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WATER AND HUMAN CIVILIZATION

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ABSTRACT

Water is intimately linked to human civilization. The rise and fall of ancient civilizations - Greek, Roman, Egyptian, Mesopotamian, Mayan, Indus Valley etc. can be traced to shortage of water supply. Optimum quantum of water required for human survival is 2 litres per day along with 1.2 kg of food.

The world is covered by 70% water and 30% land. Out of this water cover 97% is sea, 2.1% locked in polar ice caps and the rest 0.69% available as fresh water, the breakup being 0.03% surface water and 0.66% ground water. But this fresh water resource (rivers, lakes, streams, ground water) is getting severely polluted due to man-made activities with the result that we have to face water crisis in very near future.

This review paper gives at a glance the structure, properties, chemical characteristics of water, aquatic biochemical reaction, water pollution, waste water treatment and recycling, water quality standards, rivers and dams and their environmental impact. A sound water management policy is essential for conservation of our limited water resources.

INTRODUCTION

"Man can live without **air** for 7 minutes, without **water** for 7 days and without **food** for 21 days but **man** cannot live without ideas."

The history of human civilization reveals that water supply and human civilization are almost synonymous. Several cities and civilizations have vanished due to water shortage originating from climatic changes and anthropogenic activities. Examples are Indus Valley civilization [India, Pakistan], Mesopotamian civilization [Iraq, Iran] Egyptian civilization [Egypt], Maya civilization [South America], Chinese civilization etc. These flourished in the riverine flood plain and reached their peak of development particularly in agriculture.

Water Resources

Water has no alternative - it is known as "life". It is essential for the sustenance of all living organisms including plants, animals and man. All plants, insects, animals and men have 60-95 per cent water in their bodies. This water is partly released in the form of sweat, excreta, urine and vapour. So all these species require lot of water daily. Besides much water is also needed for body growth, nutrition etc. So it is absurd to think of life without water. But our usable water resources like any other natural resources is finite and is likely to be exhausted within a century. Moreover, it is getting polluted by man-made activities and unfit for use sooner than expected. Water crisis is more serious than

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food or population crisis since food production or population problems are irrelevant without water supply. Use of polluted water itself takes toll of 25000 people all over the world every day. In India in 2 lakh villages (without access of water) women have to walk daily about 1-14 km to collect water for cooking and drinking. The United Nations Food & Agriculture department estimate that if the present day practices of wasting and polluting water are not stopped, then within less than a century the world's biosphere including man will disappear.

The world's total quantum of water is 1.4 billion cubic kilometre. If all the sea beds could be filled up and brought at the level of the earth's surface, then the entire water in the seas would cover the earth's surface and make it 2.5km deep water mass. About 97 percent of earth's water supply is in the ocean which is unfit for human consumption and other uses due to high salt content. Of the remaining 3 percent, 2.3 percent is locked in the polar ice caps and hence out of bounds. The balance 0.7 percent is available as fresh water but the bulk of it, 0.66 percent, is ground water and the rest 0.03 per cent is available to us as fresh water in rivers, lakes and streams. The break-up of this 0.03 percent fresh water is : lakes and ponds 0.01 percent, water vapour 0.001 percent, rivers 0.0003 percent and water confined in plants, animals and chemicals 0.0187 percent.

[United Nation's Water Conference Report, Argentina (1977)]

Thus we see that we have a very limited stock of usable water, 0.03 percent surface water [rivers, streams and ponds] and 0.66 percent ground water. The quantity of water vapour arising from evaporation of sea water and river water returns by the same volume to the earth's surface by rainfall and back to the water sources. The hydrological cycle in nature is more or less balanced in terms of charge [cloud formation] and discharge [rainfall]. But we are drawing large quantities of ground water for agriculture and industries while the waste water from these is much polluted and on mixing with rivers is polluting the rivers also.

Table 1

Status of water and its distribution
(as percent of total = 100)*

All water (Total)	100
Oceans (Saline)	97
Inland (Freshwater)	3
Freshwater (Distributed in percentage of total freshwater)	100
Atmosphere	0.035
Rivers	0.0030
Lakes	0.300
Soil Moisture	0.060
Groundwater, less than 770m deep	11
Groundwater between 770-3850m deep	14
Ice sheets and glaciers	75

*The total amount of water in the earth is estimated at approximately 1.36 billion cubic kilometres.

It can be seen that water suitable for human consumption is precariously meagre on earth's surface and 99.7 percent of all water is not available to us for consumption. Only 0.3 percent of water is usable by humans. Again of this usable water nearly 97 percent is stored as ground water and only a meagre amount flows through the rivers. Still such rivers constitute the principal source of water on earth's surface for human use.

Hydrologic Cycle

We know that water remains in the hydrosphere, lithosphere and atmosphere in different state - water (liquid), ice (solid) and water vapour (gas) respectively. There has been a change of state of liquid water in the hydrosphere to water vapour by the process of evaporation. Subsequently water vapour is converted to liquid water through the process of condensation and precipitation. Water is frozen under very cold condition on the earth's surface to form ice which on melting yields water.

Through the ages there has been either no gain or loss of water on earth's surface. It is presumed that the amount of water that existed on earth million years ago still remains the same. The hydrologic budget given below explains the balancing of water status on earth. There has been a net loss of $0.36X10^{14}$ cubic metres per year on land.

Table 2

Hydrologic budget of the earth

Source	Cubic metre / year
Precipitation on oceans	3.24×10^{14}
Evaporation from oceans	3.60×10^{14}
Net Loss from oceans	0.36×10^{14}
Precipitation on land	0.98×10^{14}
Evaporation from land	0.62×10^{14}
Net gain on land	0.36×10^{14}

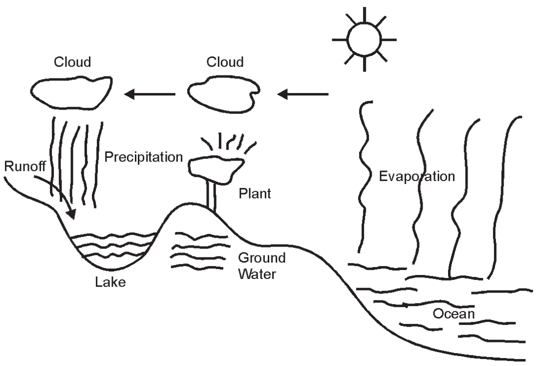


Fig. 1. The Hydrologic Cycle

The Water Molecule - Structure, Bonding And Properties

Some of the unique characteristics of water include the polar character, tendency to form hydrogen bonds and ability to hydrate metal ions. The water molecule is made up of two hydrogen atoms bonded to an oxygen atom. The tree atoms are not in a straight line, instead as shown above, they form an angle of 105°.

Water has a bent structure - oxygen atom attracts the negative electrons - more strongly than do the hydrogen atoms, the water molecule behaves like a body having opposite electrical charges at either end or pole. Thus water is a typical dipole with opposite charges at opposite ends, with tendency to attract either positively or negatively charged ions. For example, when NaCl dissolves in water to form Na^+ ions are surrounded by H_2O molecules with their -ve ends pointed at the Na^+ ions while Cl ions sre surrounded by H_2O molecules with their -ve ends pointed at the +ve ends of H_2O this kind of attraction explains why water dissolves ionic salts readily which are insoluble in other liquids.

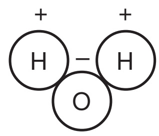


Fig. 2. Water molecule

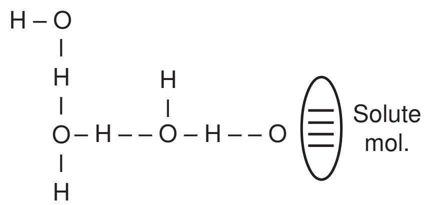


Fig. 3. H_2O – Solute molecule Hydrogen bonding

Apart from being a polar molecule, H_2O molecule has the ability to form **hydrogen bonds**. These are special type of bond which can form between H in one H_2O molecule and O in another H_2O molecule. This hydrogen bonding holds H_2O molecules in large groups and also holds some solute molecules or ions in solution.

Hydrogen bonding between H_2O molecules and between H_2O molecules and a solute molecule in solution.

Dissolved Gases in Water

Dissolved gases - O_2 for fish and aquatic organisms and CO_2 for photosynthetic algae - are crucial for sustenance of aquatic species in water.

Oxygen - Without an appreciable level of dissolved oxygen, many kinds of aquatic organisms cannot survive. It is consumed by degradation of organic matter in water. Many fish kills are caused by oxygen deficiency in water. The concentration of O_2 in water at 25°C at atmospheric pressure is only 8.3 mg/l. This can be consumed by 7 or 8mg of organic material, $\{CH_2O\}$ thorough microorganisms mediated degradation.

$$\{CH_2O\} + O_2 \rightarrow CO_2 + H_2O$$

Carbon dioxide (CO_2) - Dissolved CO_2 is present in all natural water bodies because of the presence of CO_2 in air and its production from microbial decay of organic matter. It is represented as H_2CO_3, a very weak acid.

$$CO_{2\,(aq)} + H_2O \rightleftarrows H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

$$HCO_3^- \rightleftarrows CO_3^{2-} + H^+$$

HCO_3^- is the predominant species in normal pH range of natural water while CO_3^{2-} dominates in acidic water. Pure water equilibrated with unpolluted atmosphere is slightly acidic (pH < 7.0).

Dissolved CO_2 - $CaCO_3$ mineral equilibrium is important in determining several natural water chemistry parameters eg. pH, alkalinity and Ca^{2+} concentration.

Water in equilibrium with solid $CaCO_3$ and atmospheric CO_2 shows the following concentrations.

$[CO_2] = 1.46 \times 10^{-3}$M

$[HCO_3]^- = 9.98 \times 10^{-4}$ M

$[CO_3] = 8.96 \times 10^{-6}$ M

$[Ca]^{2+} = 4.99 \times 10^{-4}$ M

$[H^+] = 5.17 \times 10^{-9}$ M; pH = 8.29

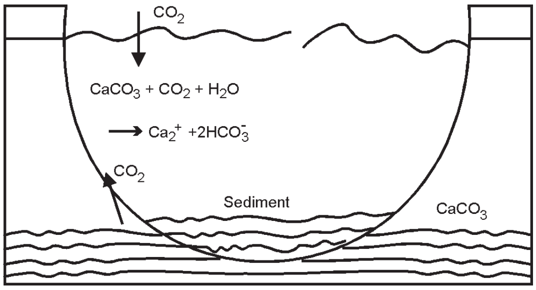
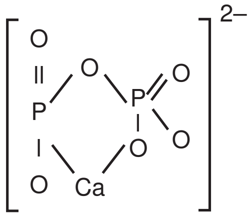


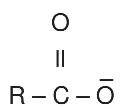
Fig. 4. CO_2 - $CaCO_3$ equilibria

Complexation and Chelation

Chelating agents are important in natural water. A chelating agent has more than one atom which may be bonded to a metal atom at one time to form a ring structure. For example, polyphosphate ion $P_2O_7^{2-}$ bonds to two sites on Ca^{2+} to form a chelate

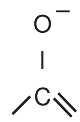


Commonly occurring ligands found in natural water and waste water contain a variety of functional groups which can donate the electrons required to bond the ligand to a metal ion. Examples are : carboxylate, phosphate, hetrocyclic nitrogen, phenoxide, aliphatic and aromatic amines :

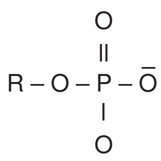


Carboxylate

Heterocyclic N



Phenoxide



Phosphate

Complexation may have several effects including reactions of both lignads and metals. Typical ligand reactions are oxidation-reduction, decarboxylation and hydrolysis. As a result of complexation, metal ion may undergo change in the oxidation state whereby the metal may become solublilized from an insoluble compound. The formation of insoluble complex compounds removes metal ions from solution.

Aquatic Biochemical Reactions

Micro organisms - bacteria, fungi, protozoa and algae - are living catalysts which help many chemical processes in water, particularly those involving organic matter and oxidation - reduction processes occur bacterial intermediates. Algae are known as primary producers of biological organic matter [biomass] in water. Micro-organism play important role in the formation of many sediments and mineral deposits.

Algae

In general, algae are microscopic organism which derive nourishment from inorganic nutrients and produce organic matter from CO_2 by photosynthesis. The most common algae is known as chlorophyta [green algae] responsible for most of the primary productivity in fresh water.

The nutrients required for algae are C [source CO_2 or HCO_3^-], N [NO_3^-], P [as $H_2PO_4^-$], S [SO_4^{2-}] and trace elements eg., Na, K, Ca, Mg, Fe, Ca, Mo etc.

In its simplest form, the production of organic matter by algal photosynthesis is given by the equation :

$$CO_2 + H_2O \rightarrow \underset{\text{Carbohydrate}}{\{CH_2O\}} + O_2 \uparrow$$

In absence of sunlight and hence photosynthesis [in the dark], algae metabolize organic matter by consuming O_2 through degradation of stored starch.

Fungi

These are non-photosynthetic organisms with filamentous structure. The size of simple fungi is 5-10μm wide, much larger than bacteria. They are aerobic [oxygen requiring] organisms which normally flourish in more acidic media than bacteria. They also can withstand higher concentration of heavy metals than bacteria.

The important functions of fungi are their synthetic relationship with algae, manifested in **lichens** which are responsible for weathering processes of rocks and also their key role in the environment in the breakdown of cellulose in wood and other plant materials. They yield substantial amount of decomposition product in water thereby determining the composition of natural and waste water.

Protozoa

Microscopic animals consisting of eukaryotic cells are called Protozoa (eukaryotic cells occur in higher life forms eg., multicellular plants and animals).

Their shapes vary and show fascinating movements under microscope.

Though they have limited role in biochemical processes, protozoa play key role in aquatic and soil environment.

- Parasitic protozoa cause several dreadful human diseases such as malaria and also fatal diseases in livestock and wildlife.
- Huge limestone deposits ($CaCO_3$) have been formed by protozoa.
- They are useful in oxidation of degradable biomass particularly in sewerage treatment.

Bacteria

These are single celled called prokaryotic micro-organisms which may have varying shapes - rods (bacillus), spheres (coecus), or spirals (vibrios, sipirilla) with size range of 0.5-3.0μm. These are characterized by semi-rigid cell wall, motility with flagella for those which can move. They produce spores like other micro-organisms.

