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Eco-Toxicological Impact Studies Pertaining To Solid Waste Extract Of A Chlor-Alkali Industry On Environment And A Crop Plant.

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Abstract

The effluent and solid waste of the Chlor-alkali industry contained significant amount of mercury. The effluent after joining the Rushikulya River significantly changes the physico-chemical properties of river water. The river water which is used for irrigation contained significant amount of mercury. Significant variation was recorded in temperature, pH, hardness, chlorinity, dissolved oxygen, BOD, COD, suspended solids, total nitrogen, total phosphorus and mercury content. The mercury concentration significantly varied in all the 5 stations of the effluent canal. The sediments collected from the effluent canal were dumped nearby. It was observed that the solid waste contained significant amount of mercury much more than prescribed limit. The lechate and washings enter into the river during rainy season increasing the mercury level in the river water. This river water was used to irrigate the crop fields at down stream. To study the impact of lechate on seed germination and seedling viability laboratory experiments were conducted taking rice crop seeds. The concentration of mercury was maintained in all the experiments. Solid waste was taken and air dried, powdered. The solid waste powder (1kg) was taken mixed with distilled water (2L) and stirred for 15days at 2hrs interval. After 15 days of stirring the whole content was allowed to sediment and the extract was decanted and kept in the fridge for experiment. The seed germination and seedling establishment decreased with the increase in solid waste extract concentration, when compared to the respective control values. The pigments like total chlorophyll, total pheophytin and carotenoid content significantly decreased in exposed seedling leaves compared to control seedling leaves of rice crop seedlings. The effluent and solid waste of the industry is highly toxic and should not be released into the environment as both the toxicants severely affect the environment and plants.

Key words: Chlor-alkali industry, Effluent, Solid waste, Residual Mercury, Crop plant, Pigment, Chlorophyll, Pheophytin, Carotenoid.

Introduction

Environmental pollution is neither a new phenomenon nor of recent origin. It originated only 6-7 decades back and came into prominence sine the last 4-5decades. Initially environmental pollution was a localized problem and generally seen in and around industrial establishments. Later on it was observed in all cities and townships. Industries are the main sources of pollution of the environmental segments (air, water and land). Industries release the gaseous waste in to air, liquid effluents into water bodies and solid waste in to land mass. Chronic local releases are cases in which discharges have taken place over such periods of time, and in such quantities, that a large region (for example, a river system, a catchments basin or the landscape downwind of a source) has been contaminated. Such a situation is association with a large industrial or municipal source (Holdgate, 1979). There can be no better example than the Minamata Bay and the Niigata tragedy of mercury poisoning, for this kind of release. The pollutants act in many ways on the living systems. Acute and / or long term actions are the most obvious eco-toxicological impacts of a given pollutant. It results demo-ecological effects at population levels which are displayed through immediate or premature death, reduced reproductive success, reduced growth, and / or increased loss at the juvenile stages. These are ultimately reflected in the lower abundance and perturbed distribution of the exposed populations of sensitive species. At present it is believed that rivers are most severely polluted by industries followed by estuaries, lakes and ocean in declining order. Heavy metal contamination caused by either natural processes or by human activities is one of the most serious eco-toxicological problems. Environmental pollution caused by mercury discharged along with liquid effluent and solid waste generated from Chlor-alkali industry and Aldehyde industry is well known and a well established fact. Pollution of surrounding biota through the discharges of effluents and solids wastes from Chlor-alkali industries have been amply demonstrated (Shaw *et al*., 1986). Gardner *et al*. (1978) analyzed sediment, plants and animals from a salt marsh contaminated by a Chlor-alkali plant. Wallin (1976) reported that samples of the carpet forming moss *Hypnum cupressiforme* from sites around six Swedish Chlor-alkali plants all contained higher mercury levels. It was highest close to the industry and decreased with the increasing distance from each industry. Bouveng (1968, 1972) studied the problem of discharge of mercury along with the effluent from chlorine and caustic soda plants and its control. Suckcharoen (1978 & 1980) reported residual mercury in the vegetation around a caustic soda plant in Thailand. Shaw *et al*. (1985) reported the residual mercury accumulation in different biotic systems available in and around a Chlor-alkali industry. The present project study is related to a Chlor-alkali industry located near our work place discharges huge amount of mercury in to a river nearer to an estuary. The present study was planned to study the physico-chemical nature of effluent and solid waste, residual mercury in economically important plants and compared with non-economically important plants growing at the contaminated site nearer to the industry.

