With the rapid growth of industries in the country, pollution in natural waters by industrial wastes has increased tremendously. Due to lack of treatment and improper modes of disposal of waste, the water bodies are polluted and they carry deadly substances. Therefore, disposal of wastes in the form of effluent poses a serious problem. As the present work is on the utilization of distillery wastes namely the effluent (stillage) and the sludge, related studies conducted on crop plants using effluents from several other sources are presented here.

Swaminathan et al. (1989) suggested that recycling of distillery and chemical industry effluents is possible because of the fertilizer value of the effluents. Effluents from various industries contain a wide variety of organic and inorganic pollutants such as oils, greases, plastics, plasticizers, metallic wastes, suspended solids, phenols, toxins and other chemical substances. Treatment of these effluents is quite an expensive and time taking process. Several studies have proved usefulness of the effluents for beneficial activities like agriculture and other processes (Khambatta and Ketkar, 1969; Rajannan and Oblisami, 1979; Bishop, 1983; Sahai et al., 1986; Swaminathan et al., 1989). The objectives of utilization of waste water for irrigating crop plant is two -
fold. The first and the foremost is safer disposal of the effluent which may otherwise have adverse effects on the environment and human health. The other objective is to recycle it as irrigation water and for its possible fertilizer cum composite value.

The treatment of waste-water developed in advanced countries is highly mechanised and energy consuming and is neither appropriate nor financially justifiable for developing countries. The development of simple and low cost technology for reuse of effluents in agriculture, offers the most suitable solution in countries like India. In addition to providing large quantities of water, some effluents contain considerable amount of essential nutrients which may prove beneficial for growth of plants. Studies were already conducted on the performance of various crops irrigated with the effluent discharged from several sources (Ajmal and Khan, 1985; Bole and Bell, 1978; Day et al., 1975; Rajannan and Oblisami, 1979; Sahai et al., 1985; Sidle et al., 1976; Srivastava and Sahai, 1987).

AGRICULTURAL APPLICATIONS OF SLUDGES AND EFFLUENTS

The most widely utilized effluent for irrigation purposes is that of paper and pulp industries (Swaminathan et al., 1992). Waste-water in industrial area adversely affects germination, growth and yield of various vegetable crops. Many farmers use the effluent from factories for irrigation purposes. These effluents not only contain useful but also many harmful substances which convert the fertile land into a sterile
one. In recent years, pre-treatment of industrial effluent is recommended prior to its use in agriculture. The effluent thus pre-treated serves as an additional potential source of fertilizer for agricultural use which otherwise would remain as an environmental hazard (Day, 1973; Pound and Crites, 1973; Bauwer and Chaney, 1974).

Qzair Aziz et al. (1994) reported that the treated oil refinery effluent met the quality criteria normally prescribed for waste water disposal. In addition, there was no adverse effect on the quality of soil, although admittedly, the duration of one crop season was rather short to come to such a conclusion. Triticale, being a hardy crop is normally considered more suitable for cultivation under adverse environmental conditions.

Discharge of either raw (or) treated effluent from pulp and paper mills into streams causes aesthetic pollution due to intense brown colour of the effluent and also increases the cost of water treatment to the downstream users. Since soil can degrade certain pollutants, land treatment is feasible for lignin removal, which would further reduce waste water treatment costs (Nutter and Red, 1985). The practice of applying paper mill effluent to crop plants as a source of irrigation has been recommended by many authors (Verma et al., 1974; Somshekhar et al., 1984).
Discharge of large amount of industrial and dairy effluents through rapid industrialization is a serious pollution threat in our country. Hence pre-treatment of the effluents prior to their disposal is recommended. This will enable recycle and reuse the valuable constituents of waste water for productive purposes in agriculture. This approach is thus capable of providing environmentally compatible solution to water pollution problems and augments the manurial and irrigational resources for the development of sustainable agriculture.

Pollutants from the industry include suspended solids, compounds coloured by lignin, Na, dissolved inorganic salts, toxic compounds like chlorinated lignins and phenolic derivatives. Discharge of untreated effluent will, therefore, create serious water pollution problem resulting in the deterioration of water quality and toxicity to aquatic life. Most of these wastes are therefore applied to the land, since soil is believed to have a capacity for receiving and decomposing wastes and pollutants of different kinds (Young et al., 1981). However, the application of pollutants from the pulp and paper industry leads to the deterioration of soil physical, chemical and biological properties.

Sewage and industrial sludges have long been suggested to have a potential use as fertilizers (Sommers, 1977) and their effects on land application and soil properties have been studied by a large number of workers (Epstein et al., 1976; Kelling et al., 1977 a-c; Stucky and Newman, 1977; Greene et al., 1980; King, 1981; El - Nennah et
al., 1982; Burns et al., 1985; King et al., 1985). Several types of agricultural wastes are used in anaerobic digesters and the resulting effluent has been suggested for land application (Atalay and Blanchar, 1984; Field et al., 1984; Fisher et al., 1984 a,b; Pigg and Vetter, 1984; Raley and Malish, 1984). The application of sewage sludge to agricultural land has become the major method of sludge disposal. Land application of sludge provides a feasible disposal alternative to many municipalities plus the environmental benefit of nutrient recycling. As available land for landfills decreases and air quality restrictions prevent incineration as an alternative to disposal, widespread employment of land application of sludges is imminent in the world. However, there are possible detrimental effects to the environment which must also be considered. The major considerations are accumulation of heavy metals in soils, contamination of ground water by NO₃-N, pathogenic organisms and toxic organics (Sommers and Barbarick, 1986).

Olson et al. (1988) assessed the potential for human exposure and resultant health risk from applying dioxin - contaminated paper mill sludge to agricultural and silvicultural lands in central Wisconsin. Among the exposure and risk assumption issues discussed were application of dioxin and furan equivalency factors, acceptable daily intake levels, cancer risk levels, and exposure scenarios including food, air, dermal and soil ingestion. They concluded from the preliminary assessment of human exposure scenarios, the involvement of many thousand-fold range of risks.
Introduction of some tolerant genotypes among the common crops and/or forest tree species in polluted area is one of the approaches to restore production of the deteriorated land.

The harmful nature of industrial effluent in relation to plant growth and development is well recognized owing to the presence of toxic chemicals present in it. Agricultural production in many countries is being heavily affected by the reckless discharge of these effluents into the water bodies, near the industrial establishments, which are the main source of irrigation. Therefore, screening of crops for their sensitivity/tolerance to different types of effluent is the need of the today; however, some effluents at certain dilutions are found to be useful for irrigation.

TOXIC NATURE OF CERTAIN EFFLUENTS

Wyatt (1988) reported that the production of toxic (or) recalcitrant waste effluents by the chemical industry is a major problem of disposal. New biotechnological approaches are now being used which will enable biological treatment of these wastes, and will, in future, replace existing methods of effluent treatment.

Agrawal and Pandey (1994) reported that the spent wash has a high capability of extracting out manganese from soil. One litre volume of spent wash of known characteristics has been found to extract out 175 mg of total Mn, 62.8% of which was
in the form of manganous ions. The spent wash has thus been identified as an agent causing Mn-deficiency in soil. The built-in mechanism of transformation of Mn (II) to Mn (IV) in soil has also been found to be impaired by the spent wash.