The importance of bacteria is due to their characteristic metabolic activity because of their small size and large surface volume ratio. For example, a tiny microscopic cell of cyanobacteria, 1μm in size, needs only a few inorganic chemicals and sunlight for its survival. It uses sunlight to convert C from CO_2, H_2 and O_2 from water, N_2 from NO_3^-, S from SO_4^{2-} and P from inorganic PO_4^{3-} into various products - proteins, nucleic acids, carbohydrates etc. required for its existence and reproduction. The work of such tiny cell is amazing which cannot be matched by humans in a big chemical factory at a cost of several billion dollars.

Typical examples of Iron and Manganese Bacteria will illustrate the key role of bacteria in aquatic biochemical system. Bacteria such as Ferrobacilus, Gallionella, Sphaerotilus utilise Fe compounds to drive energy for their metabolic processes. These bacteria serve as catalysts for oxidation of Fe(ll) :

$$4Fe^{2+} + 4H^+ + O_2 \rightarrow 4Fe^{3+} + 2H_2O$$

The C source for some of these bacteria is CO_2. They do not depend on organic matter for their C source and grow in environment devoid of organic matter. Large deposits of hydrated $Fe_2(lll)O_3$ form in areas where non-oxidising bacteria flourish.

Gallionela, a typical iron bacteria secretes large quantities of hydrated Fe_2O_3 i.e., Fe_2O_3. $3H_2O$ or $2Fe(OH)_3$ or branched structure. (Fig. 5)

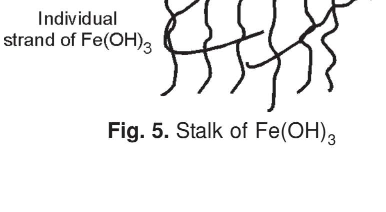


Fig. 5. Stalk of $Fe(OH)_3$

The Mn cycle in the ocean is strongly influenced by bacteria. The well known Mn-modules, an important source of Mn, Cu and Co, give differences of bacteria which mediate both the oxidation and reduction of Mn. These reactions are conducted by enzymes and sea water cations eg., Ca^{2+} and Mg^{2+}.

Acid Mine Waters

Proximity of coal mine causes the problem of acid mine drainage in aquatic environment. Water streams flowing from coal mines are highly acidic due to oxidation of pyrite FeS_2 which is catalysed by iron bacteria, Thiobacillus ferroxidants (below pH 3.5) :

$$2FeS_{2(S)} + 2H_2O + 7O_2 \rightarrow 4H^+ + 4SO_4^{2-} + 2Fe^{2+}$$

$$2Fe^{2+} + O_2 + 4^{H+} \rightarrow 4Fe^{3+} + 2H_2O$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3(S)} + 3H^+$$

Acid mine waters are covered with "yellow boy", a semi-gelatinous coating and $Fe(OH)_3$ and contains H_2SO_4 which is injurious to the environment.

Pathogenic micro-organisms have to be eliminated from water for its purification, for domestic purposes. In the past, major epidemics of typhoid, cholera and other water-borne diseases originated from pathogenic micro-organisms in water supplies. Even now constant vigilance is essential to make sure that domestic water is free of pathogens. Micro-organisms are classified under two broad classes — *prokaryotes* and *eukaryotes*. The former does not have a nuclear membrane so that nuclear genetic material is more diffused in the cell whereas the latter have well-defined cell nuclei enclosed by a nuclear membrane. These two classes of organisms differ in location of cell respiration, mode of Photosynthesis, reproduction etc. All of them give rise to spores which are metabolically-inactive bodies which survive under hostile conditions till they find favourable conditions for growth.

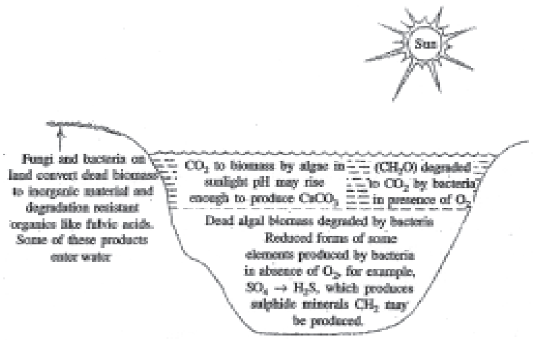


Fig. 6. Effects of micro-organisms on the chemistry of water (Reprinted by permission on Brooks/Cole Publishing Company, Monterey, California 93940, USA, from Environmental Chemistry, 3rd edn., S.E. Manahan, p. 82, 1979, Williard Grant Press, Statler Office Building, Boston, Massachusetts)

In general, fungi, protozoa and bacteria (except photosynthetic bacteria and protozoa) belong to the category of *reducers*, which break down chemical compounds into simple species and thus derive the energy required for their growth and metabolisms. Algae are classified as *producers* since they utilise sunlight and store it as chemical energy while in absence of sunlight they use the stored chemical energy for metabolic requirements. Thus, algae serve as aquatic "solar fuel cells".

All micro-organisms can be classified under four heads depending on the sources of energy and carbon which they utilize: (1) chemoheterotrophs, (2) chemoautotrophs, (3) photoheterotrophs and (4) photoautotrophs.

(1) and (2) use chemical energy as their energy source derived from oxidation-reduction reactions while (3) and (4) utilize light energy from photosynthesis.

(1) *Chemoheterotroph* use organic matter as carbon source. Examples are all fungi and protozoas.

(2) *Chemoautotrophs* use CO_2 for biomass and oxidize substances such as H_2 (Pseudomonas), NH^+_4 (Nitrosomonas), S (Thiobacillus), as energy sources.

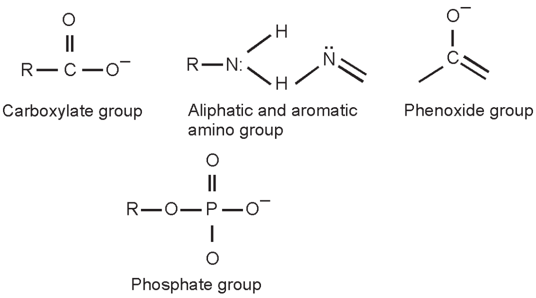
(3) *Photoheterotrophs:* These are some bacteria dependent on photochemical energy and also on organic matter as carbon source.

(4) *Photoautotrophs*: Examples are algae, cyanobacteria (blue green algae), photosynthetic bacteria which use light energy to transform CO_2 (HCO_3) to biomass by photosynthesis.

Complexation in Natural Water and Waste Water

Naturally occurring chelating agents, such as humic acids and amino acids, exist in natural water and soil. The abundance of chloride in sea water leads to the formation of some chlorocomplexes. Synthetic chelating agents, such as sodium tripolyphosphate, sodium ethlenediamine tetra acetate (EDTA), sodium nitrilotriacetate (NTA) and sodium citrate, are discharged in small amounts into aquatic systems from various industrial waters.

The ligands found in natural water and waste water contain a variety of organic groups which coordinate to metal ions:



These ligands form complexes with most metal ions (Mg^{2+}, Ca^{2+}, Mn^{2+}, Fe^{2+} Cu^{2+}, Zn^{2+}. CO^{2+}, Ni^{2+}, Sr^{2+}, Cd^{2+}, and Ba^{2+}) present in natural water and biological systems.

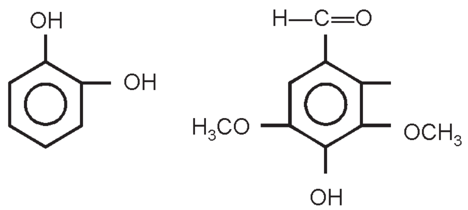
Humic Substances

These are important complexing agents which occur in nature. Their existence has been known since 1800, but their structural and chemical properties are still baffling to chemists.

Humic substances are non-degradable materials formed during the decomposition of vegetation. They occur as deposits in soil, marsh sediments and any location where large quantities of vegetation have undergone decay. They are usually classified on the basis of solubility. If a humic substance is extracted with a strong base and the resulting solution acidified, the products are (a) a non-extractable plant residue called *humin*, (b) a material which precipitates from the acidified extract, called *humic acid* and (c) an organic material which remains in the acidified solution, called *fulvic acid*. The properties of water are generally influenced by the humic substances, both soluble and insoluble due to their acid-base, adsorptive and complexing properties. The soluble fulvic acid has an effect on the properties of water, while the insoluble humin and humic acids affect water quality through exchanges of cations, organic materials, etc., with water.

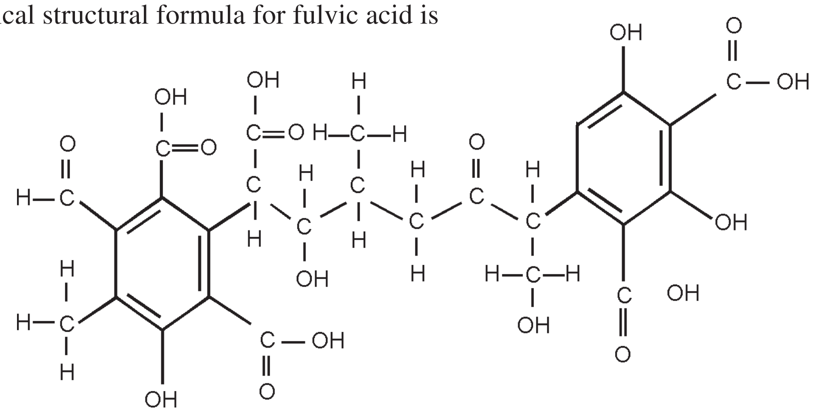
Humic substances have an elementary composition: C, 45-55%, O, 30-45%; H, 3-6%, N, 1-5% and S, 0-1%. 'Humin', humic acid, and 'fulvic acid' do not apply to single compound but to a wide range of compounds. In general, humic substances are high-molecular-weight polyelectrolytic macromolecules. The molecular weights ranges from a few hundred (fulvic acids) to tens of thousands (humic acid and humin fractions). They consist of a carbon skeleton with a high-degree of aromatic character and a large percentage of functional groups containing oxygen. They may also consist of protein-like materials and a carbohydrate fraction. These fractions can be easily hydrolyzed from the aromatic nucleus which withstands chemicals and biochemical attach.

When humic acid undergoes decomposition, some typical decomposition products are:



Catechol   Syringaldehyde   3,5-dihydroxybenzoic acid

A hypothetical structural formula for fulvic acid is



having a formula weight 666 and chemical formula, $C_{10}H_{15}$ $(COOH)_6$ $(OH)_5$ $(CO)_{2}$.

Chemical Characteristics of Water

Sea water is unfit for our consumption due to high mineral salt content. Chemically speaking, sea water is a solution of 0.05 molar NaCI (Sodium chloride), 0.05 molar $MgSO_4$ (Magnesium sulphate) containing traces of all conceivable matter in the universe. The oceans are the final sink for many substances involved in numerous geochemical processes as well as the waste dumped as a result of human activities. They receive the run-off of the continents and materials washed from the atmosphere. They are also the important habitat of the bulk of the earth's biosphere (sea plants, sea fish, etc.). The chemical composition of sea water, river and lake water is shown:

Sea water: Sodium, chloride, magnesium 90 per cent, potassium, calcium, sulphate 3 per cent, others 7 per cent.

River and Lake water: Carbonate 35 per cent, sulphate 12 per cent, chloride 5.7 per cent, silica 11. 7 per cent, nitrate 0.9 per cent; Calcium 20 per cent, sodium 5.8 per cent, magnesium 3 per cent, potassium 2 per cent, iron, aluminium oxide 3 per cent.

Ground water (wells, tube wells) contains more mineral salts, nitrate and bicarbonate than surface water (river, lake, water, etc.)

Water Pollutants

The large number of water pollutants are broadly classified under the categories:

1. Organic pollutants,
2. Inorganic pollutants,
3. Sediments,
4. Radioactive materials and
5. Thermal pollutants,

Organic Pollutants

These include domestic sewage, pesticides, synthetic organic compounds, plant nutrients (from agricultural run-off), oil, wastes from food processing plants, paper mills and tanneries, etc. These reduce dissolved oxygen (D.O.) in water. Dissolved oxygen (D.O.) is essential for aquatic life, the optimum level being 4-6 ppm (parts per million). Decrease in D.O. value is an indicator of water pollution. The organic pollutants consume D.O. through the action of bacteria present in water.

Sewage and agricultural run-off provide plant nutrients in water giving rise to the biological process known as *eutrophication*. Large input of fertiliser and nutrients from these sources leads to enormous growth of aquatic weeds which gradually cover the entire waterbody (*algal bloom*). This disturbs the normal uses of water as the water body loses its D.O. and ends up, in a deep pool of water where fish cannot survive.

The production of synthetic organic chemicals (more than 60 million tonnes each year since 1980) multiplied more than 10 times since 1950, These include fuels, plastic fibres, solvents, detergents, paints, food additive, pharmaceuticals, etc. Their presence in water gives objectionable and offensive tastes, odour and colours to fish and aquatic plants.

Oil pollution of the seas has increased over the years, due to increased traffic of oil tankers in the seas causing oil spill and also due to oil losses during off-shore drilling. Oil pollution reduces light transmission through surface water and hence reduces photosynthesis by marine plants, decreases D.O. in water causing damage to marine life (plants, fish, etc.) and also contaminates sea food which enters the human food chain.

Pesticides have been largely used for killing pests and insects harmful for crops and thereby boosting the crop production. At present there are more than 10,000 different pesticides in use. They include insecticides (for killing insects) e.g., DDT (dichloro diphenyl trichloroethane), herbicides (for killing weeds and undesirable vegetation) and fungicides (for killing fungi and checking plant disease).

It has been found that pesticide residues contaminate crops and then enter the food chain of birds, mammals and human beings. The persistent pesticide, viz, DDT (which is not degraded in the environment) accumulates in food chain, getting magnified in each step from sea weed to fish and then to man by about ten thousand times (10^4). Thus the average level of DDT in human tissues is found to be 5-10 ppm, maximum being among Indians (25 ppm) compared to Americans (8 ppm).

Inorganic Pollutants

This group consists of inorganic salts, mineral acids, metals, trace elements, detergents, etc.

Acid mine drainage: Coal mines, particularly those which have been abandoned, discharge acid (sulphuric acid) and also ferric hydroxide into local streams through seepage. The acid on entering the waterbody destroys its aquatic life (plants, fish, etc.).

