

CHAPTER 1

INTRODUCTION

1.1 Soil: its definition

As early as 5000 B.C., the Vedas and the Upanishads as well as other ancient Indian scriptures mentioned soil as synonymous with land – the Mother- supporting and nourishing all life on earth. Soil is the natural covering of most of the earth's land surface. It is the part where plants grow, ice lands, lava flows, dune moves, rock mountain stands. Soils are used to grow most of the world's food and much of its fiber. To the farmer, soil is that portion of the earth's surface which he can plough and grow crops on to provide him with food and fiber for his own needs and that of his animals. A poor man uses soil for his mud house and a rich man uses it for making bricks, which is used as a building material. Everybody uses soil as his/her source of 'Energy'-physical and mental – in this world.

As soil is a complex heterogeneous system, it is very difficult to define it. It is probably worthwhile therefore to quote the definition of soil given by Joffe (1949) who stated:

“The soil is a natural body of mineral and organic constituents, differentiated into horizons of variable depth, which differs from the material below in morphology, physical makeup, chemical properties and composition and biological characteristics”.

The limitations of this definition lie in the fact that in many cases soil horizons may be absent and the material below may be hard to find.

1.2 Soil composition

Soil is composed of partly weathered, unweathered and transformed products of rocks and rock minerals, and organic matter. The soil particles are present partly as individual and partly as aggregates or pads. The organic matter is often firmly combined with mineral particles forming aggregates, which are of various sizes and shapes just as the pores.

Soil is normally considered as a three-phase system - solid, liquid and gaseous, the liquid and gaseous matter occluded in the pores. When completely dry or frozen, soil becomes a two-phase system, the liquid phase being either absent or a part of the solid phase, but the soil pores will still contain some gaseous matter.

The solid phase is composed of (a) inorganic and (b) organic constituents. Soils having more than 20% of organic constituents are arbitrarily designated as organic soils. When inorganic constituents dominate, they are called mineral soils.

The Inorganic Fraction

The inorganic constituents, forming the bulk of the solid phase of soil, consist of silicates both of primary and secondary origin having a definite chemical composition and a well-defined crystalline structure. Soil may also contain a certain proportion of carbonates, soluble salts and free oxides of iron, aluminium and silicon in addition to some amorphous silicates.

Primary minerals found in rocks are the original source of all primary minerals found in soils. The most abundant minerals are quartz and feldspars with relatively small proportions of pyroxenes, amphiboles, olivines, micas, etc. The primary minerals in soil are mostly concentrated in the coarse fraction.

Under conditions of weathering, the primary minerals are broken down to small fragments and even to molecular species such as silica, alumina, iron oxide, etc., the latter are capable of being synthesized into structurally different silicates, which are called the secondary minerals. Soil clay fraction with particle size 0.002 mm is called the clay fraction, which possesses colloidal properties. Secondary minerals are dominant in the majority of soil clay, which are aluminosilicates in chemical composition and have crystalline structure.

The Organic Fraction

Only a small fraction of the solid phase is of organic origin. The sources of organic constituents are plants and animals. Billions of organisms, macro and micro in nature, thrive on the debris of animals and plants and other organic residues of soil and themselves add to the soil organic matter when these organisms die. Chains of biological activity start in which new organisms take over the work from old ones. In

the process of microbial decomposition of organic materials, most of them are fully decomposed but a small part is transformed into new products, which get thoroughly mixed up with the soil, and becomes an ingredient of it called soil humus. The humus and humus like fractions of the solid phase constitute the soil organic matter.

The Soil Pores

Almost half of the bulk volume of soil is generally occupied by voids or soil pores. These pores may be completely or partially filled with water. Some of the water gets adsorbed and stored in the pores and the rest returns to the atmosphere by evaporation or by transpiration through plants.

The air filled pores constitutes the gaseous phase of the soil system. The volume of the gaseous phase is thus dependent on that of the liquid phase. The sum of the volumes of the liquid and gaseous phases remains constant for a particular soil. The gaseous phase supplies oxygen for root respiration, which finally liberates carbon dioxide. This phase exchange between soil air and atmospheric air ensures fresh supply of oxygen and thereby prevents carbon dioxide toxicity.