With the rapid increase in the number of distilleries, there has been a substantial increase in liquid waste, which is discharged either into open land (or) nearby aquatic ecosystems both lentic and lotic. Thus, the homeostatic capacity of the aquatic ecosystems is affected and bio-magnification problem arise (Pandey et al., 1994). The soil-damage by the spent wash has been viewed. Today, there are 257 distilleries in India producing over 1.5 billion litres of alcohol each year. For each litre of alcohol produced, 10-15 litres of spent wash are discharged (Guruswami, 1988).

The domestic wastes and industrial effluents are being indiscriminately discharged into near by rivers, lakes and even in adjoining fields with almost no pre-treatment. Spent wash is the main type of effluent from distilleries. The spent wash is almost one hundred times more concentrated than the domestic sewage. Considerable importance was not given to study the influence of distillery effluents in this regard (Haniffa and Sundaravadhanam, 1977). One of the most important ecological and recreational benefits of industrial effluents (Mukta Arora et al., 1992; Singh and Mishra, 1987; Mishra and Behera, 1991; Cromer, 1980; Stewart and Salmon 1986; Stewart and Flim, 1984; Raja and Vuaya Kumari, 1989) is their utilization for irrigation purposes. The waste-water is produced continuously. Hence, it can cater
to substantial irrigation requirements. This alternative use of waste-water will not only prevent the wastes from becoming an environmental hazard, but also serve as a potential source of fertilizer if used rationally and at appropriate concentrations (Dilip Kumar Pandey and Prafulla Soni, 1994).

The Physical, chemical and biological parameters of the spent wash from 12 distilleries have already been reported (Gurusamy et al., 1977; Prasad et al., 1977; Subbarao, et al., 1977; Verma et al., 1979). The striking observations of their analysis are:

(i). The DO is nil in all the cases
(ii). BOD ranges from 52,345 to 70,147 mg/L.
(iii). COD is between 72,792 to 1,37,697 mg/L.
(iv). Total solids ranges from 78,025 to 1,07,943 mg/L and
(v). Dissolved solids account for 74,078 to 1,00,522 mg/L.

**MOLASSES STILLAGE WASTE**

Molasses stillage, also known as vinasse, is a liquid waste from alcohol production by fermentation of cane (or) beet molasses. Besides a low pH and high temperature, cane molasses stillage has high amounts of organic matter, potassium, sulphates and chlorides making it complicated for waste water treatment process. There are several alternatives to dispose the molasses stillage such as irrigation,
evaporation, incineration and biological treatment. Anaerobic digestion of molasses stillage achieves 50 to 60% degradation of organic matter [Chemical Oxygen Demand (COD)] and yield valuable biofuels such as methane.

Recently, the process of anaerobic treatment of highly concentrated industrial waste water has turned out more attractive and economical than aerobic processes (Lettinga et al., 1980; Speece 1983; Speece et al., 1988; Guyot and Noyola, 1991). During anaerobic digestion, organic matter is converted into volatile fatty acids which in turn are converted to CH$_4$ and CO$_2$ by methanogenic bacteria. These anaerobes are efficient in degrading organic wastes at temperature of 37°C or 55°C with optimum concentration of essential micronutrients and other physico-chemical parameters. Availability of micronutrients (Fe, Ni, Cu, Zn, Mo, Co, Se, Si, F, Mg and Na) are important for the anaerobes to achieve efficient degradation of organic wastes (Speece et al., 1983; Nel et al., 1985; Perski et al., 1985).

Ilangovan and Noyola (1993) observed that during treatment of molasses stillage with an UASB reactor, the essential micronutrients such as Ni$^{2+}$, Zn$^{2+}$ and Cu$^{2+}$ were removed from the UASB sludge matrix. The metal analysis of the sludge matrix showed a complete absence of Mo$^{2+}$ and Co$^{2+}$. Among the metals analysed in the seeding sludge, Zn [2.08 μg/g total suspended solids (TSS)], Ni (625 μg/g TSS) and Cu (2.08 μg/g TSS) were found in low concentrations as exchangeable form, compared to Ca, Fe, Na and K. It is presumed that the presence of K (2.28 g/l) in the
40% diluted molasses stillage is responsible for removal of exchangeable form of micronutrients from the sludge matrix. They concluded that it is necessary to add micronutrients to the UASB reactor during anaerobic treatment of K enriched molasses stillage. Potassium is one of the best extractant for metals bound to the exchangeable sites in a sludge. Presence of exchangeable form of metals plays an important role in the physiological functions of anaerobic microorganisms.

A common situation encountered during anaerobic treatment of this waste is the volatile fatty acid (VFA) accumulation, principally propionic acid (Sanchez Riera et al., 1985; Tielbaard, 1992). In an anaerobic filter fed with cane molasses stillage, the concentration of propionic acid was 1.2 g/l (Boris et al. 1988). On the other hand, Vlissidis and Zouboulis (1993) reported that typical composition of the effluent, from an anaerobic contact reactor treating beet molasses stillage, was 78% acetic, 6% propionic, 12% butyric acids and 4% of longer chain volatile fatty acids. The complex characteristics of cane molasses stillage limit the degradation of this intermediate substrate. The main inhibitory inorganic constituents are potassium (4-10 g/L), sulphates (3-6 g/L), and to a lesser extent, chlorides (3 g/L). Kugelman and Mc Carty (1965) reported that 5.9 g/L of potassium decreased 50% methanogenic activity. During anaerobic digestion, sulphates are reduced to sulphides, which are the major source of sulphur to methanogenic bacteria. The optimum level is about 25 mg/L and a concentration upto 150 mg/L of unionized H2S inhibits the methanogenic activity (Speece, 1988). Concentrations of 90 and 250 mg/L of hydrogen sulphide decreased
50% the methanogenic activity at levels of pH 7.8 to 8.0 and 6.4 to 7.2, respectively (Koster et al., 1986). More recently, Ilangovan and Noyola (1993) investigated that the iron, accumulated in the sludge of an UASB reactor fed with vinasse, was determined as sulphides (29%) and carbonate forms (23%). Hoban and Van den Berg (1979) found that the addition of 20 mmol/L of ferrous chloride increased the conversion of acetic acid to methane. The addition of iron (615 mg/L) to a tower fermenter fed with vinasse from cane juice, allowed the increase of space loadings from 0.8 to 5.3 K COD / m³ d with low levels of VFA. The presence of nickel (100 nM) and cobalt (50nM) increased the conversion of acetic acid to methane (Murray and Van den Berg, 1981).