Sediments

Soil erosion, as a matter of natural process, generates sediments in water. Solid loadings in natural water are about 700 times as large as the solid loading from sewage discharge. Soil erosion is enhanced 5-10 times due to agricultural and 100 times due to construction activities. Bottom sediments in aquatic bodies (streams, lakes, estuaries, oceans) are important reservoirs of inorganic and organic matter, particularly trace metals e.g., chromium, copper, nickel, manganese and molybdenum.

Radioactive Materials

Radioactive pollution is caused by mining and processing of radioactive ores to produce radioactive substances, use of radioactive materials in nuclear power plants, use of radioactive isotopes in medical, industrial and research institutes and nuclear tests. The discharge of radioactive wastes into water and sewer systems is likely to create problems in future.

Thermal Pollutants

Coal-fired or nuclear fuel-fired thermal power plants are sources of thermal pollution. The hot water from these plants is dumped as waste into nearby lake or river where its temperature rises by about 10^oC. This has harmful effect on aquatic life in the water body whose D.O. is reduced and as a result, fish kill is quite common.

Ground Water Pollution/Arsenic Contamination

Ground water is relatively free from surface contamination as it is located more than about 50 ft. below the land surface and the surface water gets filtered or screened by the underlying layers of soil, sand and stone pieces. But even then it gets contaminated due to leaching of minerals below the earth's surface.

An important case is that of A*rsenic (As)-contamination of ground water*. This arises from excessive pumping of ground water by shallow tube wells for irrigation in some West Bengal districts along the Hooghly river course and also in Bangladesh along the Padma river course. In this process air (oxygen) is injected into ground water bed which leaches the overlying mineral, iron pyrites (iron, arsenic, sulphide), oxidises it and releases arsenic into ground water.

More than one million people in six districts of West Bengal drink arsenic-contaminated ground water from tube wells in the region. Among them 20 lakh people suffer from various diseases related to arsenic poisoning like loss of hair, brittle nails, bronchitis, gangrene, etc. Several hundred deaths have also been reported. Similar calamity has threatened the lives of Bangladesh in the districts along the Padma river course.

Case study of Ganga Pollution

The most typical example of river pollution is the Ganga Pollution.

The Ganga originates from the Himalayan glacier and flows along a stretch of some 2525 km before joining the Bay of Bengal. The Ganga basin is fertile and home of about 40 per cent of population (400 million people) of the country. The river has been hailed as the "Holy Ganga" and regarded as the lifeline of the country. But in recent years it is ranked as the most polluted river of India and a killer in the highly polluted areas.

The Ganga basin carries wash water from 25 per cent of land. It is responsible for agricultural prosperity of U.P., M.P., Haryana, Rajasthan, Himachal Pradesh, Bihar and West Bengal. Ganga is the source of drinking water in the region and irrigation water for agriculture—she also supplies fish to the local markets and water to industries on both sides of the river. The Ganga basin provides maximum population density—many class I (population 100,000 and above), class II (pop. between 50,000 and less than 100,000) and class III (pop. 20,000 to less than 50,000) cities have grown in this region. Both domestic and industrial sewage join the Ganga river without any treatment and thus cause terrible pollution.

Hooghly river (in West Bengal) near Kolkata presents the worst polluted zone. There are more than 150 industries on both sides of the 125 km. stretch river belt— there are about 270 outlets of untreated sewage to the river Hooghly. The entire 140 sq. km. metropolitan area covering both banks of the Hooghly river is exposed to ecological disaster. Besides huge quantities of soil from soil erosion due to extensive deforestation are washed by rain water into the river causing siltation. This reduces the flow of water in the Ganga-Hooghly river with the result that ultimately the river will be choked and dead. In 1919 the flow of water in the Ganga was 1,10,000 cusecs (1 cusec = 1 cubic foot of water flowing per second) whereas in 1971 it was 40,000 cusecs only which during summer drops to 20,000 cusecs. This should be enough to sound the alarm bell to the Government-Calcutta and Haldia ports can survive only on 40,000 cusecs of water.

Waste Water Treatment

Water pollution is caused by domestic sewage (84 per cent) and industrial sewage (16 per cent). Though the latter has less load on water body, it contains toxic matter (inorganic and organic) which are more hazardous.

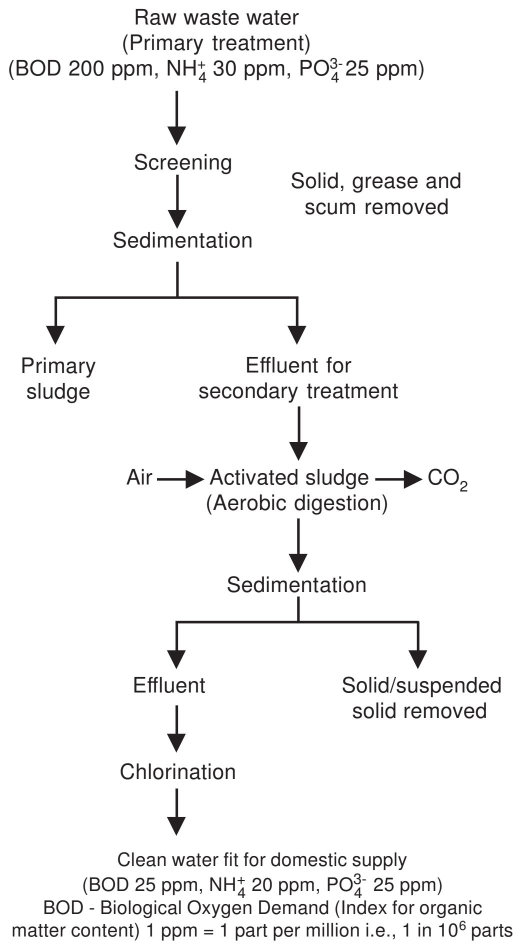


Fig. 7. Municipal waste water treatment (Primary and Secondary)

Domestic Waste Water Treatment

Sewage treatment plants, in general, depend on biological decomposition of non-toxic organic wastes using bacteria. Such biological decomposition is carried out under aerobic conditions i.e., in presence of plenty of oxygen.

Organic wastes	+ O_2	$\xrightarrow{\text{bacteria}}$	CO_2 (Carbon dioxide)
(Carbon, Oxygen,	(oxygen)		+ H_2O (Water)
Hydrogen, Sulphur,			+ NO_3^- (Nitrate)
Fluorine)			+ NH_4^+ (Ammonium ion)

The process, commonly used for municipal waste water, is. shown in Fig. 5.1. In the first stage, solid wastes are removed from water by screening-any scum (suspended matter) is removed and the sludge (muddy solid or sediment) allowed to settle at the bottom. The residual liquid is exposed to biological oxidation of soluble organic materials through a bed of microbes in activated sludge. Then the solids are removed after sedimentation. Finally the liquid effluent is subjected to chlorination for destroying pathogenic micro-organisms. Now this effluent is fairly clean and suitable for domestic use.

Drinking Water Supply

Treatment of drinking water supply is a matter of public health concern. The water treatment plants, in general, are simpler than sewage treatment plants. They operate in three steps—(i) aeration to settle suspended matter; (ii) coagulation of small particles and suspended matter by lime and ferric chloride; (iii) disinfection by chlorinatiou to kill viruses, bacteria, etc. The purified water is then supplied by municipalities through pipes for domestic uses.

Industrial Waste Water Treatment

Industrial wastes contain toxic chemicals which can damage environment (water, soil, air) much more than domestic sewage. These waste liquids (effluents) can be purified by filtration using activated charcoal or ion exchange resins. Activated charcoal has large surface area and is an effective filter medium for adsorption of organic molecules. Synthetic organic ion exchange resins are very useful for removal of industrial waste metals (cations) and non-metals (anions).

Water Quality Standards

The analyses required of water samples depend on the intended use of the water. For example, if its intended use is drinking, water should meet certain quality criteria with respect to the appearance, (turbidity, colour), potability (taste, odour), health (bacteria nitrates, chlorides, etc.) and toxicity (metals, organics). These and similar criteria are established by health or other regulating agencies to ensure that the water quality in a resource is suitable for the proposed use.

Based on the criteria, quality standards are set, which reflect the current state of knowledge of various water constituents. These standards are continuously revised as more and more is learnt about the effects of water constituents on proposed uses. Hence, these standards should not be used as absolute limits, but only as guidelines that can be used for preliminary judgements. Table 3 summarizes several quality criteria and their standards for drinking water as suggested by the following agencies:

1) Indian Council of Medical Research (ICMR)
2) World Health Organization (WHO)
3) United States Public Health Service (USPHS)

Standards have been prepared for raw waters to be used as a source for various industrial applications. The specific purpose for which the water is used usually controls the requisite water quality. Water used in food and beverage industries will need to meet standards similar to those for drinking water, while water for cooling purposes can contain much higher concentrations of impurities. Table 4 illustrates the water quality characteristics of raw surface waters that have been used as source for various industrial operations. The values listed are the maximum concentrations of different constituents in the raw surface waters used in the specified industry, and not the maximum concentrations that could be tolerated.

Table 3

Standards for Drinking Water

A - Recommended maximum concentration[a] (mg/L except where shown otherwise)

B - Maximum permissible concentration[b] (mg/L except where shown otherwise)

	ICMR		WHO		USPHS	
	A	B	A	B	A	B
Physical:						
Turbidity (unit)	5	25	5	25	5	—
Colour (unit)	5	25	5	50	15	—
Odour	Nothing	disagreeable	Unobjectionable		TO = 3	—
Chemical:						
pH, units	7-8.5	(6.5 or 9.2)	7-8.5	(6.5 or 9.2)	—	—
Total solids	—	—	500	1500	500	—
Calcium	75	200	75	200	—	
Magnesium	50	150	50	150	—	—
Iron	0.3	1.0	0.3	1.0	0.3	—
Manganese	0,1	0.5	0.1	0.5	0.05	—
Copper	1.0	3.0	1.0	1.5	1.0	—
Sulphate	200	400	200	400	250	—
Phenols	0.001	0.002	0.001	0.002	0.001	—
Fluorides	1.0	2.0	0.5	1.0-1.5	0.6-1.7	—
Nitrates	20	50	—	50-100	45	—
Toxic:						
Arsenic	—	0.2	—	0.2	0.01	0.05
Barium	—	—	—	—	—	1.0
Cadmium	—	—	—	—	—	0.01
Chromium	—	0.05	—	0.05	—	0.05
Cyanide	—	0.01	—	0.01	0.01	0.2
Lead	—	0.1	—	0.1	—	0.05
Selenium	—	0.05	—	0.05	—	0.01
Silver	—	—	—	—	—	0.05
Bacteriological:	—	1 coliform per 100 ml	—	1 coliform per 100 ml		1 coliform per 100 ml

[a]Constituents should not be present in excess of listed concentrations where other more suitable supplies are or can be made available.

[b]Constituents in excess of the concentrations listed shall constitute grounds for rejection of the supply.

Table 4

Maximum Concentrations of Constituents in Raw Water Supplies for Various Industries, mg/l

Constituent	Boiler water (0-1500) psig	Cooling water (once through)	Textile industry	Pulp and paper	Chemical industry	Petroleum industry
Silica (SiO_2)	150	50	—	50	—	85
Aluminium	3	3	—	—	—	—
Iron	80	14	0.3	2.6	5	15
Manganese	10	2.5	1 .0	—	2	—
Calcium	—	500	—	—	25	220
Magnesium	—	—	—	—	100	85
Ammonia	—	—	—	—	—	40
Bicarbonate (HCO_3)	600	600	—	—	600	480
Sulphate	1400	680	—	—	850	900
Chloride	19000	600	—	200	500	1600
Nitrate	—	30	—	—	—	8
Phosphate	—	4	—	—	—	—
Dissolved solids	35000	1000	15	1080	2500	3500
Suspended solids	15000	1500	1000	—	10000	5000
Hardness	5000	850	120	475	1000	900
Alkalinity	500	500	—	—	500	500
pH (units)	—	5.0-8.9	6.0-8.0	4.6-9.4	5.5-8.0	6.0-9.0
Colour (units)	1200	—	—	360	500	25
COD	100	—	—	—	—	—
Temperature (°F)	120	100	—	95	—	—

Rivers and Dams - Environmental impact

According to Lori Pottinger, editor of World Rivers Review, "Rivers are often called the planets' circulatory system. Like our body's circulation system, the planetary system does not work very well, when it is clogged. Man has caused disease of the world's rivers. They have clogged most of our rivers with dams, bled them dry with water diversions and given up all. To many once great rivers for dead once these are used up".

Recently it has been estimated that out of the world's 177 largest rivers, only 33% are free flowing. Once a free flowing river is damned, very important changes occur in its ecology as well as the environment of downstream villages, changes which go much beyond the submergence zones of dams.

Table 5

Typical Analysis of Some Surface and Ground Waters

Constituent, ppm	A	B	C
Silica	9.5	1.2	10
Iron (III)	0.07	0.02	0.09
Calcium	4.0	36	92
Magnesium	1.1	8.1	34
Total hardness (as $CaCO_3$)	14.6	123	169
Sodium	2.6	6.5	8.2
Potassium	0.6	1.2	1.4
Bicarbonate	18.3	119	339
Sulphate	1.6	22	84
Chloride	2.0	13	9.6
Nitrate	0.41	0.1	13
Total dissolved solid	34	165	434

[V.L. Snoeyink and D. Jenkins, *Water Chemistry*, John Wiley & Sons, New York, 6 (1980)]

A. Pardee Reservoir, Oakland, California, USA, 1976 (Water Supply Source for East Bay area of San Francisco region).

B. Niagara river, Niagara falls, New York, USA (Water supply source for Niagara Falls City).

C. Well water, Dayton, Ohio, USA (20-meters deep well used for public water supply of Dayton, Ohio, USA).

Building large dams is considered by irrigation engineers as a crucial component of water management system. They project the multiple benefits such as hydroelectricity generation, irrigation, flood control, industrial and municipal water supply which are not possible without storage of water in reservoirs by dams. Water storage is necessary in countries like India where rainfall is unevenly distributed -1100cm in Cherapunji and 10cm in Rajasthan.

The environmental impact of damming has often been ignored with disastrous consequences. Damming has led to species extinction, loss of prime farmland and forests, social upheaval, loss of clean water supplies, desiccated wetlands, disrupted fisheries etc.

Dams hold back not just water but silt and nutrients which replenish farmlands and build protective wetlands. They change the period of floods and disrupt species which evolve with natural flood cycles.