The three phases of the soil system have definite roles to play. The solid phase provides mechanical support and nutrients to the plants. The liquid phase supplies water and along with it, dissolved nutrients to plant roots. The aeration need of plants is satisfied by the gaseous phase. The soil's responsibility to sustain plant growth is thus shared complementarily by its three phases.

1.3 Soil Contamination

Since soil is a very specific component of the biosphere, it is not only a geochemical sink for contaminants but also acts as a natural buffer controlling the transport of chemical elements and substances to the atmosphere, hydrosphere and biota. Industrial effluents and municipal wastewaters usually contain high amount of heavy metals such as As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn (Larsen *et al.*, 1975; Arora *et al.*, 1985). Their continuous use on agricultural land may results in metal accumulation in surface soil (Gupta *et al.*, 1986). Some heavy metals are essential in trace amounts, namely Zn, Cu, Fe, Mn, Mo and Co for plants and in addition Cr, Ni, Sn for animals; whereas As, Cd, Hg and Pb have not been known to have any function for either plants or animals (Greenland and Hayes, 1981).

Higher concentration of these metals in the ecosystems may lead to an excessive

accumulation of metals, becoming toxic to plants and possible danger to human health problem.

Trace elements originating from various sources may finally reach the surface soil and their fate depends on soil chemical and physical properties. Metals accumulated in soils are depleted slowly by leaching, plant uptake, erosion or deflation. Soil is generally contaminated by industrial wastes and effluents, domestic and municipal wastes and also by vehicular traffic. Long distance aerial transport of volatile compounds (e.g. As, Hg, Se, Sb, etc.) may pollute soil. In this case it is very difficult to estimate the background values for some trace elements in soils. Fertilizers, pesticides and sewage material add to the pool of soil contaminant. Effects of sewage sludge application and free application of effluents on soil are especially of great environmental concern and have been the subject of many studies and much legislation.

1.4 Water

Water is the liquid of life. It is now well established that life first came into existence in an aquatic environment. The role of water in the origin of life is projected from its importance in organic world where water is an essential medium and an ingredient of biological reaction. The chemistry of water is influenced by the inputs of minerals, their solubility and the chemical equilibrium prevailing in the aqueous solution. Thus, in spite of abundant availability of water resources, high standards of life together with poor maintenance and improper drainage system have affected water quality, which has direct impact on human health, particularly due to the toxic and harmful contaminants present in water. Water quality can also have a great influence on the ability of aquatic plants and animals in a stream, pond or lake to sustain growth (Swaranlatha, N and Narsing Rao, 1997). The geology of a particular area has a great influence on the occurrence and quality of water and its movement. Many a times, ground water carries a higher mineral content than the surface water when there is slow circulation and longer period of contact. Changes in the ground water quality with the passage of time have hydrologic significances. The quality also varies due to a change in chemical composition of soil formulations over which the water flows (Rajmohan et al., 2003).

An adequate supply of wholesome water is the foundation of the health of any community. The quality of water resources usually depends on its physical, chemical

and biological characteristics. The normal ranges of these characteristics serve as the benchmark for good water quality and determine suitability or otherwise for its use in drinking and all kinds of domestic activities (Sharma, 2001).

Globally, ground water constitutes one third of the drinking water and it is important that it remains free from all kinds of pollutants. Although the surface water on land is the most easily accessible source of water for human needs including aquaculture, agriculture, and industries (Khabade and Mule, 2003), it is also the most polluted one. On the other hand, ground water has historically been considered as reliable and safe source of water protected from surface contamination by geological filters of soil layers that remove pollutants as water percolates through the same (Prasad and Bhagan, 2004). This is why ground water has been used for drinking purpose for a long time and its purity has made it a well-known source of potable water.

Still ground water is not absolutely free from the pollutants. The indifferent attitudes of the industries that discharge the effluents without any treatment have created the scarcity of good quality ground water. Various organic and inorganic pollutants have now been routinely measured in ground water (Moore and Moore 1976; Thayer, 1995; Dikshith, 1996).