Cane molasses stillage lacks molybdenum, cobalt and only has small amounts of nickel (Ilangovan and Noyola, 1993). So VFA accumulation during anaerobic treatment of molasses stillage may be due to this deficiency. Espinosa et al. (1995) reported that a laboratory UASB reactor was fed with cane molasses stillage at organic loadings from 5 to 21.5 kg COD / m³d. With an organic load of 17.4 kg COD / m³d, an accumulation of VFA, principally propionic acid was observed due to little bioavailability or lack of trace metals (Fe, Ni, Co and Mo). Associated to this, the performance of the UASB reactor was low (44% COD removal efficiency), with an alkalinity ratio above 0.4. The addition of Fe (100 mg/L), Ni (15 mg/L), Co (10 mg/L), and Mo (0.2 mg/L) to the influent reduced significantly the level of propionic acid (5291 mg/L to 251 mg/L) and acetic acid (1100 mg/L to 158 mg/L). The COD
removal efficiency increased from 44% to 58%, the biogas production from 10.7 to 14.8 l/d (NTP) and 0.085 to 0.32 g CH₄ – COD g SSVI for specific sludge methanogenic activity with propionic acid as substrate.

CHEMICAL CHARACTERISTICS

Distillery effluent:

Dilip Kumar Pandey and Prafulla Soni (1994) observed that the effluent from Doon Valley Distillery was dark reddish brown and had an odour similar to molasses. The effluent was found to be deficient in dissolved oxygen but contained high amounts of dissolved and suspended solids. The effluent was highly acidic and had high BOD, COD, total solids and very low dissolved oxygen. Very low dissolved oxygen and low pH values make this effluent unsuitable for support of any form of life. Raja and Vuaya Kumari (1989) also made similar observations for liquor factory effluent.

Sewage effluent:

Aboulrous et al. (1989) reported that prolonged use of sewage effluent in irrigation resulted in continuous increase in clay content, organic matter content, and cation exchange capacity (CEC) of the soils, and partly in a decrease in soil pH and CaCO₃ content. They also reported that after 28 years of irrigation, organic matter
content reached a stable value of 6.6%, soil pH decreased to slightly an acidic value of 5.9 to 6.8%, and CaCO₃ content almost disappeared. The increase in the buffering capacity of the soils due to accumulation of clay and organic matter prevented further decrease in soil pH after 28 years. The percentage of exchangeable Ca increased, that of Na decreased, whereas soil salinity [Electrical Conductivity (EC)] was very little affected with prolonged use of sewage effluent in irrigation. Thus, it did not seem that soil salinity (or) alkalinity will be a problem in soils irrigated with sewage effluent for long periods.

Lerch et al. (1990) reported that sewage sludge application resulted in increased soil NO₃-N levels at harvest compared with the N fertilizer at all soil depths sampled. Sludge application, at all loading rates tested, resulted in significant increase in NH₄HCO₃-diethylene triamine penta acetic acid (AB-DTPA) and extractable concentrations of Zn, Cu, Cd, Ni and Pb compared to the control in the surface (8 inches) of the soil. Because of the potential for NO₃- contamination of ground water by the higher sludge loading rates, a loading rate of 3 ton/acre is recommended as the maximum safe loading rate for dryland wheat system (Lerch et al., 1990).

**Paper Mill Effluent:**

Irrigation with undiluted paper and pulp mill effluent led to increased soil pH, EC, organic C, and available nutrients (Rajannan and Oblisami, 1979, Juwarkar and
Subrahmanyam, 1987; Kannan and Oblisami, 1990 a). Kannan and Oblisami (1990 b) reported that the application of pulp and paper mill effluent to sugarcane tended to increase soil enzyme activities. Kannan and Oblisami (1990 c) reported that irrigation of sugarcane crops with combined pulp and paper mill effluent increased soil pH, organic C, N, P and K over a period of 15 years. Effluent application increased exchangeable Na by 4.5 fold compared with control soil (well-water irrigated), which ultimately elevated the Na adsorption ratio of the soils. Rajannan and Oblisami (1979) reported that the soils treated with paper and pulp industry effluents showed high amounts of nutrients like nitrogen, phosphorous and potassium. Kannan and Oblisami (1990 c) reported an increase in pH and total dissolved salts in the soils treated with the effluent due to the alkaline nature of the effluent being higher in soluble salts. Irrigation with the combined effluent over a period of 15 years clearly increased the soil accumulation of Na and other soluble salts. When Na ions predominate in the soil solution, along with carbonates, alkali soils are formed, as reported by Rajannan and Oblisami (1979), Reddy et al. (1981), and Kannan and Oblisami (1990a). The higher concentration of suspended solids in the effluent led to an increased organic content in the soils that were irrigated with the effluent. Continuous application of the effluent containing organic and inorganic compounds increased the N, P and K contents of the soils (Kannan and Oblisami, 1990 c).

Application of the effluent, at any rate, significantly increased K, Ca, Mg, Na, and P concentrations as compared with the control. Soil Na concentrations were
increased 5- to 15-fold by effluent application. Effluent application increased soil total Kjeldahl nitrogen by 40-76% above the no-effluent (0-8 month) treatment. Effluent additions reduced ammonium - N levels as compared with no effluent; however, nitrate-N values showed an opposite response, with values being increased by > 5mg/kg by effluent application as compared with the 0-(8- month) effluent rate. Organic matter content was significantly increased by effluent application, however, no significant differences were found for the different effluent rates. Effluent addition increased soil pH from 6.5 in the control to as high as 9.3 with the 88 g total solids (8 - month) per pot rate (Sweeney and Graetz, 1991). Application of the effluent at all rates supplied an excess of P, K, Ca, Mg, Na and Mn to the soil and these elements are well known to play a major roll in plant growth and metabolism. However, Fe, Cu, and Zn concentrations in the effluent treated soil were not affected by effluent addition. This may have been due to low effluent concentrations, but possibly was influenced also by the increase in soil pH that resulted from the large accumulation of K, Na and Mg in the soil (Sweeney and Graetz, 1991). Henkins et al. (1988) also noted a potential for NO₃- (or) K buildup in soil from the application of thin stillage waste water from an ethyl alcohol production plant.

Dairy Effluent:

Gautam and Bishnoi (1992) reported that the physico-chemical characteristics of the dairy effluent was slightly alkaline with pH 8.45. It contained large amounts of
total solids 2589 mg/L and dissolved solids 2005 mg/L resulting in high BOD and COD far above the recommended tolerance of Indian Standards Institution (ISI) limits. The basic nutrients, ammonical nitrogen (0.15 mg/L), chloride (145 mg/L), phosphate (20 mg/L), nitrate nitrogen (0.01 mg/L), sulphate (0.055 mg/L) and metallic components, iron (0.02 mg/L) in the effluent were also above the recommended tolerance limit of ISI values. The EC value was 1.58 mmhos/cm showing low salinity. Gupta (1986) while classifying quality of irrigation water, it was reported that water of low salinity (EC 1.5 to 3.0 mmhos/cm) can be used for most of the semi-tolerant and tolerant crops.

Photo Film Industry:

Manonmani et al. (1992) observed that the physico-chemical analysis of the photo film industry effluent was light green in colour with phenolic odour. The temperature was 18 oC with a pH value of 7.4. The pH value is well within the limit (5.5 to 9.0) as suggested by ISI. The effluent contained 400 mg/L of total solids, 250 mg/L of dissolved solids and 150 mg/L of suspended solids. But the ISI recommended levels for industrial effluents discharged on land for irrigation are 500 mg/L of total solids, 200 mg/L of dissolved solids and 200 mg/L of suspended solids, respectively revealing that only the dissolved solid content was slightly higher in the effluent. BOD in the effluent was 30 mg/L for 5 days at 20°C, but ISI permissible amount was 100 mg/L. The effluent was having a COD of 250 mg/L. Apart from
that, the effluent contained heavy metals like cyanides, hexavalent chromium, copper, lead and mercury and also ammonical nitrogen, phenolic compounds and residual chlorine. But the concentration of these metals and metallic compounds in the effluent were within the limits prescribed by ISI.

