of water, provides nutrients (boycott fertilizer costs) increase water productivity and confers ecological benefits. Wastewater is also more reliable than surface water and its continual supply from treatments plants and community sources enables the farmers to cultivate multiple crops throughout the year and raising cropping intensity and output. Wastewater reuse and recycling of its nutrients in agriculture can contribute towards climate change variation and easing. An investigation showed that wastewater made 75 % of the fertilizer desires of a typical farm in Jordan. From an economic viewpoint, wastewater irrigation of crops under proper agronomic and water management practices may provide the following benefits: higher yields, additional water for irrigation and value of fertilizer saved [11]. On the other hand, excess nutrients can also reduce crop productivity, careful nutrient management is essential to reduce fertilizer costs and prevent a reduction in crop yield due to excess nutrients in wastewater [12].

- *The effects of long term use of sewage effluents on the farm*

Effects of wastewater on agricultural soil is mainly due to the presence of high nutrient contents which often contains high total dissolved solids (TDS) and other constituent such as heavy metals which are added to the soil over time [13]. Continual use of wastewater affects farmers life in two ways; firstly it impact the environment, that is the soil and groundwater are been affected on the result of long term use of the wastewater on agricultural land for irrigation. Secondly, health impacts- wastewater contains pathogenic microorganism such as virus, bacterial and parasite which cause disease to human due to variability in the compositions [14]. Variability in composition of wastewater components causes the imbalance and post risk to the soil and ecosystems, plants, animals and human beings (See Fig. 4 & 5). The composition of the non-pathogenic components in wastewater vary over time, sites and regions; it is necessary to monitor wastewater quality regularly and come up with maximize benefits while minimizing consequence of these negative impacts to make wastewater irrigation sustainable [15]. Irrigation especially vegetable.

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crops with untreated wastewater exposes urban residents to dangerous pathogens which include bacteria and parasites [6]. This paper therefore reviewed the Treatment and use of sewage effluent and sludge for irrigation.

Fig 3:- Wastewater entering a reservoir in Iran caused this massive fish die-off [6]

Fig 4:- Soil irrigated with untreated Sewage effluent

➢ *Irrigation water quality standard*

Before buttressing on wastewater treatment, the requirements for irrigation water quality should be well understood to determine the level of treatment. It is therefore the major water quality standards that farmer needs to obtain good quality of food especially vegetable and fruits. Soil scientist and hydrologist examines the quality of irrigation water based on the following criteria; pH, salinity hazard, sodium hazard, alkalinity, other ions like sulphate, nitrate, chloride and boron, and microbial pathogens [16].

- ***pH***

This is the measurement of the acidity or alkalinity of water. Different acceptable pH ranges has been reported by different authors [1, 2, 16, 17]. These variations are dependent of the crop tolerance. In the most recent research, pH of 6.5 to 8.4 is an excellent range for irrigation water. Below 6.5 renders the environment acidic and above 8.4 results in alkalinity [18]. Alkalinity is the summation of the quantities of carbonates (CO_3^-), bicarbonates (HCO_3^-) and hydroxide (OH^-) in water. It is expressed as mg/l or meq/l [19]. The concentration of HCO_3^- and CO_3^- results to high pH buffering in the root zone by making Ca and Mg produce soluble ions, and can be neutralized by the addition of acid [16, 20].

- ***Salinity Hazard***

This is one of the most impelling water quality monitors on crops productivity. Researcher tabulated salinity hazard based on electrical conductivity EC_w as presented in Table 1 [16]. As a result of the concentration of Na, Mg, Ca, and SO_4, electrical conductivity of water (EC_w) should not be more than 0.5mS/cm [17, 20]. This is because 1.15dSm^{-1} EC_w hold roughly 2000 pound of salt from every acre foot of water [16] which is close range with the result obtained by [17] at Montana state University. Hence, when the EC_w is higher, the ability for plant to compete for ions in the soil solution will be less even when the soil is wet, which eventually results in low yield from irrigated agriculture land. Table 2 presents the actual yield reduction when certain crops were irrigated with water of high EC_w at Colorado state university [16]. The researcher further noted that there are other factors such as soil type, salt type, irrigation and management which mitigated the yields from farm. But the quantity of water transpire by crop is directly proportional to the crop yield. Therefore EC_w must be at an acceptable level to high crop yield. The total dissolved salt (TDS) in the water is expressed in mg/litre. Eqn. 1 presents the relationship between the EC_w and TDS [18]

$$EC_w\left(dSm^{-1}\right)X\ 640 = TDS\ \left(mgl^{-1}\right) \quad \text{Eqn. 1}$$