The pollutants present in liquid effluents or solid wastes generated by human and industrial activities discharged either on land or in small watercourses leach out into the ground and then, enter ground water aquifers affecting their quality. A large amount of works (Sharma et al., 1999; Sharma et al., 2001; Hussain et al., 2001) have come to the conclusion that the ground water of an industrial area and its surroundings have poor quality due to impact of the industrial wastewater discharged on land either untreated or after improper treatment.

1.5 Contaminant uptake by Plants

Environmental pollution by metals has become extensive as mining and industrial activities increased in the late 19th and early 20th century. These pollutants, ultimately derived from a growing number of diverse anthropogenic sources (industrial effluents and wastes, urban runoff, sewage treatment plants, boating activities, agricultural fungicide runoff, domestic garbage dumps, and mining operations), have progressively affected more and more different ecosystems (Macfarlane and Burchett, 2001). Metal

toxicity and tolerance in plants is a subject that has been broadly reviewed on several occasions over the last several years (Brown and Jones, 1975; Foy et al., 1978; Ernst et al., 1992; Das et al., 1997; Sanitá di Toppi and Gabrielli, 1999; Hall, 2002; Clemens et al., 2002).

Fifty-three of the ninety naturally occurring elements are heavy metals (Weast, 1984). Among these metals, Fe, Mo and Mn are important as micronutrients, while Zn, Ni, Cu, Co, V and Cr are toxic elements, with high or low importance as trace elements. Ag, As, Hg, Cd, Pb and Sb have no known function as nutrients and seem to be more or less toxic to plants and microorganisms (Niess, 1999). The presence of both essential and non-essential heavy metals in the atmosphere, soil and water, in excessive amounts, can cause serious problems to all organisms. Knowledge of metal-plant interactions is not only important for the safety of the environment, but is also necessary for reducing the risks associated with the introduction of trace metals into the food chain.

Heavy metals are found ubiquitously in both polluted and unpolluted soils. Although these heavy metals occur naturally in the Earth's crust, they tend to be concentrated in agricultural soil because of irrational application of commercial fertilizers, manures and sewage sludge containing heavy metals and also due to contamination caused by mining and industry (Gimeno-García et al., 1996; Grant et al., 1998; McLaughlin et al., 1999). The current worldwide production of Cu, Cd, Pb, and Hg is considerable (Pinto et al., 2004). All heavy metals are toxic at higher concentrations (Marschner, 1995; McLaughlin et al., 1999) and thus, it has been a subject of extensive research in recent years (Archer et al., 2004) especially in the light of their accumulation and movement in soil and plants (Pueye et al., 2003; Kidd et al., 2004; McBride et al., 2004). Heavy metals are toxic to higher plants by causing oxidative stress, displacing other essential metals in plant pigments or enzymes, leading to disruption of function of these molecules and of many metabolic processes, and finally reducing growth and yield (Rulkens et al., 1998; Seregin and Ivanov, 2001; Verma and Dubey, 2001; Zhang et al., 2002; Wang et al., 2003). Moreover, toxic heavy metals enter the food chain due to uptake and accumulation by crops, posing a potential threat to human health (Jackson and Alloway, 1992; Brzóska and Moniuszko-Jakoniuk, 2001; Sponza and Karaoğlu, 2002). Among these metals, cadmium (Cd), arsenic (As), chromium (Cr), nickel (Ni) and lead (Pb) are commonly considered as toxic to both plants and humans. For

instance, in Japan, Cd contamination of rice led to renal impairment and bone disease in an exposed population. It is necessary to decrease toxic heavy metal accumulation in cereals for food production, particularly in rice, which is one of the most frequently, consumed cereals worldwide.