**Other Industrial Effluents:**

Hari Om et al. (1994) observed that the physico-chemical properties of the effluent-water indicated that it was slightly acidic and highly rich in COD, BOD, sulphate, sulphide, chloride and total dissolved and suspended solids. Manuchehr Tahavi and Vora (1994) reported that the analysis of effluent from a chemical factory, Gujarat, India revealed that major elements like Na, Ca, Mg, Cl and sulphate were in higher concentrations. The slightly basic nature of the effluent (pH 7.6) was not harmful for the growth and development of seeds.

Qzair Aziz et al. (1994) reported that the effluent discharged from the Mathura Refinery, Indian Oil Corporation Ltd., Mathura, India showed no significant change in pH, total organic carbon, calcium, water soluble salts, cation exchange capacity and sodium adsorption ratio. Treated refinery effluent met the irrigational quality requirements as its physico-chemical characteristics were within the permissible limits.
Agrawal and Pandey (1994) reported that the physico-chemical characteristics of the soil (pH, conductance, organic matter, sulphate content, total N, total Fe, total Mn, Li, K, Na and Ca) of the unpolluted soil were found to be significantly altered on coming in contact with the spent wash. One litre of the spent wash was found to extract out as high as 175 mg of total manganese, 62.8% of which was in the ionic state. It has also been found that the entry of spent wash in the soil matrix retarded the transformation rate of Mn (II) to higher oxidation states.

Swaminathan et al. (1992) reported that alcohol and chemical industry effluent was rich in plant nutrients like organic carbon, nitrate, nitrite, phosphate, iron, magnesium, sulphate, calcium, sodium, sulphur, copper and zinc necessary for plant growth. Swaminathan et al. (1992) reported that nutrient status of the soil was significantly increased by the addition of alcohol and chemical industry effluents. pH of the soil was not much affected, EC % was decreased, but nitrogen, phosphorus, and potassium contents were increased.

HEAVY METAL ACCUMULATION

Aboulrous et al. (1989) reported that total content of Fe, Mn, Zn, Cu, Pb, Cd, Ni and Co in soils irrigated with sewage effluent increased with increasing years of using sewage effluent for irrigation. The concentrations of Fe, Mn, Zn and Cu in tops
of alfalfa and leaves of corn grown in these soils increased substantially with increased levels of available metal content of the soil, while those of other metals were little affected. As for orange, continuous increase in leaf metal content with time was observed for Mg, Mn, Zn, Co and Cd. The concentrations of Cd, Co, Ni and Pb in corn grains and orange fruits were several times higher than normal, and this reduces their suitability for human consumption.

The sludge, depending on its origin, may be rich in organic matter and nutrient elements as well as useless toxic heavy metals (Berrow and Webber, 1972). Thus land disposal of sewage wastes is highly recommended for fertilization of soil and its improvement. High levels of heavy metals in soil may inhibit crop production (or) increased metal uptake without reduction in yield (Unger and Fuller, 1985; Vlamis et al., 1985; Smilde, 1981; Webber, 1972). Aboulrous et al. (1989) reported that soil application of sewage sludge and use of sewage effluent in irrigation caused substantial increase in the contents of heavy metals not only in the leaves but also in the edible parts of the crop. This might be favourable as far as Fe, Mn, Zn and Cu are concerned since they are essential micronutrients.

Totawat et al. (1985) reported that Zinc smelter, Debari (near Udaipur, India) with a rated capacity of 49,000 TPA Zinc discharges its effluent (3000 - 4000 m³ / day) in a stream, which after flowing for about 3 km merges to a seasonal river
Berach. By downward and lateral movement of the effluent through the soil the fields nearby got polluted with the constituents of the effluent, mainly heavy metals.

Industrial waste effluents from Durgapur Industrial Belt (DIB) contained large number of pollutants in higher concentration (De et al., 1980; De et al., 1985). These were toxic to the standing crops and vegetables and showed retardation in growth and yield of rice, pulses, and oil seeds (Ray and Banerjee, 1983,). Higher accumulation of heavy metals in different parts of the rice plants were also observed (Ray and Saba, 1988, Illogpanon and Vivekanandan, 1992). Phyto-toxicity of the industrial effluents have been studied extensively in rice, pulses and oil seeds (Ray and Banerjee, 1981; Ray and Barman, 1988). Enormous studies have been carried out by different workers regarding the heavy metal accumulation in crop plants and vegetables (Beckett and Davis, 1977; Carlson and Bazzaz, 1977; Miles and Parker, 1979; Root et al., 1975). Barman and Lal (1994) reported that the level of heavy metals (Zn, Cu, Cd and Pb) in the cultivation fields adjacent to DIB were found to be much higher than the background level. Bioaccumulation of these metals in different parts of the different plant species found either within (or) beyond the critical concentration and maximum localisation was found in the edible parts followed by non edible leaves and shoots.

The anaerobic environment allows sulphate reducing organisms to flourish so that hydrogen sulphide may be produced thus facilitating the precipitation of heavy metal ions as sulphides. Geeta & Pandey (1994) studied the self-regulated process of
de-ionisation of heavy metal ions such as Pb$^{2+}$ and Zn$^{2+}$ in the domestic sewage sludge by equilibrating the sludge with respective metal ions, and determining their concentrations after specific intervals of time. While total elimination was observed in case of Pb$^{2+}$ ions, a substantial decrease was found in case of Zn$^{2+}$ ions. Geeta and Pandey (1994) concluded that the domestic sewage sludge contained sulfur-active organisms, and their presence provided an inbuilt mechanism for the removal of heavy metal ions by precipitation as sulphides.

MICROBIAL PROPERTIES

Kannan and Oblisami (1990 c) reported that irrigation of sugarcane crops with combined pulp and paper mill effluent increased the soil populations of bacteria, actinomycetes, fungi, *Rhizobia* and yeasts. The populations of soil microorganisms were higher after 15 years of effluent treatment followed by 3rd, 2nd, and 1st year of effluent treatment; the microbial populations were directly proportional to soil organic C and to the available nutrient status of the soil. Regular monitoring of microflora showed a considerable change in the populations from one sampling month to another. Soil samples, including the control, collected in May (summer) showed maximum counts of bacteria, fungi, *Rhizobia* and yeasts. The increase in the population of bacteria, actinomycetes, fungi, *Rhizobia*, and yeasts in the soils that were irrigated for 15 years might be due to the continuous accumulation of microflora from the effluent.
Kannan and Oblisami (1989) reported the presence of considerable numbers of bacteria, actinomycetes, fungi, yeasts and *Azotobacter* in the combined paper mill effluent. The population increase might also have been due to an increase in the available nutrient status. Ross et al. (1980) reported a good relationship between microbial biomass and soil C and N contents. The soil population of *Rhizobia* spp., a symbiotic N$_2$-fixing bacterium, was not affected by the combined pulp and paper mill effluent treatment (Kannan and Oblisami, 1990 c).