Materials & Methods

Location of the industry: The Chlor-alkali industry M/S Jayashree Chemicals Pvt. Ltd., was situated at Ganjam, on the Bank of Rushikulya estuary about 1.5 km. Away from the sea, Bay of Bengal, on the East and 30 km. North of Berhampur city on the south-eastern side of India at 84^0 53'E longitude and 19^0 16'N latitude.

(Satellite map of the contaminated area, photographs of Chlor-alkali industry, effluent canal of the industry, solid waste in the form of slurry discharged from the industry; open drying of solid waste near the industry and open dumping of solid waste nearer to the River Rushikulya)

The industry was established in 1962 and started manufacturing caustic soda, liquid chlorine and hydrochloric acid by using a sheet of elemental mercury as a mobile cathode for the electrolysis of brine water (saturated sodium chloride solution) since August 1967. The industry was discharging its wastes into River Rushikulya and consequently these wastes were transported to Rushikulya estuary which finally meets Bay of Bengal. The effluent mixed river water is used for irrigation of crop fields, where rice, cereals and pulses were cultivated. The report that the production of crops significantly depleted when compared to crops of grown in uncontaminated crop fields. The industry changed its production technology from mercury cell process to membrane process in 2014-2016. The healthy and pure line rice seeds were collected from the Pulse and Cereal Research Centre, OUAT, Ratanpur (OUAT, Bhubaneswar) for conducting experiments.

The physico-chemical parameters of effluent and solid waste was estimated following the protocols of APHA (1995), EC (1979), Strickland and Parsons, (1972). Measurement of mercury in the effluent, sediment and plant samples followed the basic principles of Wanntorp and Dyfverman (1955) which has undergone substantial modification in the light of later developments. The process is described in Analytical Method for estimation of Mercury with Mercury Analyzer, MA 5800A issued and marketed by ECIL, 1981. The root and shoot length was measured by centimeter scale. Fresh weight and dry weight was measured by single pan electric balance. Moisture content was measured by a Moisture meter. The pigment contents were measured by Visible Spectrophotometer, following the protocols of Vernon (1960) and Davies (1976). The obtained data were statistically analyzed.

Results

The contaminated site was visited to select the sites to be tested to understand the extent of mercury pollution in and around the industry. The industry faces towards south and wind blows from East, the sea side. It was observed that chlorine gas along with mercury vapor spreads towards west and north of the industry. This is the general wind direction from sea to land and the wind carries the air pollutants like chlorine gas and mercury vapour released/leaked from the industry. The effluent joins the river in south side and the river flows towards east to join Bay of Bengal which at a distance of around 10-12kms on road and 2-3kms on river length. The river water on east is used for irrigation for different crop plants. Generally people of the area cultivate rice as the main crop and the second crop is either ragi or green gram. The physico-chemical properties of the effluent of the chlor-alkali industry was studied at different points after discharge from the industry and the data estimated in different sites of collection, were analyzed and compared, which indicated strong variation in the effluent characteristic features. The following figures from Fig. A.1. to A.10 showed the changes in physico-chemical properties of the effluent at outlet point and effluent at end discharge point. The effluent of the industry at outlet point inside the industry premises showed higher values compared to the effluent at end discharge point. The pH (Fig.A1); temperature (Fig.A2), hardness (Fig.A3), Chlorinity (Fig.A4), dissolved oxygen (Fig.A5), BOD (Fig.A6), COD (Fig.A7), suspended solids (Fig.A8), total nitrogen (Fig.A9) and total phosphorus content (Fig.A10) was high in the effluent collected from the outlet located inside the inside premises compared o the effluent collected from the starting point of effluent canal.

Fig.A.1;Showing changes in temperature (oC) of the effluent collected from different sites.