Heavy metal accumulation in crops is a function of complex interaction among soil, plant and environmental factors. It has been well documented that the contents of these metals in crop plants are closely associated with their levels in soil. Moreover, the uptake and accumulation of heavy metals by plants are largely dependent on the 'available' rather than 'total level' of a metal in soil (Dudka et al., 1996; Garrett et al., 1998; Norvell et al., 2000; Moral et al., 2002). The uptake of some heavy metals varies greatly among plant species (Sarić, 1983). In rice, a wide difference exists among genotypes in their ability to accumulate Cd in grains (Morishita et al., 1987; Arao and Ae, 2003; Liu et al., 2003), indicating the potential possibility of reducing grain Cd accumulation by means of genetic improvement. Breeding for low Cd accumulating cultivars has been undertaken in sunflower and durum wheat (Penner et al., 1995; Li et al., 1997). Meanwhile, environmental factors which may alter the availability of heavy metals in soil and the metabolic pattern of crop plants, are also the cause of variation of heavy metal accumulation in crops (Garrett et al., 1998; Norvell et al., 2000; Moral et al., 2002; Nan et al., 2002; Wu et al., 2002). Thus in moderately contaminated soils, heavy metal accumulation in crops could be reduced by using alternative cultivars with lower accumulation or by improving agronomic practices, such as water and fertilizer management, which lower the availability of heavy metals in the rhizosphere (McLaughlin et al., 1999; Melamed et al., 2003). These practices will depend on understanding genetic and environmental variation in heavy metal concentrations of crops.

However, little is known about genotypic and environmental variation in toxic heavy metals, including Cd, Cr, Ni, Pb and As. The sensitivity of plants to heavy metals depends on an interrelated network of physiological and molecular mechanisms that includes uptake and accumulation of metals through binding to extracellular exudates and cell wall, complexation of ions inside the cell by various substances, for example, organic acids, amino acids, ferritins, phytochelatins, and metallothioneins; general biochemical stress defense responses such as the induction of *antioxidative enzymes and*

activation or modification of plant metabolism to allow adequate functioning of metabolic pathways and rapid repair of damaged cell structures (Verkleij and Schat, 1990; Prasad, 1999; Sanita di Toppi and Gabrielli, 1999; Hall, 2002; Cho et al., 2003).

1.6 Heavy metal toxicity

The toxicity produced by heavy metals generally involves neurotoxicity, hepatotoxicity and nephrotoxicity. Differences in solubility, absorbability, transport and chemical reactivity in these metals will lead to specific differences in toxicity within the body (Stohs and Bagchi, 1995). The chemical form of heavy metals in soil solution is dependant on the metal concerned, pH and the presence of other ions (Das et al., 1997). The toxicity symptoms observed in plants in the presence of excessive amounts of heavy metals may be due to a range of interactions at the cellular level (Hall, 2002). Toxicity may result from the binding of metals to sulphhydryl groups in proteins, leading to an inhibition of activity or disruption of structure (Van Assche and Clijsters, 1990).

Enzymes are one of the main targets of heavy metal ions and prolonged exposure of soils to heavy metals results in marked decreases in soil enzyme activity (Tyler et al., 1989). Metal interaction with ligand groups of enzymes largely defines their toxicity, and the inhibition of enzymes may be due to masking of catalytically active groups or protein denaturation (Das et al., 1997). In addition, excess heavy metal concentration may stimulate the formation of free radicals and reactive oxygen species (Gallego et al., 1996; Dietz et al., 1999; Groppa et al., 2001; Sandalio et al., 2001; Fornazier et al., 2002). In order to cope with highly toxic metals, or to maintain the level of essential metals within physiological ranges, plants have evolved *complex* mechanisms that serve to control the uptake, accumulation and detoxification of metals.

1.7 Textile Industry and the environmental issues

The colored drawings on the walls on the Altamira cave in Spain are dated at 15,000–9000 before Christ. The drawings were performed with inorganic pigments, which can last a very long time. Dyed clothes have been produced in all cultures since a very long time ago but the durability of these products is limited. Thus, very old

samples of dyed textiles are rare, e.g., dyed textile material from Egypt could be dated to 3200 BC, and in India dyed textiles were dated at 2000 BC.