Ross et al. (1981) and Granatstein et al. (1987) reported that numerous factors affect the soil microbial biomass and that cropping history, time of sampling and seasonal changes must be taken into account when microbial biomass data are compared. Kannan and Oblisami (1990 c) indicated that both the effluent-treated and the control soils showed a similar pattern of population variation. Hence the fluctuations could be attributed to seasonal variations. Both quantitative and qualitative data on soil microflora provide an useful index of soil fertility.

**SEED GERMINATION**

Swaminathan et al. (1992) reported that the alcohol and chemical industry effluents were not much toxic to tomato plants. At lower concentrations, the effluent could even stimulate seed germination and plant growth. An increase of 10% in seed germination was observed in seeds of *Solanum lycopersicum* soaked in effluent diluted...
to 25, 50 and 75% concentrations but could not cause any further significant change in percent germination. They also reported that pure effluent showed inhibition in seed germination. When the effluent was used for irrigation of the test plant *Solanum lycopersicum*, the germination capacity of the seeds and plant growth were stimulated.

Gautam and Bishnoi (1992) reported that the percentage germination of wheat seeds in pure and diluted effluent was on par with that of control. This shows that the permeability of wheat grain / seed coat to the effluent is approximately the same as that of water. Similar observation was made by Bumbla and Singh (1965) that barley was the most tolerant at EC levels of 2,4,5,12 and 16 mmhos/cm and followed by wheat, sugarbeet, berseem, mustard and gram. The shoot and leaf elongation (14.06, 10.26 and 10.46 cm respectively) of the seedlings was stimulated by the diluted effluent than the pure one and water. The stimulatory effect may be due to sufficient amount of basic nutrients and low salinity of the diluted effluent.

Manonmani et al. (1992) observed that the diluted photofilm factory effluent exhibited only a slight toxicity to seed germination and seedling development of the test plants, *Arachis hypogaea* and *Zea mays*. Seed germination studies revealed that the photofilm industry effluent was not much toxic upto 75% both for ground nut and maize seeds. But pure effluent was significantly toxic to both the seeds and maximum toxicity was observed in maize seeds. The same trend was observed in the
germination index and embryonic axis development also. In ground nut seeds, the
tigour index was considerably decreased by 50 and 100% effluent concentration,
whereas in maize seeds the decrease was significant at 100% only. They also revealed
that only the pure effluent could exhibit significant toxicity on ground nut and maize
seedlings with a percent phyto-toxicity of 26.77 and 13.93 respectively. To pure
effluent treatment maize seedlings had a high effluent tolerant index of 0.86 when
compared to groundnut seedlings (0.73). The toxicity of this pure effluent on seed
germination and seedling development was attributed to the total, suspended and
dissolved solids present in the effluent. These solids would disturb the osmotic
relations of the seed and water, thus reducing the amount of absorbed water and
retarding seed germination by enhanced salinity and conductivity of the solutes being
absorbed by seeds prior to germination. Moreover, the germinated seeds did not get
sufficient oxygen, thus restricting their energy supply through aerobic respiration so
necessary for growth and development of young seedlings (Flinn and Smith, 1967;
Kittock and Law, 1968; Saxena et al., 1986; Dayama, 1987). Moreover, the metallic
ions like cyanides, chromium, copper, lead and mercury present in the effluent might
also be responsible for toxic nature of the pure effluent. Among plants tested Zea
mays was found to be more tolerant than the Arachis hypogaeae. They concluded that
by properly diluting the factory effluent and selecting crop plants of tolerant varieties,
the photofilm factory effluent could be utilized for irrigation purposes.
Totawat and Chauhan (1992) reported that smelter effluent when diluted with well water had no adverse effect on the germination of crops like maize, wheat, *Sorghum*, black gram, barley and mustard. Totawat and Chauhan (1992) reported that diluted effluent in 1:1 proportion showed the highest germination for maize and *Sorghum*. However, the difference was statistically significant for maize receiving undiluted effluent and diluted effluent having effluent in 1:2 proportion. In case of black gram, the undiluted effluent resulted in significantly higher germination (82.5%) followed by 2:1 diluted effluent. Different dilutions of effluent used did not affect the magnitude of germination recorded for wheat. However, data on germination of barley revealed that dilution of the effluent with well water in 2:1, 1:1 and 1:2 proportions significantly increased the germination as compared to the treatment receiving undiluted effluent. In mustard, the effluent when diluted in 2:1 proportion resulted in significantly higher germination than the treatment receiving effluent in equal proportion with well water (1:1). Tatawat and Chauhan (1992) inferred that Zinc smelter's effluent when diluted with water had no adverse effect on the germination of kharif and rabi crops. In general, a higher proportion of the diluted effluent improved the germination. Decreased germination, growth as well as vigour index of seedlings of rice, black gram and tomato seeds were observed when undiluted effluent from paper factory was applied (Rajannan and Oblisami, 1979).

Totawat and Chauhan (1992) tested the performance of crop genotypes on the agricultural field situated in areas polluted with Zinc Smelter's effluent. It was
distinctly clear from the average yield of three experimental sites that growing maize Ganga-2, *Sorghum* SPV - 346, black gram J4-27 in kharif and wheat Lok-1, barley RDB-1 and mustard T-59 in rabi gave the highest seed yield. Their straw yield was also highest among the genotypes tested except barley where RD-216 gave the highest straw yield. Further, among the cereals, maize in kharif and barley in rabi gave better response as was evident from the higher seed yield. The superiority of maize, Ganga-2 and wheat Lok-1 under problematic soils was already reported by several workers [Annual report of the ICAR adhoc scheme (1972-73), 1973; Annual report (1989-90), 1990; Totawat and Mehta, 1985].

Somasekar et al. (1984) studied the effect of industrial waste water on soil, seed germination and seedling growth. Hari Om et al. (1994) investigated the combined effect of effluents of distillery and sugar mill at different concentrations viz, 5, 15, 25, 35, 50, 75 and 100 percent on seed germination, seedling growth and biomass of Okra. Germination percentage, seedling growth and biomass increased up to 25% effluent concentration. Germination was completely inhibited in 100% effluent. Germination was noted in 75% effluent, but seedling did not survive. However, the waste waters of distillery and sugar mill were recommended for irrigation after diluting the effluent to 75%. Hari Om et al. (1994) reported that the upper Ganges sugar mill and a distillery situated at Seohara Bijnor, UP, India discharged a large quantity of effluent in agricultural area. It was observed that the growth and yield of crops were retarded in the land due to irrigation with effluent. The
data for the root length and shoot length in 10-day old seedlings indicated that the growth of the plants was maximum in the 25% effluent. The growth was gradually decreased with the increased concentration of the effluent in Okra. Fresh and dry weights of the root and shoot were increasing from control compared to the 25% effluent. High BOD, COD and absence of the dissolved oxygen damage the plant cells, so that plants could not grow up in the concentrated effluent. Hari Om et al. (1994) suggested that the maximum germination and seedling growth can be achieved with 75% diluted effluent.