Limitation for use	**Electrical conductivity (dS/m)**	**TDS (mg/L)**	**Remark**
Excellent	0.25 – 0.60	160 -380	No problem
Good	0.75	480	Normal
Fair	0.76 – 1.5	486.4- 960	Trace
Moderate	1.5 -3.00	486.4 – 1920	Leaching required at higher range
Severe	>3.00	>1920	Good drainage needed and sensitive plant may have difficulty at germination

Table 1: Guideline for salinity hazard of irrigation was based on conductivity
Source: Moderated [16]

Crop	**0%**	**10%**	**25%**	**50%**
		[2]EC_w		
Barley	5.3	6.7	8.7	12
Wheat	4.0	4.9	6.4	8.7
Sugarbeet[3]	4.7	5.8	7.5	10
Alfalfa	1.3	2.2	3.6	5.9
Potato	1.1	1.7	2.5	3.9
Corn (grain)	1.1	1.7	2.5	3.9
Corn (silage)	1.2	2.1	3.5	5.7
Onion	0.8	1.2	1.8	2.9
Dry beans	0.7	1.0	1.5	2.4

Table 2: Actual yield reduction from saline water of certain crops
Sources: [16] EC_w= electrical conductivity of the irrigation water in dS/m at 25°C: [3]Sensitive during germination therefore EC_w should not exceed 3dSm^{-1} for garden beet sugar.

- ***Sodium Hazard***

This is a problem caused by the presence of large amount of sodium contain in irrigation water. Any water that is in this condition is known as *sodic water*. Its pH value ranges between 8.5 and 10 [2, 21]. It is expressed in sodium adsorption rate (SAR). Grey-water (effluent from bathroom, kitchen and other domestic uses) is most often sodic. This type of wastewater therefor posts risk of high sodium content to crop grown as a result of the breakdown in soil structure if used for irrigation. SAR is expressed as the ratio of sodium to square root of calcium and magnesium average as presented in Eqn. 2 [16, 18, 21]

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$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \qquad 2$$

The high sodium content problem can be reduced in the water if calcium and magnesium are higher [18]. The author noted that increase in the sodium absorption in irrigation water may result to increase in pH in the soil and decrease in micronutrients availability. A researcher presented a standard for sodium hazard based on SAR value as indicated on Table 3.

SAR	Sodium Hazard of water	Comment
1-10	Low	Use on sodium sensitive crops such as avocado
10-18	Medium	Amendment (such as gypsum) and leaching are required
18-26	High	Generally unsuitable for continuous use
>26	Very high	Generally unsuitable for use

Table 3: The sodium hazard of water based on SAR value
Source:[21]

Residual Sodium Carbonate - Important information to note is residual sodium carbonate (RSC). It defines the variation between bicarbonate and dose of Ca and Mg in meq/litre [18]. It is calculated using Eqn. 3 [22]. For irrigation water to be considered as good for use, the value of RSC should be less than 1.25 meq/litre and it is termed harmful for irrigation if it is more than 2.5 meq/litre [18]

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \qquad 3$$

Soluble sodium percentage - is the percentage of sodium in irrigation water over the total elements in Meq/litre. It is presented as in Eqn. 4 [22]. According to US salinity laboratory, the standard value for soluble sodium percentage is ranging from 40% to 60%, any value above this will result to breakdown of the soil physical properties [23]

$$\frac{Na}{Ca+Mg+K+Na} X\,100 \qquad 4$$

- *Other trace of elements found in irrigation water*

- *Boron*

The presence of boron in irrigation water perhaps can be useful to some plants. But the imbalance of boron (B) concentration in irrigation water can cause toxic reaction to crops, and therefore renders it unfitting for use [21]. The venomousness of B concentration can even occur at less than 1.0 ppm [16]. Another finding shows that when more than 670µgL^{-1} is found in irrigation water, sensitive crops will indicate damage, therefore maximum limit should be 750µgL^{-1} for sensitive plants [24]. However, the use of boron concentrated water for irrigation should be checked to determine the kind of crop to be irrigated with.