Depending on the climate, various plants serve as sources for natural dyes, e.g., indigo plant, madder, barberry etc. (Schweppe, 1992). Up to the end of the nineteenth century natural dyes were the main colorants available for textile dyeing procedures. The development of synthetic dyes at the beginning of the twentieth century has led to improvement in quality and more reproducible techniques of application. As a result, a distinct lowering in the dyestuff costs per kg of dyed goods has been achieved (Taylor, 1986). The predominance of synthetic dyes has hindered a continuous development and adaptation of natural dyeing to the changing requirements of modern dye houses. As a result, a considerable gap now exists, separating the knowledge about natural dyes from the demands of commercial dyeing processes.

Dyes are an abundant class of coloured organic compounds that present an increasing environmental danger. Many dyes are difficult to decolourise due to their complex structure and synthetic origin. There are many structural varieties, such as, acidic, basic, disperse, azo, diazo, anthroquinone based and metal complex dyes.

Synthetic dyestuffs are extensively used in textile, paper, printing industries and dye houses. The textile industry utilizes about 10,000 different dyes and pigments in the world (Spadaro et al., 1994) The chemical reagents used are very diverse in chemical composition, ranging from inorganic compounds to polymers and organic products (Mishra and Tripathy, 1993; Banat et al., 1996; Juang et al., 1996). Colored effluents have been produced, most certainly, since the dyeing technique was invented. Through hundreds of years, obviously, the scale of production and the nature of dyes changed drastically, consequently having a more and more negative impact in nature (Waters, 1995). Recent estimates indicate that, approximately 12% of synthetic textile dyes used each year are lost during manufacture and processing operations and that 20% of these lost dyes enter the environment through effluents that result from the treatment of residual industrial waters (Weber and Stickney, 1993).

It is therefore necessary for dye-containing effluents to be treated in an effective manner before being discharged into natural waterways. Although the dyes may have been effectively removed, industries still face the problem of the disposal of this concentrated sludge (Robinson et al., 2001). Due to increasing awareness of dyestuffs

contamination to the soils, the dye manufacturing and textile processing industries have been forced to change their working culture in effluent discharge and disposal of waste by (a) reduction of the volume and toxicity of discharges, (b) adoption of alternative processing methods and chemicals and (c) recycling and reuse of water, chemicals and colourants (Lomass, 1983).

The most pressing environmental problem facing the textile industry is related to reactive dyes (Lin and Lin, 1993; Zissi and Lyberatos, 1996; Beydilliet et al., 1998). Reactive dyes are, commercially, a very important class of textile dyes, whose losses through processing are particularly significant and difficult to treat. Thus, in the case of cellulose fibers dyed with these dyes, nearly 50% may be lost to the effluent (Easton, 1995). These dyes, that didn't react with the fiber and are in a hydrolysed state (Cooper, 1993), encounter themselves in a different and irretrievable form in the resulting effluent.

The textile industry produces large quantities of highly coloured effluents, which are generally toxic and resistant to destruction by biological treatment methods. Textile wastewater, being mostly non-biodegradable under both natural and sewage treatment plant conditions, is a potential nuisance to the environment. Textile wastewaters contain a wide range of non-polar and polar compounds, but polar ones are predominant. They comprise substances, which are used as auxiliary products in textile production and treatment and are washed out of the textiles having run off with the wastewater. These polar organic pollutants in textile wastewater may give rise to problems due to the fact that they are non-biodegradable and their elimination is incomplete. Moreover, some of the contaminants have a toxic effect on the bacteria applied for wastewater purification.

In the case of textile industry, the more complex environmental problems associated with the effluents are due to extensive use of carcinogenic or mutagenic azo dyes which are resistant to microbial degradation (Chao and Lee, 1994). Most dyes have a low toxicity (Chung, 1983) but their components and breakdown products can be more toxic. Dyes discharged from textile dyeing and finishing processes are a priority pollutant for the Regulating Authorities and Water Utilities because of their visibility at low concentrations (Easton, 1995). Ineffective colour removal is obvious and causes complaints (Brown et.al.1998). Direct discharge of these effluents causes formation of

toxic carcinogenic aromatic amines under anaerobic/anoxic conditions in receiving media (Weber and Adams, 1995).