Manuchehr Tahavi and Vora (1994) reported that the effluent from a chemical factory, Gujarat, India was not harmful to shoot/root growth. The major elements like Na, Ca, Mg were high in concentration. Besides the slight basic nature of effluent, the effluent concentrations even in the range of 60%, 80%, and 100% were not harmful. Elongation of growth was directly proportional to the concentration of the effluent.

CHLOROPLAST PIGMENTS

Swaminathan et al. (1992) reported that the chlorophyll content of the alcohol and chemical industry effluent-irrigated tomato plants was higher compared to the water-irrigated tomato plants. With increase in effluent concentration, an increase in total chlorophyll content was observed. Maximum amount was recorded in plants
irrigated with 50% concentration of effluent. Chlorophyll a content increased with 50% effluent irrigation with no significant effect on chlorophyll b content.

Manonmani et al. (1992) observed that the diluted photo film factory effluent exhibited minor reduction in chlorophyll pigments, carbohydrate (starch, total and reducing sugars) and protein content of the test plants *Arachis hypogaea* and *Zea mays*. Only the pure effluent exhibited significant toxicity over these plants. By properly diluting the factory effluent and by selecting crop plants of tolerant varieties, the photo film factory effluent could be utilized for irrigation purposes. Among the plants tested *Z. mays* was found to be more tolerant.

Manuchehr Taghavi and Vora (1994) observed that higher concentration of the effluent from a chemical factory, Gujarat, India was detrimental to the chlorophyll content of *Cyamopsis tetragonoloba*. Total chlorophyll content of the seedlings of *Cyamopsis tetragonoloba* was higher at control, 10%, 20%, and 40% effluent treatment as compared with that of high concentration of the effluent. Increase in phenol content at higher concentration of the effluent was observed. The seedling growth was retarded at higher effluent concentration. Phenols are known as growth inhibitors and hence a phenol, might have caused reduction in seedlings growth.

The level of protein increased up to 20% and decreased at higher effluent concentration, while the level of free amino acids increasing up to 80%. This may be
due to the inverse relationship between protein and amino acids, where increased protein content was followed by decreased free amino acid. Initial rise in amino acids may be due to the higher protease activity which suggest that proteins are in a continuous state of turn over and the amino acids newly incorporated into proteins are not in association with those resulting from protein break down (Bid-well, 1979). This view was also expressed by Sane and Zaliks (1986). They found different composition of amino acids in endosperm protein and embryonic protein in germinating barley seed. At higher concentration (60%), the amino acids increased and at 80% no variation was observed, while 100% effluent reduced them. But a reduction in amino acids was followed by concomitant rise in protein content. At 20% effluent treatment, protein content increased by several fold. *Cyamopsis* being a proteinaceous seed, during germination, proteins got built up from amino acids at certain percentages of effluent treatment. Manuchehr Taghavi and Vora (1994) concluded that the effluent from fertilizer complex even at its higher concentration had no deleterious effects on germination pattern and associated root/shoot elongation of *Cyamopsis* seed. The metabolic pathways of the effluent- treated plants showed minor deviations from the control. Hence, industrial effluent after proper dilution could be used for irrigation purpose.
RESPIRATION

The effects of a sugar mill effluent on respiration of rice (Oryza sativa) seedlings were investigated by Behera and Sayeed (1987). A marked increase in the rate of respiration was noticed upon treatment with various concentrations of the effluent. The time dependent changes in the respiratory rate were about threefold after 12 h of treatment, and thereafter a rapid loss was noticed. Additionally, the respiratory quotient was studied to elucidate the nature of the metabolism of seedlings as influenced by the effluent.

GROWTH

Ajmal and Khan (1984) found that irrigation with a 50% solution of brewery effluent resulted in increased pea (Pisum sativum) and wheat (Triticum aestivum) growth when compared with the use of 100% effluent. Kelling et al. (1977 a) hypothesized that reductions in rye (Secale cereale L.) and sorghum-sudan (Sorghum bicolor L.) yields at higher application rates of anaerobically - digested sewage sludge may have been due to large amounts of soluble salts in the sludge. The effluent used by Sweeney and Graetz (1991) had relatively higher amounts of K and Na and it may account, in part, for the reduced grass growth with the 88-g total solids (4-month) per pot during the first 4-month period. Coody et al. (1986) found that yield of reed canary grass (Phalaris arundinacea L.) was inversely proportional to the rate
of COD in a synthetic waste water. Thus reduced plant growth was due to higher COD of the effluent. When effluent application was stopped after the first 4 months for the 88-g total solids (4 month) per pot and only water was applied during the second 4-month period, the grass appeared to recover as indicated by increased dry matter production and decreased visual signs of chlorosis. The apparent improvement in grass growth in the 88-g (4 months) total solid treatment may be related to reduced K and Na soil levels and to the high potential decomposition rate in soil (Sweeney and Graetz, 1988) which may reduce COD. During the initial 4 months, St. Augustine grass dry matter yield was more than 60% higher with the two lower application rates, 44-g (8 months) and 88-g (8 months) total solids, as compared with the higher 88-g (4 months) application rate or the 0-(8 months) effluent control. By the end of the initial 4-months period, the higher 88-g (4 months) total solid treatment had resulted in plant chlorosis and drying of tissue and thus slightly a lower cumulative dry matter yield than obtained with the control. (Sweeney and Gratez, 1991).

Rajannan and Oblisami (1979) reported that the diluted paper mill effluent significantly enhanced the paddy growth and reduced the growth and productivity of ground nut and finger millet and they concluded that when effluents are utilized for irrigation purposes, selection of tolerant plants should be essential.

Swaminathan et al. (1992) reported that alcohol and chemical industry effluents at all concentrations significantly increased the height of the tomato plant.
Maximum growth was observed in 25% concentration. The length of the root system was not much affected. When formation of leaves was considered, maximum number of leaves was formed in plants treated with 25% concentration but at higher concentrations leaf formation was affected significantly. They also reported that the leaf area was also very high in plants treated with the diluted effluent. In plants irrigated with pure effluents, the leaf area was slightly decreased marginally. The increased nutrient status of the soil due to irrigation with effluents was attributed to profuse growth of plants in the effluent treated soils. They concluded that alcohol and chemical industry effluents could be used as irrigation water, rich in nutrients for tomato plants after diluting it to 25% concentration. Gautam and Bishnoi (1992) observed that the growth of the wheat plants was better in diluted dairy effluent than the control. Consequently, there was an increase of biomass in diluted effluent. In 60 days old wheat plants, the length of shoot (31.2 cm), root (51.5 cm) along with the number of leaves and nodes per plant were more in diluted dairy effluent than in pure (27.4 cm/shoot and 45.8 cm/root) effluent and control (26.1 cm/shoot and 43.6 cm/root). There was an increase in shoot and root biomass. The number of tillers per plant, spike length, seed output and biomass of shoot and root were higher in effluent (pure and diluted) treatments than that of the control. It might be due to the presence of mineral nutrients along with nitrate and phosphate in favourable concentrations in the effluent. The diluted form of the effluent showed more favourable results than the pure one. It might be due to decreased concentration of the total dissolved solids (TDS) and other mineral nutrients to favourable concentration. Hence, they
concluded that the dairy effluent can be used as an additional potential source of liquid fertilizer for better crop production.