A typical example of neglecting environmental impact assessment [EIA] of dams is that of Damodar Valley Corporation (DVC). The Chief Engineer of Tenssesse Valley Authority [TVA] of USA was the Chief Adviser to USA. The Project involved construction of nine dams in the upstream of Damodar Valley and tributaries. These dams were expected to supply water for Industries in Dhanbad-Durgapur belt i.e., the envisaged Ruhr Valley of India. There would be a degree of flood control in the low valley of Bengal [downstream]. A civil engineer from Bengal presented a brilliant EIA of the Project and also cautioned against the construction of so many dams which would aggravate the problem of flood control with immediate loss of life and property and also fail to supply water for irrigation and industries. But this EIA caution was ignored and the then government [new free India government] decided to go ahead with the plans as advised by the Chief Advisor. People in the downstream region of Bengal continue to suffer as before inspite of marginal benefits of hydro electricity etc. This is also an example of the politics of environmental policy.

Shortage of water supply along trans-national rivers may lead to eruption of wars in future among the countries. Recently the world has witnessed an upsurge in regional unrest. Tension builds up between two or more countries when and upper riparian nation tries to control the waterways of trans-boundary rivers.

Recently tension is brewing in South Asia and SE Asia as China took unilateral decision to construct dams and river diversion projects in Tibet. The Tibetan plateau happens to be the world's largest tank - all the ten major river systems of Asia including the Indus, Sutlej, Brahmaputra, Irrawaddy, Salween and Mekong. The rivers flowing from Tibet constitute the lifeline of 6.92 billion people including 2 billion (30%) in South Asia from Afghanistan to the Ganga-Meghna-Brahmaputra basin. The water resources of Tibet should be viewed as global commodity. The present activities of China in Tibet might lead to ecological disaster resulting from receding glaciers in Tibet and the Himalayas. South Asian countries including India will be badly affected.

Inside India several environmental movements took the centrestage centring around dam constructions. Notable examples are Silent Valley Project and Narmada Dam Project.

Silent Valley Movement : The Kerala State Government planned to construct a dam on the Silent Valley for generation of 120MW electricity. It was located at an altitude of 3000 ft in the tropical rain forest of an important biosphere. The sustained movement by students, teachers and people finally succeeded in stalling the project with the support of international Committee in India and abroad.

Narmada Dam Movement : Narmada, the largest west flowing river through Madhya Pradesh and Gujrat covering 1300km, has been subject of interstate dispute. The MP government undertook gigantic plan of construction of 31 large dams for Narmada and its tributaries for providing the benefits of thousands of megawatt of power, irrigation of several million hectares of land and water supply to thousands of industries etc. But these are overshadowed by the environment costs - displacement of 1 million people, mostly tribals, submerging over 1000 villages, loss of forests and 50000 hectares of agricultural land. A sustained movement led by the noted environmentalist, Medha Patkar partly succeeded in stalling Sardar Sarovar and Narmada Sugar dams.

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APPENDIX

I

John Hopkins Institute Study-Don Hinrichsen, UN Consultant

There is no more fresh water on earth than there was 2000 years ago. At that time the world's population was 3% of the current size and people then didn't have industrial wastes and agricultural pesticides polluting and poisoning fresh water.

At present, about 1.0 billion people around the world in 31 countries-mostly in the Middle East and Africa-face water shortages. By 2025, the number will increase to 2.8 billion people and 17 more countries will join the list including Ethiopia, India, Kenya, Nigeria and Peru.

The UN report calls for a Blue Revolution to conserve and manage fresh water, just as the green revolution of the 1960s sought to transform agriculture. Seeds of the blue revolution are ready evident in India—rainwater harvesting, drip irrigation, water recycling etc.

II

Earth Summit, Johannesburg *(2002)*-The UN Summit on sustainable development was held at Johannesburg from August 26 to September 4, 2002 (South Africa). The Summit was attended by 40,000 delegates including representatives from 190 countries, NGOs, and a host of environmental groups, social organizations as well as industrial and business houses. It took note of the fact that Agenda 21, a plan of action for sustainable development, adopted by the Rio Summit in 1992, was not implemented. At the inaugural session of the Johannesburg Summit, the South African President, Thabo Mbeki declared: "*A global human society based on poverty for many and prosperity for a few characterized by islands of wealth, surrounded by a sea of poverty, is unsustainable*." The conference identified five thrust areas:

- Water and sanitation
- Energy
- Health
- Agricultural productivity
- Biodiversity and ecosystem management

Plan of Action

- Commitment to halve the number of people without access to safe drinking water and sanitation by 2015.
- Effective increase of the use of renewable energy, without setting any targets.
- Phasing out the use of toxic chemicals which pose a threat to human health- by 2020.
- Ear-marking funds from Global Environmental Facility (GEF) for prevention of desertification.
- Restoration of global fish stocks to the maximum sustainable yield as well as significant reduction of the rate at which plants and animals are getting extinct by 2015. Agreement to share the benefits of using biodiversity with tribal people who have the traditional wisdom and knowledge of their use.

Observations

"If the wars of the 20th century were fought over oil, the wars of the 21st century will be fought over oil and mainly, water."—Vice-President of World Bank (1995).

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THE DAM - ITS PAST, PRESENT AND FUTURE

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The total volume of usable water in our planet is not increasing, it is the same as it was in Roman times. Global water use tripled just between 1950 and 1990. More than 70 per cent of usable water is now consumed in agricultural fields for irrigation purpose where water is being wasted, mismanaged and polluted on a grand scale producing massive impact on the sustainability of the ecosystem. According to the reports from the United Nations and Stockholm Environmental Institute, by the year 2025, two third of the world's population will be affected by water shortage and the scarcity of water would become the sole limiting factor against maintaining the rising graph of crop production at par with demand.

Although the surface of the 'Blue Planet' is two-third water, 97% of it is sea water, while additional 2.31% is locked up in the polar icecaps, and less than 1% (0.69%) water accessible for human use distributed quite unevenly in rivers, lakes and at various depths of land surfaces. Almost all the terrestrial plants and animals are well accustomed with the scarcity of water in their environment and accordingly they adapt themselves with such environment through evolving various amazing body organs, like kidney, nephridia, etc., for repeatedly purification and recycling of water. Herbs, shrubs and trees growing in dense, virgin forests do not require irrigation. And rain-fed, single-crop cultivations do not pose any serious threat to the water reserve of the aquifers.

Now-a-days, the technologies of water management of crop fields have been developed centering round the dam-based irrigation network as well as shallow and deep tubewell-based irrigation systems. They are obviously not eco-friendly and as such require critical appraisal. Farmers mainly depend on these technologies because of the fact that the volume and frequency of rainfall are not uniformly distributed over the country and available at desired amount through out the year.

Since the birth of civilization, farmers and rulers have been impounding water. Eight thousand years ago, the Sumerians built an irrigation-based civilization between the rivers Tigris and Euphrates, then lost it to the salinization that now plagues some 20% of Iraq's arable territory. By the first century BC, low dams had been built in the Mediterranean, the Middle East, Central America, China and India. Limited technology kept their height low. In India about 2,300 years ago, during the time of Chandragupta Maurya a massive Sudarsan dam was constructed in Gujarat on the confluence of three ancient rivers named Palasini, Sikta-bilasini and Arjikia forming a vast Sudarsan reservoir. The dam and the reservoir functioned perfectly well for nearly 1200 years. It was thoroughly renovated during the times of Skandagupta but ultimately the dam and the reservoir became totally extinct. Numerous dams were constructed with almost all the rivers of India, but none of them survived for an indefinite period of time solving the water crisis in agriculture on a permanent footing. Modern technology, perhaps, was first applied in construction of Veri dam on the Veri river by famous engineer Ballav Bhai Desai at the native state Gondal in Gujarat as early as 1900 AD. The height of Veri dam was 37 feet with 30 sluicegates. It used to supply enough water through the year round for irrigation, industrial and drinking purposes for more than 75 years, but gradually stopped functioning due to heavy siltation.

Today, most of the world's large rivers are dammed. Worldwide, some 40,000 'large' dams (over 15m high according to the International Commission on Large Dams) and 800,000 smaller ones have been constructed impounding five times the volume of all the river water. The technology of large dam was developed to improve human quality of life by providing drinking water and to support economic growth by diverting water for irrigation, power, navigation and flood, control. In many ways dams have succeeded. Late Prime Minister Jawaharlal Nehru saw them as the new 'Temples of development'. The dam-based irrigation systems have enabled India to be self-sufficient in food production since 1960s. It is an undeniable fact that the year round cultivations (2-3 crop/year) of high yielding varieties would not be possible without these dams. Dam-based irrigation on most of the arable land of Punjab has made this state as the granary of India. In addition, in many parts of the world, dams have helped to remedy life-threatening problems such as poverty from lack of economic development, famine as a result of drought, devastation from floods and continued disease from lack of potable water supplies.

But the adverse effects of river impoundments - disruption of ecosystems, decline of bio-diversities, forced resettlements, dam-based diseases and its temporary lifespan have changed the perception of large dams and dam buildings to a great extent. The construction of gigantic dams in different parts of Asia, South America and Russia are still in vogue. China's most ambitious project since Great-Wall, the Three Gorges Dam will displace nearly two million people as it swallows up cities, villages, farms and the canyons of the Yangtze river. This 600 feet thick, mile-wide project is so large that it will be visible from the outer space.

The large scale displacement of people from the proposed dam site can be a death sentence to a community. Twenty years after, about 90,000 people were displaced from the site of a hydroelectric dam project in Ghana, none of them could be found, they simply disintegrated and perished.

Dam changes the chemical, physical and biological process of the river systems. They alter free-floating systems by reducing river levels, blocking the flow of nutrients, changing water temperature and dissolve-oxygen levels and impeding or preventing fish and wildlife migration. Tropical reservoirs and irrigation networks are also the ideal breeding ground for mosquitoes, snails and flies, the vectors that carry malaria, schistosomiasis and river blindness. Incidence of schistosomiasis, the long-term consequences of which can include pulmonary lesions, liver failure and bladder cancer, has nearly doubled since the 1940s. In many instances, infection can be directly correlated to the slow-flowing reed-filled water of irrigation canals.

Hydro-electricity has been shown very clean and cost effective, but planners for large dams have ignored numerous additional cost factors, including potential structure failure, changing or disruption of river-flow, reduction of life-span of the dam than anticipated figure and long-term environmental consequences. The hydropower is not so clean as depicted, the inundating vast wetland is a major emitter of greenhouse gases like carbon dioxide and methane and increases the catalysis of methyl mercury, a nerve toxin, from inorganic sediments. A badly managed hydropower project may produce more greenhouse gases than a coal-fired equivalent.

Large irrigation schemes have also proven not to be cost-effective compared to smaller, locally controlled operations. At the same time, it is impractical and poor strategy to oppose all dams on principle. In fact, there are many more good dams than bad ones. The bad dams are the shallow ones that flood large area of land and produce relatively little power and irrigation facility. By all accounts, large dam construction in developing countries is fraught with corruption. Frequently it costs more and take longer time than anticipated, sometimes to a grotesque degree. For example, the cost of building Brazil's Itaipu Dam, estimated at $3.4 billions over 15 years, expanded to $20 billions over 18 years. The cost of its production, electricity-unit also would be several times higher due to such overruns of capital expenditure.

The life span of a dam is inversely proportional to the silt-load deposited per unit area of the reservoir per unit time. Proper maintenance can extend its life span. The silt deposition can be reduced by checking erosion of the river bank through proper large scale afforestation programme or other effective means. The health of the network of irrigation canals also should be properly maintained which is often neglected. In fact, the maintenance of a water body is much more difficult and costly than maintenance of forested land of equivalent size. Most of the dam-based irrigation systems of our country are not properly maintained. At present there is no alternative for dams. But dam is not the answer for distant future of mankind. Every dam has got a fixed life-span mainly based on the rate of siltation. The water holding capacity of its reservoir is the maximum immediate after its construction, then gradually it is reduced with time and becomes totally defunct when it is full with sediment brought down by the river. The trouble starts when it is half filled with sediment, it could not hold all the water of the monsoon, the excess volume of water has to be discharged creating man-made floods in the surrounding localities. Ironically, this dam was once created for controlling floods.

The dam is the instant solution against water crisis but without any sustainable future. Hence, some of us may feel that sinking deep tubewells coupled with saving of huge wastage of water in agricultural fields is the feasible remedy for water crisis of the country like India. Irrigation by sinking shallow or deep tubewells, which has largely been practiced in India after independence, could not be alternative technology for the dam. Such practices have already created serious environmental hazards in various parts of the country, particularly where the rate of lifting outspaced the replenishment. In north western India, in Gujarat and Maharastra, fluorides are coming up with water. The arsenic problem is acute in many districts in West Bengal which was unknown before independence. In central and south India salinization of soils is rapidly increasing. Judicious irrigation with ground water taking all precautions, can be used as a subsidiary technology but can not replace the current role of dams. Worldwide over 40% of arable land is being irrigated by 840,000 large and small dams and water requirement in agriculture is doubling in every 20 years. Hence, considering the future requirement, we have to procure water by using all sorts of technologies, and specially from those potential sources which have not yet been largely tapped. At the same time, proper precautions to be taken to minimize their impacts on environment.

In Agricultural fields, a huge amount of water is simply wasted due to free evaporation and faulty water management. On an average, 80% of irrigation water is lost during transit before reaching the roots of crop plants, Crop plants themselves are also responsible for losing a considerable amount of water through transpiration. When one gramme of dry matter is accumulated in plants, 300 -1000 gramme of water is lost through transpiration, 10 to 25 per cent of transpiration loss can be checked by spraying the crops with various antitranspirant agents, like PMA or soil emulsion. In fact, crop plants are somehow pampered by over irrigation. It has been shown that they could be trained to thrive with relatively less amount of water without hampering the yield. Raising the drought resistant varieties is another means to cope with the situation. But today, the most efficient technology to save water in the crop fields is the drip irrigation, also called micro-irrigation. The basic tool for drip irrigation consisting of a simple length of perforated pipe hooked up to a pump. In this Israeli-devised technique small amounts of water are directly applied to the plants roots through pipes buried along rows of crops. The method is 95 per cent efficient - meaning that 95% of water passed through the pipe is utilized by the crops - compared with as little as 20% in traditional irrigation. In this technique very small amount of water is lost to free evaporation or runoff. Today, drip irrigation water at least 16,000 sq km crop field in two dozen nations - still less than 1 percent of all irrigated land.