Inefficient dyeing of textiles has resulted in large amounts of the dyestuff being lost directly into wastewater and consequently having a detrimental effect on flora and fauna. The presence of low concentrations of dyes in effluent is highly visible and undesirable, reducing light penetration and potentially inhibiting photosynthesis (Mishra and Tripathy, 1993; McMullan et al., 2001). In the past, municipal treatment systems were used for the purification of textile dye effluent, but due to the xenobiotic and recalcitrant nature of many dyes, the treatment was found to be ineffective. The same is true when dyes are released into aquatic systems—anaerobic bacteria in the sediment are unable to mineralize dyes completely resulting in the formation of toxic amines (Banat et al., 1996; Nigam et al., 2000). Wastewater is the principal route by which dyestuffs also enter the soil environment (Elliot, 1996).

Textile industries, particularly those involved in finishing processes are major water consumers and the source of considerable pollution. The environmental challenge for the textile industry is associated with liquid waste, which tends to dominate over air-emissions and solid wastes in terms of the severity of environmental impacts. A typical textile unit generates various types of wastewater differing in magnitude and quality. Typically, textile wastewaters consist of a variety of waste streams from different operations. The wastewater from printing and dyeing units in a textile plant are often rich in color, containing residual of reactive dyes and chemicals, and needs proper treatment before releasing into the environment. Since synthetic dyestuffs are resistant to biological degradation, colour removal by bioprocessing is difficult.

Effluent from textile industry when discharged on open land affects the soil and water quality in many ways. Colour removal from effluents of textile dyeing and finishing industry is becoming important because of aesthetic as well as environmental concerns (Balcioglu and Arslan, 2001). The efficient removal of dyes from textile industry effluents is still a major environmental challenge. Some dyestuffs are highly structured polymers and are very difficult to decompose. Currently, various chemical, physical and biological treatment methods are used to remove color. Because of the high cost and disposal problems, many of these methods for treating dye wastewater have not been widely applied in the textile industries. A literature survey shows that

research has been and continues to be conducted in the areas of chemical and combined chemical–biological treatments in order to improve the biodegradation of dyestuffs and minimize the sludge production. Many of the dyes are carcinogenic, mutagenic and detrimental to the environment. As toxicity standards become more stringent, the development of new techniques for minimizing the concentration of dyes and their breakdown products in the wastewater also becomes necessary. Although some existing technologies may have certain efficiency in the removal of reactive dyes, their initial and operational costs are so great, that they constitute an inhibition to dyeing and finishing industries. On the other hand, low cost technologies don't allow a wishful color removal or have certain disadvantages, needing to be integrated into a more complex and complete treatment plan, such as a combination of biological, chemical and physical procedures (Yeh et al., 1993). Hence, research has been directed to other non-conventional materials and procedures of color removal that will combine effectiveness with cheapness (Laszlo, 1994).

In the absence of any specific government regulations on the eventual disposal of these dyes, the problem remains as the main environmental problem related to textile activities. Since some regulations have been introduced to control the disposal of dyestuffs, mainly because of their high polluting potential, the development of alternative treatment methods will become important (Nasr et al., 1997). There is no universally useful method available for treatment of dye wastes, probably because of the complex and very varied chemical structures of these compounds (Peralta-Zamora et al., 1998). Protection of human health and the environment is now perceived as more important than the profitability and efficiency of a business.

1.8 Objectives of the present work

The present work was designed to evaluate the impact of a textile mill at Rangia (District Kamrup, Assam) on quality of soil and water in the surrounding areas. The principal objectives were:

- (i) To monitor the quality of soil, particularly from the area receiving the Mill effluent, with respect to important physico-chemical properties, and compare the same with that of unpolluted or 'Control' soil from no-impact zone.

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- (ii) To study the quality of water that keeps the agricultural land near the textile mill in a submerged condition.
- (iii) To study the quality of water from different sources (pond, dug well, tube well) in the impact zone to find out if there is any infiltration of the textile mill effluent.
- (iv) To investigate if the rice grain and husk have accumulated a few heavy metals that is found in the Mill effluent.

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