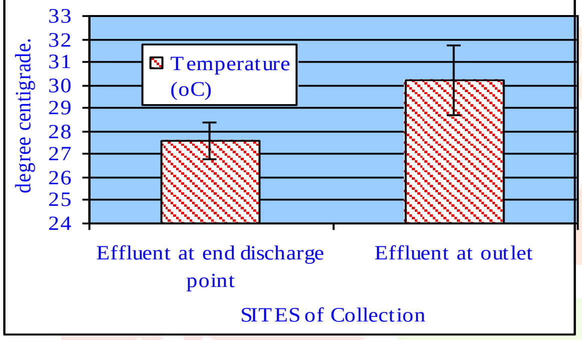


Fig.A.2: Showing changes in pH in two different stations of the effluent canal.

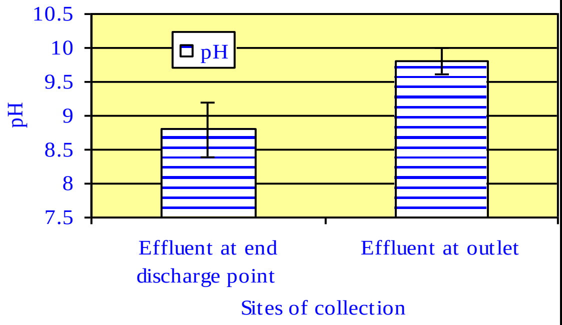


Fig.A.3: Showing changes in hardness (as CaCO3 in mg l-1) in samples collected from the effluent canal.

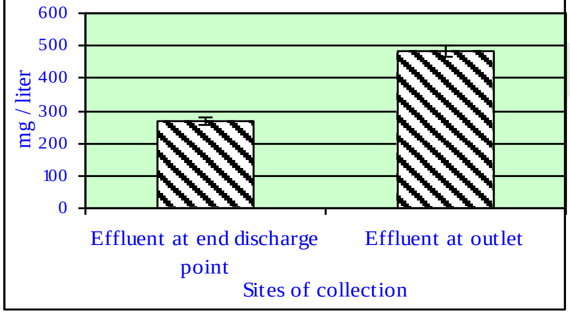


Fig.A.4: Showing changes in Chlorinity (mg l-1)in water samples collected from effluent canal.

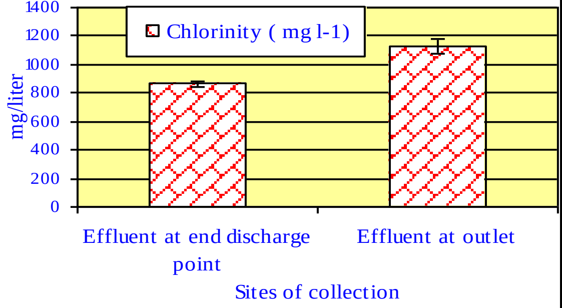


Fig. A.5: Showing changes in Dissolved Oxygen (mg l-1) in samples collected from the effluent canal.

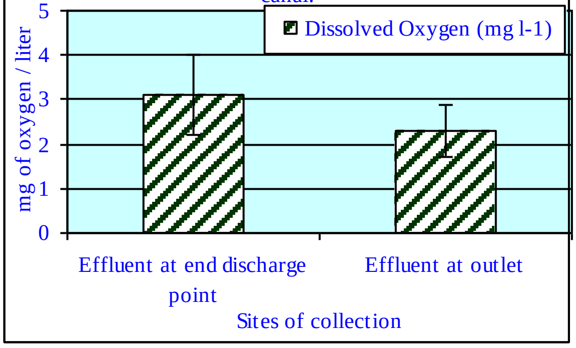
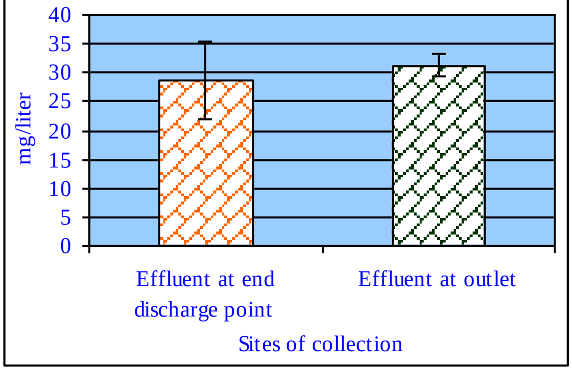


Fig.A.6: Showing changes in BOD (mg l-1) in collected effient samples at different stations.