Rajanan and Oblisami (1979) reported better germination at higher concentration of the paper factory effluent while at lower concentration, no differences were observed. But at 96h, extension growth of shoot was enhanced, while that of root remained the same. The effects of effluent were more prominent especially on extension growth of shoot at 96h germination. From the data of Manuchehr Tahavi and Vora (1994) it is clear that elongation of growth is directly proportional to the concentration of the effluent which suggests that up to 100% concentrated effluent, there was no adverse effect on shoot/root growth.

Qzair Aziz et al. (1994) reported that the effluent discharged from the Mathura Refinery, Mathura, India increased all the growth and yield parameters. Treated effluent proved superior to ground water for the growth of both crops (triticales and wheat) as is evident from increased height, leaf number, tiller number, fresh weight and dry matter production at all stages. This may be attributed to the presence of additional quantities of nutrients, like phosphate, potassium, nitrogen, calcium and sulphate in the effluent. These, being readily available to the plants, could possibly result in increased growth through enhanced cell division, expansion and differentiation. Similar beneficial effects of various effluents were noted by other workers (Rajanan and Oblisami, 1979; Srivastava and Sahai, 1987; Neelam and
Sahai, 1988; Singh et al., 1985; Veer and Lata, 1987). All the cultivars studied, gave higher yield under different effluent irrigation. Since treated effluent proved superior in its effect on growth, it is reasonable to presume that this manifested itself in improved yield parameters, like ear number, ear weight, grain number, 1000 grains weight, and grain and straw yield through better utilisation of inputs, improved photosynthetic activity and favourable partitioning of photosynthates. These findings are in agreement with earlier reports (Day et al., 1975; Veer and Lata, 1987; Samiullah Khan et al., 1992).

PHENOL

Phenol is a troublesome contaminant which contributes to off flavours in drinking and food-processing water. Phenol in the effluent stream mainly comes from oil refinery, coking leather, petrochemical industries etc. Most frequently used method for phenolic waste water treatment is biological treatment because of its efficiency and low capital cost. One of the most effective methods is the activated sludge process, where mixed microbial population is used under aerobic conditions for degradation. (Benefield and Randall, 1980; Richards and Shieh, 1989). The biodegradation mechanism of phenol has been predicted by different workers on different microbial system (Yang and Humphery, 1975).
Sudhani et al. (1991) reported that occasionally a large amount of phenol gets into the waste water treatment plant by phenol discharging industries, creating shock loading concentrations on activated sludge system. Addition of phenol upto 1600 mg/L as a pulse dose in the stabilized activated sludge reactor does not cause significant adverse effects. Addition of 400 mg/L of phenol in continuous mode every day can maintain the plant operating parameters to certain extent, but the concentration at 800 mg/L has caused complete upset of the operating plant.

BROILER WASTE APPLICATION TO LAND

The rapid expansion of poultry industry lead to disposal of large amounts of wastes (litter) into the land. Although research with broiler litter as a fertilizer has demonstrated salutary effects for crop production constricting economic factors often dictate increasing and / (or) long-term application on the agricultural soils within a broiler production region (Simpson, 1991). Increasing use of animal wastes may lead to detrimental environmental effects. The main problems that can arise from excessive manure applications are pollution of ground and surface water due to leaching and run-off of nutrients and soil accumulation of heavy metals (Wadman et al., 1987). High application rates of poultry manure in field plots has reduced germination and adversely affected the growth and yield of corn due to excessive soil salinity (Shortall and Leibhardt, 1975; Weil et al., 1979). Field trails with cattle on tall
fescue pastures fertilized with broiler litter strongly indicated fescue toxicity problems due to high levels of N in plant tissue (Wilkinson et al., 1971).

Kingery et al. (1994) reported that litter application increased organic C and total N to depths of 15 and 30 cm, respectively, as compared with non-littered soils, whereas pH was 0.5 units higher to a depth of 60 cm under littered soils. Significant accumulation of NO₃-N was found in littered soils to (or) near bed rock. Extractable P concentrations in littered soils were more than six times greater than in non-littered soils to a depth of 60 cm. Elevated levels of extractable K, Ca and Mg to depths greater than 60 cm also were found as a result of long-term litter use. Extractable Cu and Zn had accumulated in littered soils to a depth of 45 cm. These findings indicated that long-term land application of broiler litter, at present rates, has altered soil chemical conditions and has created a potential for adverse environmental impacts in the Sand Mountain region of Alabama. (Kingery et al. 1994).

PIG SLURRY

Although pig slurry is not a complete fertilizer for any crop, it does provide important quantities of K in the form of soluble salts, which originate almost totally from the urine of the animals (Cheverry et al. 1979). This soluble K⁺ equilibrates with the soil exchange complex and/or is taken up by the crop. Pilar Bernal et al. (1993) reported that the addition of pig slurry to soil with a mainly illiticclay content causes a
linear increase in exchangeable K' as rates of slurry application increase. The soil with a low clay concentration showed a poor K' retention capacity.

MUNICIPAL SLUDGE

Land application of municipal sewage sludge utilization is an effective and cost effective method that recycles nutrients to the soil. Sludge additions improved soil physical and chemical properties. Thus, land application in the agricultural sector is in response to the USEPA'S policy (40 CFR 503, USEPA, 1989) of promoting beneficial use of municipal sewage sludge. The environmental fate of organic contaminants that can occur in sludges, however, threaten routine use of the practice. The organic contaminants of principal concern in municipal sludges are polychlorinated biphenyls (PCBs), Poly nuclear aromatic hydrocarbons (PAHs), phenols, chlorinated hydrocarbon solvents, phthalate ester, petroleum hydrocarbons and organochlorine insecticides.

A field study of industrial organic contaminant uptake, in particular PCB uptake, by growing crops was conducted during 1990 at the St. David Coal Refuse Pile Reclamation Site, Fulton County, Illinois by Webber et al. (1994). Despite the very large rates of Chicago sludge employed in this study, findings of Webber et al. (1994) indicated that it did not (i) result in high levels of organic contamination in the treated
coal refuse, and ii) represent a significant organic contaminant hazard to the quality for food and feedstuffs of crops grown on the treated coal refuse.

**BIODEGRADATION OF LIGNIN**

The pulp and paper mill waste characteristically contain very high COD and colour. The presence of lignin in the waste which is derived from the raw cellulosic materials and is not easily biodegradable, makes the COD/BOD ratio of the wastes very high. Lignin bearing wastes creates environmental pollution problems due to the presence of lignin - derivatives, which cannot be removed in conventional treatment process, as these treatment plants lack the presence of specific group of microorganisms which can degrade lignin. In mature wood decay takes place by microbial process particularly by fungal cultures, which are both cellulolytic and lignolytic.