- *Sulphate*

Sulphate (SO_4) concentration in irrigation water can cause harm to crops through accumulation of salts in the soil, unlike boron which has fertility benefit to crops [16]. Therefore the concentration of SO_4 should be less than 0.7mmol/litre in irrigation water [20].

- *Chloride*

Chloride is very essential in plant though in less quantity due to the fact that it causes harm to sensitive crops if the concentration is high [16]. The authors pointed out that high concentration of chlorine and sodium can lead to burning of leaves, therefore it can be reduced by night irrigation. The United States environment protection agency (EPA) reported that 250mg/L is the recommended standard for chlorine concentrated water for both irrigation and human consumption [24].

Other parameters such as Biochemical Oxygen Demand (BOD_5), Total Suspended Solids (TSS), total Phosphorus (Total P), and total Nitrogen (Total N) are to be analysed to determine the quality of wastewater erstwhile to irrigation use. Trace elements found in wastewater includes arsenic, cadmium, chromium, cobalt, nickel, lead, selenium, etc.[25] With frequent applications of sewage effluent for irrigation use, these trace elements tend to accumulate in the soil surface and overtime becomes part of the soil milieus. They could also be accumulated in crops to a level that it become detrimental to the health of humans, domestic animals, and wildlife that consume those crops. [26]

- *Wastewater and Composition*

The definition of wastewater can only be well understood if the term *water* is comprehensively understood. Water is a compound that consists of molecules of hydrogen and oxygen. It is said to be waste when it constitute impurities such as metabolic waste either from home or industries influenced by either human and/or animal activities [27]. The amount of water consumed per person per day determines the amount of wastewater generated [28]. For instance in breweries, to brew a bottle of beer which is 0.75 litre, nearly ten litres of water is required [29]. If 10 litres of water is required to brew a bottle of beer, it signifies that 9.25 litres (92.5%) of the water become wastewater which is termed as industrial effluent. However, the significant difference between clean water and wastewater is the percentage of physical, chemical and biological properties present in the water. The composition of wastewater varies with its source.

- *Sources of Wastewater and sewage effluent*

There are basically two different sources of wastewater and sewage effluent: point sources and non-point sources.

1. *Point sources*

Point sources of wastewater are discrete and identifiable sources. This sources is divided into domestic and industrial. The domestic sewage effluents are those ones from residential areas and business; pollutants such as faecal and vegetable matter, grease and scum, detergent, rags and sediment, while industrial effluents on the other hand are those from textile, food processing, radioactive waste, large amount of sediment with high temperature, mining and refineries or companies. The type of pollutants found in the wastewater depend on the source of the wastewater. Because of their size, these sources are generally easier to collect, but harder to treat (e.g., their chemical content can vary tremendously). There are different types of wastewater or sewage depending on the source from which it is generated from domestic dwelling; black-water and grey-water [30]. Sewage generated from this sources, contain 99% of water in it and remaining 1% is what qualifies to be wastewater. The black-waters are generated from toilets while grey-waters are those ones generated from homes with the exception of toilet source: contaminant here depends on the household utilities [31]. Research indicates that some parameters that defined the quality of domestic sewage as the presence of solids, indicators of organic matter, nitrogen, phosphorus and indicators of faecal contamination. But the most common elements found in wastewater generated from this source that when used for irrigation it imperils the some crops' growth are antimony, chloride chromium, cobalt, fluoride molybdenum, selenium nitrogen and phosphorus [32]. When agricultural land is continually irrigated with sewage water, the presence of some heavy metals gets accumulated on the soil crust which eventually become toxic to some plants that may not tolerate the added amount [33] and eventually damage the soil by rendering it unfit for crops growth. For instance, the amount investigated metals in the wastewater and sewage effluent presented on Table 4 was generated for just a week. It is either the required amount of metals in the soil for crop growth is increased or decreased [34].