When we look for a long term permanent solution, perhaps there is no other alternative than desalination of sea water which would sustain through millennium for unlimited consumption. Procurement of usable water from the polar ice-caps is also another possibility with hopeful future. Improved technology for low-cost distillation with solar power of atomic energy from fusion of hydrogen isotopes generated from heavy water or upgraded technology or reverse osmosis of sea water would be the ultimate answer for mankind of the next millennium. The life once evolved from the sea. No doubt, it would naturally have all its sustenance in the sea.

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AGRICULTURE - INDUSTRY - ENVIRONMENT : THE TRILOGY OF THE CENTURY

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ABSTRACT

Agriculture originated some 10,000 years ago signalling the beginning of human civilization while industry can be traced to about 25-30 centuries ago. Agriculture sustains life on earth providing food to humans and animals. Industries provide necessary input for infrastructure and high quality of life. Both agriculture and industry play complementary roles in building sound economy of the country. Agriculture - industry transition, land acquisition through ages, current land acquisition issue and probable remedies etc. are discussed. The impact on environment is outlined.

Agriculture

Agriculture originated about 10,000 years ago and signalled the starting point of human civilization while industries came to scene only approx. 25-30 centuries ago. Ancient China and India were the richest nations on earth long before Europe emerged. They had higher standards of living, numerous scientific and technical inventions and dominated the world's manufacturing output. In 1700 A.D. India had about 24% of global GDP followed by China (22%) and Europe (20%).*

It takes hundreds of years to create 10-12 inches top soil by Nature with fossil and humus cover, favourable for growth of flora but land once surrendered to industries, it can neither retain nor regain its fertility. The eminent agricultural scientist, M. S. Swaminathan warns against giving away prime agricultural lands. Industries flourish and perish but the land, held by them, can never be restored to their original fertility. Whereas agriculture enriches the environment, industries pollute the environment. The race between agriculture and industry is like that of Aesop's fable : tortoise and hare - the former offers permanent benefits while the latter provides quick and transient benefits. Let us examine these in depth.

Green revolution and post - Green revolution Eras

The Green Revolution started in 1968, based on high input - high output technique (high inputs of fertilizer and pesticides, extensive irrigation and use of high yielding variety seeds).

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*The World Economy; A millennium perspective, OECD, 2001

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It led to quantum jumps in productivity and production of wheat and rice. India attained self-sufficiency in food. But even the architect of Green Revolution cautioned that Green Revolution has a life span of 30 years - it is like riding a tiger : once you are on it, you have to keep going. In other words, it has to be sustained with new components otherwise the myth will be all over. In India this has happened - the last decade witnessed decline in productivity and fertility of soil. That is, food grain production has fallen short of faster population growth. Our government has urged doubling of annual food grain production from present 210 million tons to 420 million tons within 2015 - the target year for achieving UNMDG (United Nations Millennium Development Goal) viz. reducing the number of hungry persons by half, This will require production of 160 million tons of rice from 160 million hectares (mha) and 100 million tons of wheat from 25 mha. At present of the total foodgrain production of the country, the three states - U.P., Punjab & West Bengal account for 41% of the total production. It is interesting to note the relevant parameters in the following Table.

Table 1

Agricultural Statistics (India vs West Bengal)

	INDIA	WEST BENGAL
Geographical Area	328.7 mha	8.88 mha
Net Cropped Area	142.2 mha	5.44 mha
% Net Cropped Area / Geog. Area	43.3	61.3
Forest Area	68.33 mha	1.19 mha
Population	1020 m	81.6 m
Density of Population	267 /Km^2	767 / Km^2

In West Bengal agricultural land is 1.65 crore acres and 1 lakh acres (non-agricultural land) is available for industrialisation. The break-up of land is : 62% - agriculture ; 19% - urban areas; 18% - forest and 1% - fallow (unused unfertile) land.

Industry

In ancient times China and India dominated the world's manufacturing output. However, in course of time their leading positions crashed. As a matter of history, the 19th century belonged to Britain as the leader of Industrial Revolution (1780), the 20th century belonged to USA as economic superpower and the present 21st century is making a full circle in belonging to Asia-China and India. Today China and India account for 40% of world population and 18% of global economy based on purchasing power parity.

In recent years India is witnessing a surge of an industrial renaissance. In the manufacturing sector it is an emerging manufacturing power. Many Indian firms have become MNCs themselves based on Merger & Acquisition (M&A) on an unprecedented scale. The M&A deals during the first half of 2006 amounted to $25.6 billion - an increase of 220% over the corresponding period in 2005. The top-ranking companies in the global market are : Tata group, Jindal Steel, Asian paints, Hindalco, Videocon, IT industries (TCS, Infosys, Wipro) etc. Due to new industrial policy following economic reforms in the nineties a significant number of industries in the public sector are now flourishing along with many industries in the private sector.

Among the leading industries are steel, textiles, leather, cement and fertilisers. India is 9th largest steel producing country in the world - the annual growth rate being 6% in 2003-04. Textiles contribute 14% to the industrial production and about 4% to GDP. India is the third largest producer of nitrogenous fertilisers in the world. Besides there are 105 lakh small scale industries which have production worth $56 billion.

Agriculture - Industry Transition

As modern economy progresses, economic growth takes route from agriculture to low end manufacturing, then to high-end manufacturing and thereafter to services. During the period 1984-2005 the share of agriculture in the country's GDP declined from 35% to 20% and that of industry (manufacturing, mining and quarrying, electricity, gas, water supply and construction) remained steady at about 26%. On the other hand, unprecedented expansion of services sector (transport, railways, civil aviation, roads including highways etc.) from 39% to 54% within 10-15 years stood out as a notable feature of economy.

Employment potential of agriculture vis-a-vis industry may be analysed. Agriculture employs about 54% of the country's labour force producing about 20% of the national income while industry employs only 15% of the labour force. Agriculture is labour-intensive while industry is capital intensive with tremendous employment potential. According to report of ASSCHEM, manufacturing sector is poised to generate 25 million new jobs by 2010. Manufacturing exports will increase to $100 billion from the present level of $50 billion by 2010 and $300 billion by 2015 (McKinsey). Textiles employ 91 million people while small scale industries about 25 million persons.

Land Acquisition through ages

Some 5000 years ago India had a forest cover of 80% but now it has dwindled to about 12%. The quantum of deforestation is to meet increasing pressure on land for housing, agriculture, industry, urbanisation, infrastructure etc. The process of land acquisition or the model for agriculture-industry transition is a matter of history in many countries in different periods - Russia, Japan, China, USA, India. These models in the initial stage had one common feature viz. aggressive policy for land acquisition by authoritarian regime. In Russia it was Tsarist monarchy followed by communist authoritarianism. In China it was and is Communist aggression while Japan also followed imperialist aggression in the early stage of industrialisation but later adopted a unique policy of giving high priority to education among people. Gradually Japan had a largely literate population compared to China and Russia so that it could raise agricultural productivity without drastic change in the size of land holdings. Side by side, small scale industries were encouraged which blended with agriculture and provided employment to rural people. This Model suited Japan well in view of its small land area and lack of mineral resources - agriculture and industry played complementary roles - but the only negative aspect is rather strongly authoritarian element in Japanese society. USA has handled agriculture-industry under strong administration so that it has maintained its status of super power on both the fronts over all these years.

Now in India we have different scenario. In ancient times it was the monarchical regime which ruled agriculture-industry fronts. During the British period land acquisition was governed by British Land Aquisition Act (1894) which empowers the government to acquire land for public purposes. This Act is still in force, as it has not been amended so far. The British used this Act for forcible acquisition of land and eviction of farmers for indigo plantation. This, however, gave rise to mass revolt. For a democratically elected government it is not proper to follow British policy, particularly because the same Government condemned in 2003 some non-Left State Governments for giving away thousands of hectares of land to MNCs for setting up industries. This has obvious reference to Singur - Nandigram issues (West Bengal) for setting up Tata Motors at Singur (1000 acres) and mega-chemical hub at Nandigram. The disturbances including loss of several lives have sent shock waves all over the state. It is time to examine this high-voltage situation in its proper perspective.

The need for industrialisation is no longer a matter of debate. Industry ensures greater productivity and higher income so that transfer of labour from farm to factory appears inevitable. But the logic cannot be pushed far in real terms when we compare the market price or wealth between farm and industries. Let us take Singur as example. The agricultural output is 2900 tons of rice, one third of which feeds the population (6800) and the rest goes to the market and state granary. On the other hand Tata Motors will yield an income of Rs. 1000 crore per year which is almost ten times that from agriculture. They will employ 10000 people whereas there will be 20000 jobless farmers resulting from land acquisition. The wealth the Tata cars will not go to the state exchequer whereas that from agriculture will go to the state granary and the National exchequer. The farmers are poor and mostly illiterate but they are contented with their lot which will be lost once they swell the ranks of displaced jobless vagabonds following land acquisition. Industrial employment calls for different work culture and skill which can be fulfilled by educated labour. In this context Japanese model is most relevant except authoritative undertone. The Special Economic Zones (SEZ) which are coming up in future will also require skilled workforce which will be drawn mostly from upper class and middle class families.

A healthy rural economy does not survive on agriculture alone. It needs support of other complementary activities including agro-based industries. But in absence of such support the economy suffers and a sick countryside makes also cities sick.

India's democracy does not favour forced transition from agriculture to industry or migration of labour from villages to cities though such transitions occurred in other countries and other eras. This explains the recent disturbances in West Bengal. The authorities should be cautious about the risk factor involved - that is to say, violence in any form gets ready support from terrorist and separatist forces already active in the country and this may lead to civil war. Such situation is certainly avoidable using tactful diplomacy.

Environment

Environment has been the victim through ages for all kinds of transitions. From the caveman to the 21 century man it has been a long journey from primitive to high-tech life – budding and growth of human civilization : agriculture, industrialisation since Industrial Revolution (1780), nuclear age, space age, cyberage, information technology etc. Side by side, Nature and Environment continued to be degraded, deforestation, air pollution, water pollution, soil pollution continued to vitiate the environment and ultimately the Biosphere endangering the survival of man himself on earth. Ever since the Green Revolution (1968) use of massive quantities of fertilizer and pesticides caused water pollution through agricultural run-off inflow into water bodies. Excessive withdrawal of ground water for irrigation caused Arsenic contamination of ground water. This led to Arsenic poisoning cases accompanied by loss of several lives in several districts of West Bengal (Malda, Murshidabad, Nadia, 24 Parganas, Kolkata) and Bangladesh along the Hoogly and Padma river courses. Industrial pollution is more severe accelerating air, water, soil and food pollution. The toxic wastes from industries – gaseous, liquid and solid are dangerous for the environment and for man.

CONCLUSION

Both agriculture and industry are essential for our daily living and ensuring high quality of life. They have to be restrained from their harmful effects on environment using eco-friendly materials and techniques. There is urgent need for environmental education for all age-groups of people so that they are conscious enough to protect the environment and keep it clean for daily living. In this context the Chinese proverb is quite appropriate :

" If you plan for 1 year, Plant rice.
If you plan for 10 years, Plant trees.
But if you plan for 100 years,
Educate people".

Let us hope that the heat and dust (agriculture-industry controversy) will settle and we shall see light at the end of the dark tunnel and agriculture-industry-environment trilogy will radiate peace, happiness and welfare for mankind.

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MID-STORAGE SEED INVIGORATION TREATMENTS IN RICE (cv. Satabdi) FOR EXTENDED STORABILITY AND COMPARATIVE STUDY ON FIELD PERFORMANCES BY EMPLOYING CONVENTIONAL AND SYSTEM OF RICE INTENSIFICATION METHOD

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ABSTRACT

Mid-storage seed invigoration treatments in medium vigour rice seeds effectively controlled seed deterioration of rice after subsequent ageing. Dry dressing treatment with aspirin (*ortho*-acetyl salicylic acid) @ 100mg/ kg of seed, crude plant material, viz., neem leaf powder @ 2g/ kg of seed and wet treatment (soaking in double volume of water for 4 h at room temperature and then drying back to its original moisture content) showed significant improvement on field performance and productivity over untreated control in both System of Rice Intensification and conventional method. Among the treatments, dry treatments have shown better results in improving field performance and productivity. The increase in yield was significantly higher in SRI method than the conventional one. Among the dry and wet treatments, aspirin in particular showed better results in improving storability, yield and other yield attributes. The interaction between treatment effect and cultivation methodology was not significant implying thereby that the treatment effect was independent of cultivation method. The membrane functions as measured by electrical conductance of seed leachate and leakage of sugar were significantly lower in the wet and dry treated seeds than the untreated control. The dehydrogenase activity was significantly higher in the treated seeds than the untreated control. On the basis of the present result, mid-storage dry treatment with aspirin and neem leaf powder employing System of Rice Intensification has been suggested to the rice growers for improved storability, field performance and productivity.

INTRODUCTION

In India, especially in eastern region and coastal belts, maintenance of vigour and viability of rice seeds is a serious problem. Very often, the locally stored seed becomes unsuitable for sowing and the cultivators have to depend on seed supplied by various agencies from sources outside this state and most of our farmers stored their seeds in cloth bag or gunny bag under ambient conditions for next planting. This situation is more serious for '*rabi*' crops because seeds harvested in March – May absorbs a lot of moisture from the humid atmosphere which coupled with high temperature greatly hastens the ageing process of the seed with a consequent loss of vigour, viability and yield potential of the crop (Teckrony and Egli, 1991). Basu and co-workers reported that pre-storage dry treatments and mid-storage hydration-dehydration treatments of stored seeds of several crop plants are effective for the maintenance of vigour, viability and productivity (Mandal and Basu, 1983; 1986). Mid-storage soaking-drying treatments have some disadvantages in drying seeds to its original moisture content due to monsoon months (July – August) and it has been noticed that storage of seeds which are not adequately dried would adversely affect storability. In such a situation, an inexpensive and easily practicable seed storage technology would be most welcome to solve the above mentioned problem.

To mitigate such problems, Mandal and Basu (1986) reported that dry seed treatments with halogenated compound (bleaching powder) has maintained post-storage germinability of freshly harvested wheat seeds. There are, however, some problems with farmers who may consume any surplus seed if treated with toxic seed protective chemicals. To overcome such eventualities, Mandal and co-workers (Mandal *et al.*,2000; Sengupta *et al.*, 2005) suggested that treatment of high-vigour seeds with crude plant-materials (neem leaf powder, nisinda leaf powder) and widely used pharmaceutical formulations (acetyl salicylic acid) proved to be effective in controlling seed deteriorations.