Geetha and Joshi (1992) observed that *Penicillium* sp. in Czapek medium removed 70% and 82% of colour and lignin respectively; however, the same species in malt extract medium removed 65% and 79% of colour and lignin only. *Penicillium* sp. showed promising results in removal of both colour and lignin from the paper mill effluent followed by *Phanerochaete chrysosporium* and *Trichoderma viride*. Geetha and Joshi (1992) concluded that the percentage reduction in colour and lignin is more by Penicillium in both Czapek and malt extract media presumably due to favourable experimental conditions. All these cultures are having the ability to remove colour and
lignin from the lignin bearing waste water in the presence of Co-substrate in the form of glucose. Eventhough the performance of Penicillium culture is better than the other two, all the three cultures can be used for biological treatment of colour and lignin from pulp and paper mill waste water.

WORK DONE ON DISTILLERY WASTES

Biofilters:

In view of social hazards and environmental deterioration, the effective treatment of distillery effluent is very essential. Research on effluent treatment using living organisms which act as 'living filters' are being carried out recently. Abdul Rahaman et al. (1992) reported that Artemia functions as living filter for the secondary treatment of distillery effluent, which reduces up to 69% of the total solids and 33.34% of BOD in the saline medium of 60 ppt. Chemical analysis of the diluted effluent after treatment with Artemia showed a significant (P<0.001) decrease in the electrical conductivity, calcium and pH values. However, an increase in sodium concentration and pH values was recorded. A major problem of distillery effluent is its high BOD level. A reduction of 58.34% was observed after treatment of effluent with Artemia along with continuous aeration. This reduction in BOD may be attributed possibly to the decrease in the organic load of the effluent by the continuous feeding of Artemia. Since Artemia live in a stressed environment, they are found to be considerably more
resistant to the toxicity of the pollutants than any other aquatic organisms (Trieff, 1980). Abdul Rahaman et al. (1992) revealed that *Artemia* may be used as a living filter for screening suspended solids thereby reducing the organic load and BOD.

The addition of anaerobic digester distillery effluent, regardless of rate, raised soil pH from 6.5 to approximately 9, owing to increase in soil K, Na, Mg, and Ca levels. The data obtained by Sweeney and Gratez (1991) suggested that the lowest effluent application rate, 44-g total solids (8 months) may result in acceptable St. Augustine grass growth. However, the apparent elemental buildup in the soil and the potential adverse effects on ground water quality suggested that even lower rates may be necessary for long-term continuous disposal of the distillery anaerobic digester effluent (Sweeney and Graetz, 1991).

**Reclamation of soil:**

Rajukkannu et al. (1996) from their studies showed that application distillery spent wash (untreated), (10 lakh L/h) effectively reduced the pH and ESP of the sodic soils from 9.7 to below 8.5; and 31.0 to below 12.0 respectively. They also proved that reclamation of sodic soil using spent wash was more effective when compared with the application of gypsum.
The soil pH, EC, organic carbon content, available N and K were increased by fertigation with secondary treated distillery effluent when compared with control (normal irrigation). There was no difference in the soil available P. The yield of cashew nuts was also found to be increased by fertigation with secondary treated distillery effluent when compared with control (Nagappan et. al., 1996)

A composting technology was developed by Dharani Sugars and Chemicals Ltd., Nellai Kattabomman District to prepare fortified pressmud in a period of 5.7 weeks using pressmud, distillery effluent and biodegradables like bagasse. Pressmud and bagasse were mixed in a ratio of 10:1 volume and placed in windows and allowed to dry for a week. After this period, treated distillery effluent was sprayed on the windows @ 2 parts of effluent with one part of pressmud and allowed for composting for 5-7 weeks. The fortified pressmud thus got was found enriched with essential nutrients like N, P and K when compared with farm yard manure (Ramalingam et. al., 1996).

**Irrigation:**

Lakshmanan and Gopal (1996) reported that irrigation with treated distillery effluent to sugarcane soil under varying dilutions significantly altered the microbial load in the rhizosphere region. The population varied with period under effluent irrigation and the population peak was recorded in the fifth month. The microbial
population was found to be high in the soil that was irrigated with 50 times diluted effluent.

Nagappan et al. (1996) reported that there were no significant differences in the pH and EC of soils irrigated with distillery effluent and control. However the levels of organic carbon, N, P and Ca in the soils increased and the yields of crops like sugarcane, rice, cotton, maize, sorghum, bajra and redgram were significantly superior in the soils irrigated with effluent than the control. Pujar and Manjunathaiah (1996) studied the effect of distillery treated effluent irrigation on growth, yield and quality of crops in vertisols and concluded that although the quality parameters of the crops and yield were not affected by diluted effluent irrigation, it is very difficult to conclude the effect of distillery effluent on crops due to limited number of irrigations given to the soil and that there is a need to study the long range effect of effluent irrigation on soil health, productivity of soil and quality of the crops/seeds produced.

According to Devarajan et al. (1996) distillery effluent irrigations significantly increased the pH, EC organic carbon and available nutrient contents of the soils. They reported that potassium can be withdrawn from fertilizer schedule under effluent irrigation. The sugarcane variety CoC.771 registered significantly higher cane yield than Co. 8021 in both plant and ratoon crops. The Co.8021 gave higher cane yield at 50 times dilution only, whereas, the CoC.771 gave high cane yields at 50, 40 and 30
times dilutions in both plant and ratoon crops. The Co. 8021 registered higher CCS% than CoC.771 in both plant and ratoon crops.

The survey of 23 distilleries in four states of India indicates that the use of distillery effluent in agriculture in India is confined only to the agricultural lands near the distilleries. The experiments with post methanation effluent did not indicate toxicity to crops upto 30% dilution. Crop yield had also increased as compared to control and partial fertilizer application (50%). The effluent treatment (post-methanation) at 20 % dilution with 50% N and P application had shown the best yield (5.3 ton/ha) in case of maize (GS-2), saving 50% N and P and 100% K. At this rate of effluent application, odour problems were also not encountered. There was significant salt built up in the upper layer of 0-30 cm but its extent was not as high as to cause any alarm for sustainable agricultural production (Joshi et al., 1996).

Lakhsmanan and Gopal (1996) studied the effect of treated distillery effluent on germination of seeds and seedling vigour index (SVI) of crop plants like maize, Sorghum, black gram, cotton, Acasia nilotica and Sesbania rostrata at different dilutions. They reported that germination of seeds and SVI were reduced with increasing concentrations of the effluent.

Dilip kumar Pandey and Prafulla Soni (1994) studied the effect of different concentrations of distillery effluent on germination of three multi-purpose tree species;
Acacia catechu, Dalbergia sissoo, and Morus alba. Low effluent concentration (10%) enhanced the germination of all species. Higher effluent concentrations (>10%), however, inhibited germination, and germination percentage was in order of >0 >10 <20 <40 <60 <80% effluent concentrations. Experimental findings indicate that the seeds of A. catechu were more resistant and more vigorous than D. sissoo and M. alba. An effluent concentration of 10% was more favourable for seed germination compared to ordinary water. Raja and Vuaya Kumari (1989) observed that rice seed treated with different concentrations of distillery effluents showed a decreasing emination trend with increasing concentrations. No germination was observed in 100% effluent because of its high acidic and toxic nature.