2. Non-Point Sources

They are diffused and generally occur from water runoff. Because they are spread over large areas, they tend to be more difficult to control, and in recent years they have gained greater attention from researchers. They are divided into agricultural, urban, and atmospheric sources. Agricultural sources Include farms, which can contribute fertilizers, pesticides, soil erosion, and plant and animal wastes to water run-off. Collectively, they usually constitute the largest source of pollutants to water, and the erosion contributions are being worsened by the deforestation occurring in various parts of the world [41]. The true possibility of the problem from urban sources is still not very well understood, but it is clearly a major contributor. Urban sewage effluent could be generated from runoff from streets and parking lots during precipitation that may contain motor oil and gasoline. Atmospheric sources includes air pollution contributed during precipitation (e.g., acid rain). However, it is a typical example of the multi-media role of wastewater pollution. [41]. Therefore, sewage effluents from any of the aforementioned sources need to be monitored before embarking on irrigating agricultural land. Though the consequences wastewater and sewage effluent used for irrigation on crop depends on the crop type and level tolerance.

Faced with these risks incurred from different wastewater sources countries seeking to improve wastewater use in agriculture should pursue the following key objectives; Minimize risk to public health, minimize risk to the environment, improve livelihoods for urban agriculturalists and integrate wastewater into the broader water resources management context [42].

➢ *Methods of treatment and use of sewage effluent*

Municipal wastewater consists of suspended and dissolved solids, both organic and inorganic, and includes large numbers of microorganisms. Wastewater treatment is provided to minimize the detrimental effect to the receiving environment, by achieving the following; removal of any floating matter and grit, reduction of suspended solids, oil and grease, reduction of dissolved organic matter and nutrients and reduction of microorganisms [43].

In selecting the type of wastewater treatment process, a best practicable treatment approach is utilized whereby the effluent limits are based on the use of established and proven treatment technologies. Wastewater lagoons, activated sludge process, and rotating biological contactors are examples of systems allowed for municipal wastewater treatment in Alberta. The treated effluent may then be discharged to either land or water. Methods of land application for the treatment and/or disposal of wastewaters generally include irrigation, high rate irrigation, rapid infiltration, and wet lands disposal [44].

a. Wetland method

This is a natural wastewater treatment technology. It is also known as reed bed. A constructed filtering system planted with wetland vegetation such as reed canary grass with a distinct filter and wastewater flow way [45, 46]. The wastewater flows through the wetland vegetation which must be permeable enough to mitigate the problem of clogging. The flow is either horizontal or vertical depending on the purpose for which the system is designed. During the process of the wastewater flow, purification takes place by linkage of physical, chemical and biological processes [39]. It denotes the biological treatment stage of wastewater treatment plants. It may also be used for secondary and tertiary treatment of effluent from mechanical-biological treatment plant [40].

In this method of treatment of wastewater, organic compound are removed from the wastewater by microbial aerobic and anaerobic respiration; colloidal particles can then be removed from the wastewater by filtration, sedimentation or adsorption. However, de-nitrification do not take place. Phosphorus is removed by gluing phosphorus to the filtering material and bacterial is significantly minimized too [46].

The treatment wetland with horizontal flow are designed using Eqn. 5 which is derived from kinetics equation of the first order for removal BOD5assuming piston flow;

$$A = -\left(\frac{Q}{k}\right). In\ (\frac{C_0 - C^*}{(C_i - C^*)}) \qquad 5$$

Where:
C_i: inlet BOD concentration, (mg l^{-1})
C_0: outlet BOD concentration, (mg l^{-1})
C*: background BOD concentration, (mg l^{-1})
A: surface area of the constructed wetland filter (m^2)
KBOD: rate constant of pollution depletion (m $year^{-1}$)

b. Land application

This method is based on the controlled application of wastewater to the surface of the soil such that as it permits through, it is been treated by the physical, chemical and biological processes. This method is grouped into three; these includes overland flow, slow rate and rapid infiltration [8]. Most arid western state have used this method for the treatment of sewage effluent for agricultural irrigation. It has gone viral today as one of the common methods employed in the treatment of industrial effluent [28]. This is the cheapest of all the method of wastewater treatment, nevertheless, it has potential impact on the crop that may be grown and water sources (groundwater and surface water) [2].

c. Wastewater treatment plant

The wastewater treatment plant is an advanced treatment technology which further stabilize oxygen demanding substance in the wastewater. It may involve physical-chemical separation techniques like flocculation, membranes for further filtration process, ion exchange and reverse osmoses [47]. Any degree of controlling pollution can be accomplished to any desired level, if these processes are employed. This treatment method is not only aimed at having water for irrigation purpose alone but also for urban, landscape, industrial cooling and processing, recreational uses and water recharge [48].