The System of Rice Intensification (SRI) is a new and evolving alternative to conventional methods of rice cultivation. This method was developed in Madagascar and popularized in the 1980s by Henri de Laulanie, a French Jesuit priest. It plays an important role in enhancing rice productivity, maintaining soil fertility with well ecosystem preservation. This method provide an alternative approach to rice production that address most of the problems that are being faced by farmers. Given this performance, SRI has understandably generated widespread interest in other rice growing regions of the world, with recent, largely successful on farm trials in atleast ten countries (Uphoff, 2000). Several researchers have reported that yield increased about 20% to 40% in SRI method than the conventional method. In the present study, experiments were taken up to evaluate the treatment effects in improving storability of rice seeds as well as field performances and productivity in both System of Rice Intensification (SRI) and conventional method.

MATERIALS AND METHODS

Medium vigour rice (*Oryza sativa* L., cv. Satabdi) seeds were collected from the Agricultural Experimental Farm of the Calcutta University at Baruipur, West Bengal and then seeds were cleaned and thoroughly dried in the sun for 4-5 days to a moisture content of 10.5%. After drying, seeds were stored in rubber stoppered 2.5 litre capacity glass bottles till they were used for treatments.

Five month old rice seeds were dry-dressed with finely powdered pharmaceutical formulations viz., aspirin (0.1g/kg of seed) and crude leaf powder of neem (*Azadirachta indica* L.) at 2g/kg of seed in rubber stoppered glass bottles (500ml capacity) at room temperature (29 ± 1^oC). After treatment, bottles were shaken twice in a day upto 7 days for thorough mixing of pharmaceutical products and crude plant materials with the seeds.

Rice seeds were also soaked in double volume of water for 4h at room temperature (29 ± 1^oC) with occasional stirring. After 4 h, the excess amount of water was decanted off and the seeds were surface dried by blotting paper and finally dried back to its original moisture content in a drying cabinet over a current of dehumidified air at 35 $\pm$ 1°C for 3 – 4 days followed by storage over calcium chloride in the glass dessicator for uniform level of moisture into the seed (Mandal and Basu, 1983).

After treatment, seeds were subjected to accelerated ageing at 100% RH and 40 $\pm$ 1°C temperature for 14 days to evaluate the treatment effects on germinability. Accelerated ageing was done by placing the seeds of the different treatments in perforated paper packets kept in a glass dessicator containing 400 ml of water. Germination tests were carried out following the inclined glass plate blotter method of Punjabi and Basu (1982) with minor modifications. Germination tests were performed immediately after treatment and after natural ageing for 85 days by taking over 400 seeds for each treatment (ISTA, 1996).

Field experiment

Treated (dry and wet) and untreated seeds of rice were sown in the field by employing two cultivation methods to evaluate the treatment effects on field performance and productivity. Field experiments were carried out at the Agricultural Experimental Farm of Calcutta University, Baruipur, West Bengal during pre-*kharif* season (February to May) in two consecutive years (2008-2009 and 2009-2010); using completely randomized block design with three replications for each treatment. After land preparation, the plot was divided into 24 subplots (2 cultivation methods × 4 seed invigoration treatments × 3 replications); each measuring 10 sq.m.(4m × 2.5m). A fertilizer dose of N : P_2O_5 : K_2O at the rate of 60:30:30 kg per hectare was added. During final land preparation, 50% of the total nitrogen and the whole amount of phosphate and potassium were added. The rest of the nitrogen was supplied in two split doses, one at peak tillering stage and other at panicle initiation stage.

At first, nursery bed was prepared following the recommended practices and then seeds were sown at the rate of 40 kg per hectare in case of conventional method and 5 kg per hectare in SRI method. In case of conventional method, usual practices in nursery bed was maintained. But in SRI nursery bed, seeds were sown in100 sq.m. area by keeping a space of 4-5 cm between the seeds. The other cultural practices were same as practiced in conventional nursery bed.

In SRI method, 10 days old seedlings were transplanted by giving a space of 25 cm between the row and 25 cm between the plants. In SRI, only one seedling without injuring the root system was transplanted per hill. In conventional method, 25 days old 2-3 seedlings per hill were transplanted following the same distance between the row and plants as given in the SRI method. In conventional method, 2-3 cm standing water was always maintained during the cropping period. But in case of SRI method, only saturated moist condition of the soil was maintained throughout the cropping period. The other cultural practices were followed as usual in both the method of cultivation.

Data on field emergence (plant population) were taken after two weeks of sowing while plant height, number of tillers per unit area, effective tillers per unit area and panicle length were recorded at the pre-harvest stage. After harvest, grain yield per unit area, number of seed per panicle and 1000-seed weight were taken replication-wise for each treatment.

RESULTS AND DISCUSSION

Germination test conducted immediately after mid-storage treatment, treated seeds did not show any significant beneficial effect on germinability over untreated control (Table 1).

Only a marginal difference was noticed on shoot and root length between treated and untreated seeds (Table 1).

But, after accelerated ageing at 100% RH and 40 $\pm$ 1^{o}C temperature for 14 days, germination percentage and seedling length of treated (dry and wet) seeds showed improvement over untreated control (Table 1). Among the dry treatment, aspirin followed by neem leaf powder showed considerable improvement on storability. The wet treatment (soaking-drying) was equally effective in slowing down seed deterioration.

Studies on field performance in both the cultivation method, field emergence percentage, grain yield per unit area and other yield attributes viz., plant height, number of tillers/hill, number of effective tillers/hill, length of panicle, number of seeds per panicle and 1000-seed weight were significantly improved in the dry and wet treated seeds than the untreated control. Among the treatment, aspirin and neem leaf powder showed better results in improving field performance and productivity (Table 4 and 5). The field performance and productivity in SRI method was marked superior than the conventional cultivation method.

The treatment effects were, however, independent of cultivation methodology. The interaction effects between treatment and methodology in improving yield was not significant. The System of Rice Intensification method was significantly superior than the conventional one in improving field performance and productivity (Table 6, 7, 8, 9, 10 and 11).

Regarding the mode of action of seed invigoration treatments, there are two major possibilities viz., the involvement of cellular repair system in correcting age-induced

Table 1

Effect of mid-storage seed invigoration treatments on the germinability of rice seed (cv. Swarna masuri) immediately after treatment and after accelerated ageing at 100% RH and 40 $\pm$ 1^{o}C temperature for 14 days

Treatments	Before ageing					Accelerated ageing				
	Germination		Mean root length (mm)	Mean shoot	Vigour index*	Germination		Mean root length (mm)	Mean shoot length (mm)	Vigour index*
	(%)	Arc-sin length (mm)				(%)	Arc-sin			
Control	80	63.44	98	64	12960	69	56.17	71	44	7935
Neem leaf powder	86	68.03	107	71	15308	76	60.67	74	44	8968
Aspirin	84	66.42	111	75	15624	79	62.72	77	47	9796
Soaking-drying	84	66.42	108	76	15456	74	59.34	76	46	9028
L.S.D. at 0.05P	–	NS	NS	1.5	–	–	NS	1.6	1.5	–
L.S.D. at 0.01P	–	NS	NS	2.6	–	–	NS	NS	NS	–

Data on germination percentage, root and shoot lengths were recorded after germination for 8 days at 30 $\pm$1^{o}C.
Germination percentage data were transformed to their respective arc-sin value prior to computation.
*Vigour index was calculated by multiplying the germination percentage with seedling length.
NS – Non significant

Table 2

Effect of mid-storage seed invigoration treatments on field performance and productivity of rice (cv. Satabdi) by conventional method

Treatments	Field emergence (%)	Plant height (cm)	Total no. of tillers /hill	No. of effective tillers/hill	Length of panicle (cm)	No. of seed/ panicle	Seed yield (g)/ m^2	1000-seed weight (g)
Control	72	82.6	10	7	20.0	92	166.6	16.0
Neem leaf powder	73	103.3	11	8	20.6	94	181.6	20.3
Aspirin	76	100.0	11	7	21.0	110	181.0	20.6
Soaking-drying	73	94.3	10	8	22.0	105	176.6	19.6
L.S.D. at 0.05P	NS	7.3	NS	NS	NS	2.6	8.53	1.97
L.S.D. at 0.01P	NS	NS	NS	NS	NS	4.4	NS	2.98

Other details are same as in Table 1.

Table 3

Effect of mid-storage seed invigoration treatments on field performance and productivity of rice (cv. Satabdi) by SRI technology

Treatments	Field emergence (%)	Plant height (cm)	Total no. of tillers /hill	No. of effective tillers/hill	Length of panicle (cm)	No. of seed/ panicle	Seed yield (g)/ m^2	1000-seed weight (g)
Control	73	92.3	19	15	23.0	162	263.3	19.3
Neem leaf powder	79	111.6	24	22	24.6	186	340.0	20.6
Aspirin	78	110.0	26	24	24.0	183	341.6	21.6
Soaking-drying	75	106.6	23	21	24.3	182	296.6	20.0
L.S.D. at 0.05P	NS	13.7	2.95	2.9	NS	3.4	26.1	NS
L.S.D. at 0.01P	NS	NS	4.48	4.4	NS	5.7	39.5	NS

Abbreviation : SRI- System of Rice Intensification
Other details are same as in Table 1.

biochemical lesions during seed hydration (Villiers and Edgcumbe, 1975; Burgass and Powell, 1984) and counteraction of free radical induced lipid peroxidation reactions in the stored seed (Berjak, 1978; Buchvarov and Gantcheff, 1984; Wilson and McDonald, 1986b; McDonald, 1999) that could be reduced by hydration-dehydration treatments (Basu, 1994). The beneficial effect of wet treatment was noted only after storage indicating the prophylactic nature of the effect rather than curative.

In the present study, dry treatments were selected on the basis of previous studies conducted in the present laboratory with seeds of other crop plants (Mandal and Basu, 1986; Mandal *et al.*, 1999; 2000) for their possible effectiveness in controlling free radical reactions as antioxidants, antioxidant-synergists and

Table 4

Effect of mid-storage seed invigoration treatments on number of effective tillers per hill in different methods of cultivation of rice (cv. Satabdi)

Treatment	Method		Mean
	Conventional	SRI	
Control	7	15	11
Neem leaf powder	8	22	15
Aspirin	7	24	16
Soaking-drying	8	21	15
Mean	8	21	–

	Probability level	
L.S.D value for mean effects	0.05	0.01
Physiological treatments	1.6	2.1
Cultivation method	1.1	1.5
Interaction	2.1	2.7

Treatments and other details are same as in Table 1 and 3.

Table 5

Effect of mid-storage seed invigoration treatments on grain yield (g)/m^2 in different method of cultivation of rice (cv. Satabdi)

Treatment	Method		Mean
	Conventional	SRI	
Control	166.6	263.3	214.9
Neem leaf powder	181.6	340.0	260.8
Aspirin	181.0	341.6	261.3
Soaking-drying	173.3	296.6	234.9
Mean	175.62	310.37	-

	Probability level	
L.S.D value for mean effects	0.05	0.01
Physiological treatments	14.4	19.1
Cultivation method	10.2	13.5
Interaction	19.0	24.3

Other details are same as in Table 1 and 3.

radioprotective agents. The role of natural plant preparations could also be due to reduced lipid peroxidation because volatile aldehyde production was lower in seeds treated with such preparations than in the control (Mandal *et al.*, 2000). Sung and Chiu (2001) have given strong

Table 6

Effect of mid-storage seed invigoration treatments on 1000- seed weight (g) in different method of cultivation of rice (cv. Satabdi)

Treatment	Method		Mean
	Conventional	SRI	
Control	16.0	19.3	17.6
Neem leaf powder	20.3	20.6	20.4
Aspirin	20.6	21.6	21.1
Soaking-drying	19.6	20.0	19.8
Mean	19.1	20.4	-

	Probability level	
L.S.D value for mean effects	0.05	0.01
Physiological treatments	1.57	2.07
Cultivation method	1.11	NS
Interaction	2.07	NS

Other details are same as in Table 1 and 3.

Table 7

Effect of mid-storage dry and wet physiological treatments on germinability, membrane permeability and dehydrogenase enzyme activity of stored rice seeds immediately after treatment (before ageing) and after subjecting to accelerated ageing at 100% RH and 40 ± 1ºC temperature for 14 days

Treatments	Before ageing					Accelerated ageing				
	Germination		Electrical conductance (dsm^{-1})	Leakage of sugar (μg/ml) (O.D.)	Dehydro-genase activity	Germination		Electrical conductance (dsm^{-1}) (O.D.)	Leakage of sugar (μg/ml)	Dehydro-genase activity
	(%)	Arc-sin value				(%)	Arc-sin value			
Control	82	65.3	1.7	0.10	0.14	60	55.8	3.8	0.18	0.05
Neem leaf powder	84	66.4	1.5	0.08	0.17	73	58.7	3.8	0.12	0.10
Aspirin	86	68.0	1.7	0.07	0.17	74	59.3	3.5	0.14	0.09
Soaking-drying	81	64.5	1.6	0.1	0.21	74	59.3	3	0.16	0.06
L.S.D. at 0.05 P	–	NS	0.48	NS	0.01	–	1.6	0.13	5.06	5.06
L.S.D. at 0.01 P	–	NS	NS	NS	0.01	–	NS	0.23	NS	NS

Other details are same as in Table 1.

support to the concept of free radical induced lipid peroxidation as a causative factor of seed deterioration in sweet corn (*Zea mays* L.) thereby confirming similar findings of this laboratory. The protein protective role of acetyl salicylic acid (aspirin) might be partly responsible for viability maintenance of stored seed (Mandal *et al.*, 2000). Takaki and Rosim

(2000) reported that aspirin application to *Raphanus sativus* L. seed, would increase the tolerance to high temperature and synchronize seed germination. But an important point which requires further elucidation is the mechanism of entry of dry active ingredients into the dry stored seed. The cracks and crevices in the seed coat may possibly serve as entry points of exogenously applied substances which may help to invigorate the seed.

