

**In Jinja District, irrigation** water from a nearby agro-processing plant has been used during prolonged dry conditions. Over time, farmers observed that crops developed weak stems, reduced biomass, and delayed maturation.

Field officers also reported that some workers exposed to the water for long periods complained of fatigue and reduced physical endurance. Environmental assessment suggested the presence of substances that interfere with normal metabolic processes in living cells.

Plant samples were analysed to determine cellular performance.

**Table: Metabolic Indicators in Plant Cells**

Parameter	Control Plants	Exposed Plants
Rate of oxidative phosphorylation (%)	100	40
ATP yield per glucose molecule	36	14
Enzyme catalytic efficiency (%)	100	55
Oxygen consumption rate (mg O <sub>2</sub> /g/h)	8.0	3.5



**Task**

- (a) Analyse how reduced oxidative phosphorylation and enzyme efficiency affect ATP production and growth processes in plant tissues.
- (b) Suggest sustainable interventions that would restore normal metabolic function in crops and reduce human health risks.

**RESPONSE**

(a) Metabolic inhibitors in irrigation water reduce activity of **cytochrome c oxidase** in the **electron transport chain**, limiting electron transfer to oxygen and reducing formation of the **proton gradient** across the inner mitochondrial membrane. Reduced activity of **ATP synthase** lowers ATP yield from 36 to 14, leading to insufficient energy for growth and delayed maturation.

Reduced **oxygen consumption** decreases the rate of **aerobic respiration** and **oxidative phosphorylation**, lowering ATP production. Limited ATP fails to support biosynthesis and active transport, resulting in weak stems and reduced biomass.

Reduced **enzyme catalytic efficiency** affects enzymes in **glycolysis and Krebs cycle**, including dehydrogenases. Disruption of enzyme-substrate interaction reduces production of **NADH and FADH<sub>2</sub>**, limiting electron supply to the electron transport chain and further decreasing ATP production.

Low ATP availability reduces **active transport** of mineral ions such as nitrates and phosphates, limiting synthesis of amino acids and nucleotides. Reduced **protein synthesis at ribosomes** leads to poor tissue development and stunted growth.

Reduced ATP supply slows **mitosis**, affecting **DNA replication by DNA polymerase** and spindle formation, resulting in reduced cell division, decreased biomass, and delayed maturation.

Insufficient ATP limits **cellulose synthesis**, weakening cell walls and causing soft stems.

In exposed workers, inhibition of **cellular respiration** reduces ATP production in muscle cells, limiting **actin-myosin interaction** and leading to fatigue and reduced physical endurance.

**(b) Strategies**

- **Effluent treatment before discharge** removes inhibitors, restores **ETC enzyme activity**, maintains ATP production, and improves plant and human health.
- **Use of clean irrigation water** prevents toxin entry, maintains enzyme function, and restores normal metabolism and growth.
- **Phytoremediation** reduces pollutant levels, protects mitochondrial enzymes, and restores cellular respiration in crops.
- **Protective gear for workers** limits toxin exposure, maintains respiratory enzyme function, and prevents fatigue.
- **Environmental monitoring and regulation** controls pollutants, maintains metabolic conditions, and prevents long-term damage.