II. CONCLUSION

Sewage is looked on as an asset in various areas because of its possible use as a supplemental irrigation water supply. Sewage irrigation, from the outlook of western agriculture, is an effect of sewage disposed. It is not synonymous with sewage disposal. Therefore, irrigation with this particular water supply, in areas in which irrigation is important or essential to agriculture, is an agricultural problem. Sewage effluents from treatment plants are used for irrigation of crops in most communities. With several important exceptions sewage from the largest western cities is not now being diverted directly for irrigation. This use of sewage in some areas has been discontinued for various reasons. In some communities, sewage is diverted from municipal effluent and channels into treatment plants. Areas now irrigated with sewage taken directly from outfalls or treatment plants range from 1 or 2 acres to several thousand. The use of sewage effluent for irrigation has proven beyond every doubt to produce higher yield in agriculture production. It usage depend on the soil texture contained in as coarse soil texture has proven to better garbed to sewage effluent irrigation [25]. Locally grown crops around community are therefore irrigated with wastewater, otherwise it has to be treated before use. Western States, particularly those in which sewage effluent irrigation is important, have formulated policies for the regulation or guidance of such practices [49]. This is to curb the problems incurred by usage sewage. In some States public control is exercised by State officials, and in others, educational and advisory action is taken but without enforcement of specific regulations. City and county officials have certain powers in controlling sewage-irrigation practices, independently or in cooperation with the State. Effective regulation, where the irrigated area is extensive and the Irrigators are numerous, may require frequent inspections. The complete reclamation of sewage to a point at which the effluent is suitable for use on any and all crops eliminates the necessity for control over its use, but increases the necessity for supervision over operation of the plant which produces the effluent. The tendency of regulatory bodies is toward increasingly high standards of use of effluents in irrigation. The possibility of polluting ground waters by extensive applications of sewage under favourable conditions may be inferred from the findings of several investigators. The spread of pollution and the limits of spread under conditions in which the experiments were conducted have been demonstrated. The quantity of initial pollution, character of the soil, and location and direction of flow of the ground water appear to be the important factors. Where effluents have been rendered safe this danger is removed and the effluents become available for augmenting underground water supplies for subsequent use [28].

The suitability of effluents for irrigation depends on the chemical as well as the bacterial constituents. Excessive salinity affects the growth of sensitive plants; excessive proportions of sodium produce unfavourable soil conditions. Small quantities of boron are toxic to many plants, and have given concern in some sections in southern California. Where the proportions of salts in a municipal water supply are increased as a result of industrial wastes to a point at which the water becomes hazardous for irrigation, separate disposal of the industrial wastes is necessary if the effluent from the domestic sewage is to be used on crops. Sewage is one form of return flow after diversion of water for beneficial use.

The courts in some States adhere to the public-ownership theory of return flow, which means that return waters from irrigation (unless appropriated from a different watershed from that in which the water is put to use) are not the private property of the appropriator; while those in other States have sanctioned the appropriator's right to recapture return flow under certain circumstances. So far as municipal waters appropriated from streams in the public-ownership States are concerned, it would appear that new uses of sewage from such municipalities for irrigation, before being discharged into stream channels, will be largely confined to the sewage return from water brought by the cities from other watersheds. Such extensions of sewage irrigation practices as may occur within the near future are expected to be in the field of supplemental irrigation, although some new enterprises in orchard areas are probable [50]. The cost of sewage to individual farmers so far has usually been low. However, the cost of sewage to farmers for irrigating crops which require treatment of the effluent beyond that now required of the city under public-health laws will doubtlessly involve payments by the farmers for part or all the cost of the added treatment. The cost of effluents for future irrigation, in areas in which the sewage is not now reclaimed, will definitely vary from nothing to a substantial percentage of the cost of reclaiming the sewage. It is reasonable to anticipate that the actual charges in a given case will be influenced on the one hand by estimates of the ability of the farm lands to pay for the water, and on the other hand by whatever pressure may be exerted at that time upon the city to treat its sewage. But to farmers in the rural areas wet-land method of waste treatment is recommended since it does not incur higher cost of treatment.

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