The yield increase in SRI method, there are several possibilities have been reported by a number of researchers. Kishan Rao, ANGR Agricultural University, Hyderabad reported that in the conventional method, 30 days old seedlings are thrust into the puddled soil and the roots take 'U' shape i.e., the tips of root face upward. Therefore, the roots require time and energy to turn downward and establish in the soil. In SRI method, young seedlings are planted shallow and hence establish quickly. Kronzucker *et al.* (1999) observed that when rice plants are provided with a given supply of nitrogen in the soil in both ammonium (NH_4^+) and nitrate (NO_3^-) forms, their yield response can be 40 – 60% higher than the nitrogen when entirely available either in one form or the other. When soils are kept completely flooded, nitrogen will be available almost entirely as ammonium, whereas with alternate wetting and drying (AWD) of soil, as with SRI practices, there is a mix of NH_4^+ and NO_3^- forms. Neumann and Romheld (2001) and Brimecombe *et al.* (2001) reported that when soils are alternately flooded and drained, this gives both aerobic and anaerobic bacteria as well as mycorrhizal fungi an opportunity to contribute to plant growth. Under these conditions, there is increased biological nitrogen fixation (Magdoff and Bouldin, 1970) and phosphorus solubilization (Turner and Haygarth, 2001).

The key physiological role behind the principle SRI measures is to provide optimal growing conditions to individual rice plants so that tillering is maximized and phyllochrons are shortened which is believed to accelerate growth rates (Nemoto *et al.*, 1995). It was also observed that tiller mortality is reduced. Furthermore, intermittent irrigation is believed to improve oxygen supply to rice roots, thereby decreasing aerenchyma formation and causing a stronger healthier root system with potential advantages for nutrient uptake (Stoop *et al.*, 2002).

Whatever may be the exact mechanism of action of seed invigoration treatment, dry dressing treatments in high-medium vigour seeds with pharmaceutical products and crude plant powders especially aspirin (@ 0.05g/kg seed); and neem leaf (*Azadirachta indica* L. @ 2g/kg seed) powder respectively are recommended for the improvement of storability and field performance employing System of Rice Intensification (SRI) cultivation methodology.

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STUDIES ON CHARACTER ASSOCIATION OF DIFFERENT QUANTITATIVE TRAITS IN TOMATO

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ABSTRACT

Correlation and path analysis were performed on plant and fruit characters of fifteen tomato genotypes grown in a three years field experiment to determine for fruit yield, the direct and indirect effects of the following traits: days to 50% flowering, plant height, number of primary branches/plant, no. of fruiting clusters per plant, no. of fruits per cluster, number of fruits/plant, fruit weight. The results of correlation coefficient in the present investigation, implies that fruit weight, fruiting clusters per plant, fruits per plant may be considered for selection for yield improvement in the population of tomato under study. The results of path analysis indicated that days to 50% flowering, number of cluster per plant, fruit per cluster and fruit weight are the important characters determining fruit yield in the population of tomato under study.

INTRODUCTION

Among different vegetable crops, tomato is one of the most popular and widely grown in the world. Information regarding association of characters like growth, earliness, quality, yield and its component characters is very useful for plant breeder in developing commercial variety or hybrid. Many of these characters are interrelated in desirable and undesirable direction. Correlation study measures the mutual relationship between various characters and helps in determining the component characters on which selection can be based for improvement in yield. Correlation coefficient, which measures the simple linear relationship between two traits, does not predict the success of selection. The implication of correlation studies becomes more evident when correlation is partitioned into its components in path analysis in order to determine the relative magnitude of various attributes contributing to correlation. Hence, in the present investigation, an attempt has been made to study the association of different traits, direct and indirect effects of characters on fruit yield.

MATERIALS AND METHODS

The experimental materials, consisting of 15 diverse genotypes, were grown in a randomised block design with three replications during three consecutive *Rabi* seasons of 2007, 2008 and 2009 at Horticulture farm, Visva-Bharati, Sriniketan, West Bengal. The experimental plot of each genotype was consisted of 3 rows of 3meter length keeping plant-to-plant and row-to-row spacing of 50 cm apart. Data on five competitive plants selected at random for 7 quantitative characters were recorded. Data collected on these quantitative characters were pooled ,correlation coefficients (genotypic & phenotypic) and path analysis was performed as suggested by Johnson *et al.* (1955) and Al. Jibouri *et al.* (1958), and Dewey and Lu (1959), respectively.

RESULTS AND DISCUSSION

An estimate of genotypic and phenotypic correlation coefficients among different pairs of characters is presented in Table 1. Positive and significant correlations with fruit yield were found for the characters like clusters per plant and fruit weight at both genotypic and phenotypic levels indicating the importance of these characters for yield improvement. The results are in agreement with Padma *et al.* (2002), Joshi *et al.* (2004), Manivannan et al. (2005), Ramana *et al.* (2007) for fruit weight. Fruits per plant also showed positive correlation with fruit yield. Positive association between yield per plant and number of fruits per plant was also found by Dhankar et al. (2001), Harer *et al.* (2002), Singh *et al.* (2004) and Makesh *et al.* (2006). Positive and significant correlation were observed in case of days to 50% flowering with plant height, primary branches per plant with fruits per cluster; plant height with primary branches per plant; primary branches per plant with fruits per cluster; fruiting clusters per plant with fruits per plant and fruit weight; fruits per cluster with fruits per plant. Positive correlation at both phenotypic and genotypic levels were noted in case of plant height with fruits per plant; primary branches per plant with fruiting cluster per plant; primary branches per plant with fruiting cluster per plant. Padma *et al.* (2002) recorded positive association between plant

Table 1

Genotypic (G) and phenotypic (P) correlation coefficient of seven quantitative characters in tomato

Characters		Plant height (cm)	Primary branches per plant	Fruiting clusters per plant	Fruit per cluster	Fruit per plant	Fruit weight (g)	Yield per plant (g)
Days to 50% flowering	G	0.553**	0.494**	-0.632**	0.207*	-0.256**	-0.480**	-0.514**
	P	0.401**	0.244**	-0.469**	0.149	-0.160	-0.364**	-0.357**
Plant height (cm)	G		0.514**	-0.372**	0.054	-0.245**	-0.245**	-0.585**
	P		0.410**	-0.363**	0.057	-0.224**	-0.239**	-0.568**
Primary branches	G			0.007	0.023*	-0.073	-0.047	-0.400**
per plant	P			0.017	0.165	-0.050	-0.039	-0.305**
Cluster per Plant	G				-0.282**	0.253**	0.422**	0.678**
	P				-0.276**	0.237**	0.411**	0.656**
Fruits per cluster	G					0.425**	-0.079	-0.045
	P					0.378**	-0.070	-0.040
Fruits per plant	G						-0.333**	0.154
	P						-0.305**	0.141
Fruit weight (gm)	G							0.483**
	P							0.464**

* Significant at 5% level ** Significant at 1% level

height and primary branches, while Singh *et al.* (2004) reported positive correlation between number of fruits per plant and number of fruits per cluster. Fruit yield per plant, however, was negatively and significantly correlated with days to 50% flowering, plant height (cm), primary branches per plant at both phenotypic and genotypic levels and negatively and non significantly correlated with fruits per cluster at both phenotypic and genotypic levels. The results are in agreement with Mohanty (2003) for primary branches per plant, Mohanty (2002), Padma *et al.* (2000) and Mohanty (2003) for plant height. Significant negative correlation at both levels in this experiment were observed for days to 50% flowering with fruiting clusters per plant, fruits per plant and fruit weight; plant height with fruiting clusters per plant, fruits per plant and fruit weight; fruiting clusters per plant with fruits per plant; and fruits per plant with fruit weight. Negative correlations at both levels in this experiment were observed for primary branches per plant with fruits per plant and fruit weight; and fruits per plant with fruit weight. Similar result was obtained for plant height with fruit weight by Mohanty (2002) and Padma *et al.* (2002). Significant negative correlation at both levels were also found between number of fruits per plant and fruit weight by Mohanty (2002and 2003), Padma *et al.* (2002), Joshi *et al.* (2004), Singh *et al.* (2004). Such type of negative association may arise primarily from developmentally induced relationship (Adams, 1967).

In the present investigation, in general, correlation at genotypic and phenotypic levels showed similar trend but genotypic correlation coefficients were of higher than the corresponding phenotypic correlation coefficients in most of the characters under study indicating an inherent association among characters. Very close values of genotypic and phenotypic correlation were also observed between some character combinations that might be due to reduction in error (environmental) variance to minor proportions as reported by Dewey and Lu (1959). Wide difference between genotypic and phenotypic correlations between two characters is due to dual nature of phenotypic correlation, which is determined by genotypic and environmental correlation, and heritability of the character (Falconer, 1981). The results of path analysis (Table 2) indicated that days to 50% flowering, number of fruiting clusters per plant, fruits per cluster and fruit weight are the important characters determining fruit yield in the population of tomato under study. Harer *et al.* (2003) observed that the number of fruiting clusters per plant, number of fruits per cluster and average fruit weight had direct maximum effect on yield. The results of path analysis are in conformity with Verma and Sarnaik (2000), Dhankar *et al.* (2001), Mohanty (2002), Padma *et al.* (2002), Mohanty (2003), Manivannan *et al.* (2005), Ramana *et al.* (2007) for fruit weight; Sharma and Verma (2000), Verma and Sarnaik (2000), Dharkar *et al.* (2001), Mohanty (2002), Harer *et al.* (2003), Lakshmikant and Mani (2004), Kumar *et al.* (2003), Mohanty (2003), Joshi *et al.* (2004), Singh *et al.* (2004), Makesh *et al.* (2006) for fruits per plant; Lakshmikant *et al.* (2004), Singh *et al.* (2004), Makesh *et al.* (2006), Ramana *et al.* (2007) for number of fruiting clusters per plant and fruits per cluster.

In the present investigation, it has been observed that correlation coefficient between any casual factor and the effect was not equal to its direct effect in any way, indicating that direct selection through any of the traits would not be so much effective. However, for the character like fruit weight, fruiting clusters per plant, days to 50% flowering and fruits per

Table 2

Genotypic path coefficient of seven quantitative characters on fruit yield in tomato

Characters	Days to 50% flowering	Plant height (cm)	Primary branches per plant	No of cluster per plant	Fruit per cluster	Fruit per plant	Fruit weight (g)	Correlation with fruit yield
Days to 50% flowering	0.552	-0.094	-0.319	-0.606	0.063	0.019	-0.130	-0.514**
Plant height (cm)	0.305	-0.170	-0.332	-0.357	0.017	0.019	-0.067	-0.585**
Primary branches per plant	0.272	-0.087	-0.646	0.007	0.062	0.006	-0.013	-0.400**
Number of fruiting clusters per plant	-0.349	0.063	-0.004	0.958	-0.086	-0.019	0.114	0.678**
Fruit per cluster	0.114	-0.009	-0.131	-0.270	0.305	-0.032	-0.021	-0.045
Fruit per plant	-0.141	0.042	0.047	0.243	0.130	-0.076	-0.090	0.154
Fruit weight (g)	-0.265	0.042	0.030	0.404	-0.024	0.025	0.271	0.483**

Residual = 0.1709; * Significant at 5% level; ** Significant at 1% level
Diagonal values (Bold) indicate direct effect

cluster had positive direct effect. For the character like fruit weight, the positive and significant correlation coefficient was due to the direct effect of the character as well as indirect effect via plant height, primary branches, fruiting clusters per plant, fruits per plant indicating selection of these traits would be rewarding at least for the present situation. For the characters like fruiting clusters per plant for which correlation coefficient was significantly positive and the direct effect was very high and positive, but indirect effects via other characters were either low or negative; so this character alone should be considered for yield improvement. For the character, fruits per cluster, for which correlation coefficient was negative but the direct effect was positive, thus a restricted simultaneous selection model is to be followed, i.e. restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect (Singh and Kakor, 1997). For the character like fruits per plant for which the correlation coefficient was positive but the direct effect was negative, indirect causal factors (having positive effect) like number of fruiting clusters per plant, fruits per cluster, primary branches per plant and plant height are to be considered simultaneously for selection.

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USE OF PHENOLOGY IN ASCERTAINING THE THERMAL REQUIREMENT OF MULBERRY (*Morus sp.*)

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ABSTRACT

Mulberry, an important commercial crop thrives in tropical and temperate countries. Its foliage serves as exclusive food for the silkworm, *Bombyx mori* L. Study of phenology of mulberry in the context of sericulture pivots on the comprehension of the time pattern related to the development of biological events like buds and leaf emergence, unfurling, maturity and yield of foliage in the plant life cycle as influenced by the plant environment. The time pattern related to the development of different phenophases is triggered by the specific quantities of Accumulated Degree Days which are genetically controlled. In the present study, recording of corresponding temporal data on specific heat requirement along phasic development was initiated immediately after pruning of three high yielding mulberry varieties at Central Sericultural Research & Training Institute, Berhampore, India. Varied heat requirement of the varieties for initiation and completion of specific phenophases was observed. The estimates of Growing Degree Day (GDD) index would be useful towards foliage yield prediction, and also for replacing the prevailing calendar day-based mulberry crop schedule complimenting silkworm rearing.

INTRODUCTION

Mulberry (*Morus* sp.: Moraceae) thrives extensively in tropical and temperate countries and serves as a very important commercial crop. Its foliage is the exclusive food for the silkworm, *Bombyx mori* L., a highly specialized phytophagous insect. Mulberry is perennial in nature and its assimilatory organs are harvested during various vegetative growth stages in commensuration with silkworm rearing.

Phenology of mulberry in the context of sericulture can be defined as the study of the time pattern related to the development of biological events such as axillary buds and leaf emergence, unfurling, maturity and yield of foliage in the plant life cycle as affected by the plant environment. The study of phenophases is the most essential component of any crop-weather relationship which could be used to quantify the most appropriate rate and time of the specific developmental phases for the maximization of the crop yield during the life cycle (Kumar *et al.*, 2008). In a long-term study on the phenology of tree species of tropical dry deciduous forest ecosystem of Bandipur, South India, the patterns of strong seasonality with respect to vegetative growth was observed by Prasad *et al.*, 1986.

The metabolism of any plant is governed by a set of genetically pre-determined chemical reactions which include physiological life cycle processes and phenotypic expressions of all genetic traits. The speed at which the metabolism occurs is thermally controlled because the enzymes that drive the reactions are mostly thermo-sensitive. Foliage harvest is a heavy stress on mulberry and Fukui (2000, 2001, 2005, 2007 and 2008) felt the necessity of estimating the state of the growth in order to obtain a stable yield and design silk worm rearing encompassing the effect of temperature on phenophases of mulberry.

Unless stressed by other environmental factors like moisture, the developmental rate of foliage from emergence to maturity of mulberry depended upon the daily air temperature (Sugazawa, 1968; Suzuki and Kanaya; 1981). Plant development phases are very much dependent on antecedent and prevalent temperature and the daily accumulation of heat (Klepper, 1991). The amount of heat required to move a plant to the next phase of development remains constant from year to year owing to genetic pre-disposition. However, the actual amount of time in terms of calendar days can vary considerably from year to year because of weather conditions. Tracking development, growth and yield using thermal units has taken momentum since 1990's in agricultural field crops and insects (Altman *et al.,* 1995; Tripathy *et al.,* 2004; Dubey *et al.*, 2006). Development and growth can be estimated by accumulating degree days between the high and low temperature thresholds throughout the life. Since many developmental events of plants depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a growing season regardless of differences in temperatures from year to year. Each developmental stage of an organism has its own total heat requirement (Miller *et al.,* 2001).

The basic concept of growing degree days is that plant development occurs when temperatures exceed a base temperature. In mulberry the base temperature was experimentally determined as 13^{o}C (Rangaswami *et al.*, 1976; Dutta, 2002; Sarkar *et al.* 2005; Ganga and Chetty, 2008). Sarkar *et al.* (2005) deciphered the relationship of growing degree days (GDD) with shoot elongation and leaf yield of mulberry and emphasized the necessity of a mulberry crop calendar basing on GDD replacing the currently prevalent crop schedule based on calendar-day.

The time pattern related to the development of different phenophases in the plant as affected by the environmental factors was reported by a number of authors while taking the accumulated degree day into consideration for estimation of phenophase duration, growth and yield of various fields crops (Sinclair, 1984; Rickman and Klepper, 1991; Tripathy *et al.*, 2004; Bazgeer *et al.*, 2008).

The objective of the present study was to estimate the accumulation of GDD required for initiation and completion of sequential phenophases of mulberry foliage.

MATERIALS AND METHODS

A field experiment was set up at the farm of Central Sericultural Research & Training Institute, Berhampore (24^{o}06$^{/}$ North Latitude and 88^{o}15$^{/}$ East Longitude) with three high yielding varieties of mulberry namely, S1, S1635, C2038. All these varieties were developed gradually in the Institute in different years with a yield potential of 28-29, 44-45 and 54-55 MT per hectare per year respectively (Bajpeyi *et al.*, 2007). The soil of the experimental site is Gangetic Alluvial with a pH of 7.5. The study was conducted with temporal agrometeorological observations during monsoon (July-August), 2012 on an established and irrigated mulberry plantation having a spacing of (150+90) cm x 60 cm. After pruning the plants at 15cm above ground level, the recording of maximum and minimum temperatures from the Automatic Weather Station, CSR&TI, Berhampore (courtesy Indian Meteorological Dept., Govt. of India) along with phenological observations on days required for sprouting of buds, leaf tip emergence, unfurling and maturity of foliage were initiated immediately. The GDD for each day was calculated considering the base temperature for mulberry as 13°C, below which the growth of mulberry is virtually zero. The GDD index or the accumulated GDD (AGDD) was calculated using the following formula:

$\Sigma GDD = \{[T_{max} + T_{min}]/2 - T_b\}$

Where,

T_{max} = Maximum daily temperature in

T_{min} = Minimum daily temperature in °C

T_b = Base temperature for mulberry. in °C

RESULTS AND DISCUSSION

Average of five replicated observations on sequential development of phenophases of mulberry and the requisite accumulation of GDD started with the ground level pruning on the 2nd of July 2012 was presented in Table 1. It revealed that var. S1 and S1635 took 3 days to put forth the axillary buds triggered by an accumulation of 49.35°C day of GDD. But it required 4 calendar days and an antecedent GDD index of 65.60°C day for the var. C2038 for the same event. Differential responses to GDD were observed in case of each subsequent phenophase which too were at slight variance among the three varieties in respect of leaf tip emergence and unfurling of leaves. While S1 and C2038 responded in the same manner in the phenological events of leaf tip emergence and attaining leaf maturity taking seven and 20 days respectively activated by 115.20°Cday of GDD followed by 325.950°Cday of GDD, var. S1635 struck early maturity amounting to six and 17 calendar days set off by 98.75°Cday of GDD followed by 276°C day GDD. It took eight, nine and seven calendar days coupled with 131.95°Cday GDD with respect to var. S1, 48.30°Cday GDD in case of var. C2038 while the same for var.S1635 was recorded as 115.20°Cday GDD, respectively, for leaf unfurling. Fig.1 elucidated the calendar days required to complete different phenophases starting from leaf-bud emergence till maturity of leaves. The estimates of GDD index could be useful in preparation of GDD calendar for the growth and development of mulberry foliage

Table 1

Phenophases and thermal requirement of Mulberry

Events	Phenophases and thermal index	Variety		
		S1	C-2038	S-1635
1	Days to sprout after pruning	3	4	3
	Accumulated GDD _(°C Day)	49.35	65.60	49.35
2	Days to leaf tip emergence	7	7	6
	Accumulated GDD_(°C Day)	115.20	115.20	98.75
3	Days to unfurling of leaf	8	9	7
	Accumulated GDD_(°C Day)	131.95	148.30	115.20
4	Days to maturity	20	20	17
	Accumulated GDD_(°C Day)	325.95	325.95	276

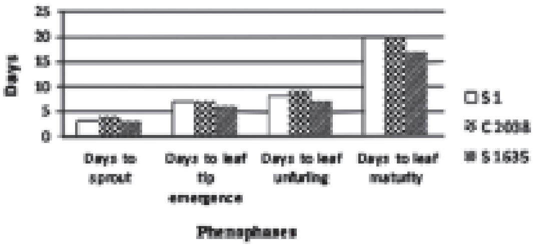

Fig. 1. Duration of phenophases of mulberry varieties.

catering silkworm instar-specific diet on different dates of pruning. The present finding agreed with the studies on various crop plants conducted by Miller *et al.*, 2001.

Nevertheless, the first ever temporal observations of the present study may be repeated in a similar experiment at spatio-temporal level for even more precision results.

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ASSESSMENT OF HEAT USE EFFICIENCY OF MULBERRY (*Morus sp.*) FOR FOLIAGE YIELD

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ABSTRACT

Mulberry sericulture is a remunerative vocation practiced widely across tropical and temperate countries. Being monophagous, the indoor-reared silkworm, *Bombyx mori* L., is fed with mulberry foliage. Periodical foliage harvest is a heavy stress on mulberry. Quick regeneration, vigorous growth and yield for longer duration are culmination of many temporal plant processes and affected by thermal responses. The paper illustrates the first ever comprehensive report on estimates of Heat Use Efficiency with respect to the phasic duration and foliage yield of improved mulberry varieties. The differential inter- and intra-varietal efficiency in heat use of mulberry was estimated on different harvest dates and stages of leaf maturity. The findings are expected to open up a new vista for scheduling the time and size of rearing towards maximizing the income from sericulture.

INTRODUCTION

Mulberry (*Morus* sp.: Moraceae) based sericulture is a remunerative vocation practiced widely across tropical and temperate countries. The monophagous silkworm, *Bombyx mori* L., is reared on the feed of mulberry foliage. Being perennial, its economic life extends at least up to 20 years. During this period it sustains periodical pruning of aerial biomass and stripping off of leaves at various vegetative growth stages corresponding the specific instar of the silkworm larvae. Hence estimating the foliage growth and harvestable yield is essential for designing silk worm rearing (Fukui, 2001; 2005). Plant growth is a complex process. It is defined as an irreversible increase in size of a plant or a plant part describing a quantitative change in a plant or a plant part in response to different environmental factors (Milthorpe and Moorby, 1974; Evans, 1978).

Most of the metabolic processes of biological entities is triggered and controlled by a certain amount of heat and specific temperature to develop from one point in the life-cycle to another (Reid *et al.*, 1990; Gordon and Bootsma, 1993). Plants cannot internally regulate their own temperature and are dependent on temperatures to which they are exposed in the environment. The quantification of heat use efficiency (HUE) over time provides a physiological time scale in conjunction with biological yield which is agronomically more accurate than calendar days and economic yield (Anonymous, 2003; Tripathy *et al.*, 2004; Anil Kumar, 2008; Sarma *et al.*, 2008). It is useful for the assessment of yield potential of a crop in different environments and is used extensively in varied crop plants (Hundal, S.S. 2004).

In the present study, the extent of leaf yield from a series of harvests over the phasic durations of three high yielding mulberry varieties and their heat use efficiency (HUE), hitherto not reported upon, were quantified.

MATERIALS AND METHODS

The study was conducted with established and standing crop of three improved mulberry varieties namely S1, C 2038 and S1635 in paired row system with spacing of (150+90) cm x 60 cm. After pruning at 15 cm above ground level, the daily maximum and minimum temperatures (Automatic Weather Station, CSR&TI, Berhampore: courtesy Indian Meteorological Dept., Govt. of India) had been recorded immediately from temporal observation. The recording of leaf yield on fresh and dry weight basis at particular time was initiated at 30 days after pruning (DAP) on July 2, 2012 and continued till 60 DAP at an interval of five days as per methodology standardized by Sarkar *et al.*, (2005). The increment in leaf yield of selected five plants was estimated by using the mean fresh weight of unit shoot length of another five plants (sample) of similar size sacrificed at each harvest. The dry weight was taken by subjecting the aerial biomass at 70°C for 48 hours in the Hot Air Oven. The leaf yield of the experimental plants of each variety at each schedule of harvest was continuously monitored from five plants of similar type pruned at particular harvest. At each harvest five sample plants were pruned on 30, 35, 40, 45, 50, 55 and 60 DAP and total length of effective shoots per plant were measured. Leaves were separated and average weight of leaves per unit length of shoot was calculated from the sample plants by the formula given below, derived from Sarkar *et al.*, 2005:

$$\frac{\text{Total Weight of leaves}}{\text{Total length of shoots}}$$

On the same day of harvesting, the total length of shoots of the experimental plants from each variety was measured. The average leaf yield at a particular harvest for individual varieties was calculated from the sample plants and used for estimating the leaf yield of the experimental plants at different harvests.

The heat use efficiency (HUE) was computed by using the following formula proposed by Nuttonson (1955).

$$HUE = {}^{BY}/_{GDD}$$

Where,

BY= Biological yield (dry aerial biomass in g/plant)

GDD= Growing Degree Day accumulated (calculated with lower threshold temperature of 13°C)

HUE= Heat use efficiency (the unit used in the present paper: g/plant/ °C day)

RESULTS AND DISCUSSION

The leaf yield (on fresh weight basis) increment followed almost a sigmoid pattern as can be observed in the graphical representation in Fig.1. Vars.S1 and C2038 yielded upward steadily reaching the peak on the 50th day after pruning, achieving 556.56 g/plant and 407.46 g/plant respectively. But in S1635 the course of yield increment deviated slightly than that from S1 and C2038. Till 45th day leaf yield was observed to increase up to 216.12 g/plant. Thereafter it decreased and reached a plateau

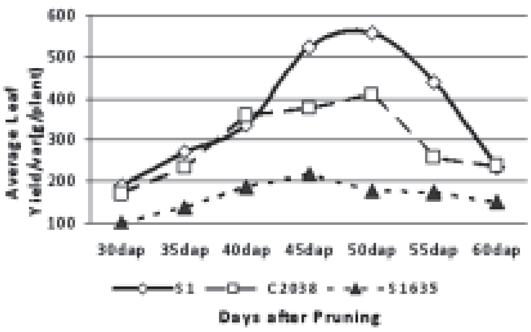

Fig. 1. Leaf yield of different varieties during growth phase.

Table 1

Heat Use Efficiency of Mulberry

Harvest schedule	Variety		
	S1	C2038	S1635
1. 1st Aug (30 Dap)	0.21	0.15	0.09
2. 6th Aug (35 DAP)	0.21	0.17	0.12
3. 11th Aug (40 DAP)	0.25	0.24	0.15
4. 16th Aug (45 DAP)	0.23	0.18	0.11
5. 21st Aug (50DAP)	0.23	0.11	0.10
6. 26th Aug (55 DAP)	0.21	0.14	0.07
7. 31st Aug (60DAP)	0.29	0.18	0.10

till the next 10 days followed by a plunge in yield of 150.36 g/plant on 60th day due to onset of senescence. Least yield was also recorded on 60th day in respect of S1 and C2038. Table 1 deciphers that Heat Use Efficiency (HUE) for var. S1 ranges from 0.21 to 0.29 covering all the seven harvests. Var.C2038 appeared to be less efficient in heat use ranging from 0.11 to 0.24 while S1635 showed even less Heat Use Efficiency which ranges from 0.07 to 0.15. Generally var. C2038 is a higher yielder than both the varieties S1 and S1635, but during the monsoon, 2012 crop, var. S1 excelled over the other two varieties in terms of the foliage yield on fresh weight basis as silkworm feed, as well as efficiency in heat use. The Table 1 also reveals that HUE differed in magnitude depending on phases of maturity attained by the leaves even when they were harvested progressively at the same interval of five days. It was observed that higher value of HUE determines not only better leaf yield but also progressive initiation of new leaves as was recorded on the 60th day after pruning. Basing on HUE of mulberry the time and size of silkworm rearing can be scheduled, so that maximum leaves can be utilized for raising cocoon crops for optimum revenue earning without wasting natural and human resources.

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EDITORIAL

We are delighted to publish the Indian Biologist, volume 44, No. 2, 2012 as a special volume on Water within the stipulated date. We will try our level best to publish the issue on scheduled time.

We are glad to announce that next five issues will be published as special issues on five burning problems of our environment which affect the very existence of a large number of biological species including human species. Topics of coming five special issues of Indian Biologist are as follows : (i) Land and Soils, (ii) Energy, (iii) Population vis-à-vis Natural Resources, (iv) Food, Nutrition and Food Adulteration, and (v) Genetically Modified Crops.

Usual research papers of our Members on other biological topics also will be included in those special issues.

The Indian Biologist is circulated to all major countries around the world and abstracts of its articles are now being published regularly in leading abstracts of the world in different languages. During the last 44 years, Indian Biologist has gained notable reputation in India and abroad mainly due to the constant patronage from our members and well wishers. The quality of its publication are commendable. The 'Indian Biologist' has been rated **2.2** by the NAAS academy for the year, 2013. We hope, the authors/contributors of the research papers or articles will bear us in this regard.

The contributors are cordially requested to send their manuscripts/articles in original for publication in the journal "Indian Biologist".

We sincerely request our members and well wishers to offer their patronage and co-operation as before.

T. M. Das and A. K. Mandal