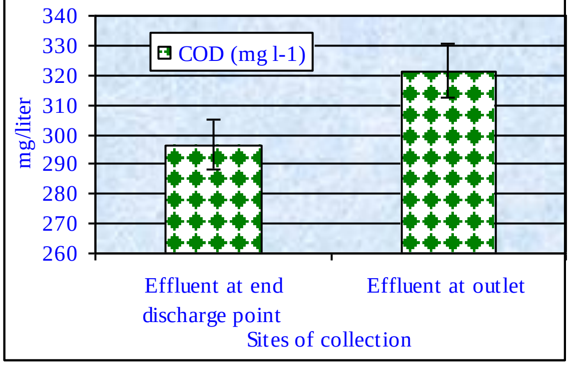


Fig.A.7: Showing changes in COD (mg l-1) of effluent samples at different sites.

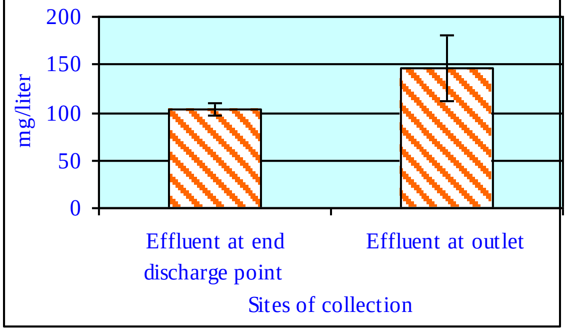


Fig.A.8: Showing changes in Suspended solids (mg l-1) in the samples collected from effluent canal.

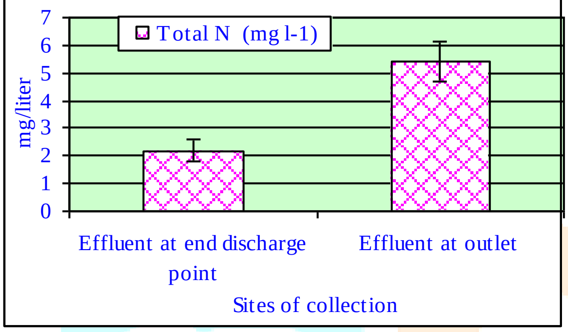


Fig. A.9: Showing changes in Total Nitrogen (mg l-1)content in effluent samples collected from different sites.

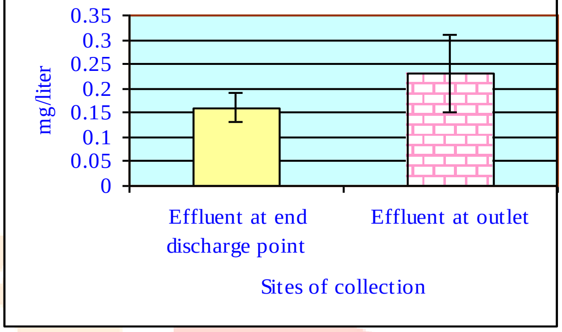


Fig. A.10: Showing changes in Total Phosphorus content (mg l-1)in effluent samples collected from different sites.

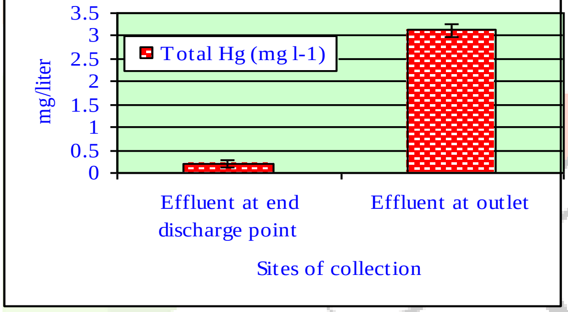


Fig.A.11: Showing changes in Total Hg (mg l-1)content f the effluents collected from different sites.

The differences probably due to the impact of treatment chamber 1 and 2, where the effluent was stocked for treatment. During the holding time the chemicals were getting settled and sedimented. The effluent was showing a mean temperature of 30.2^{0}C at the discharge point and the temperature depleted to 27.6^{0}C at the discharge point where effluent meets the river water. The depletion in temperature was due to mixing of other waste water coming from the industry, not from the cell house. The pH ranged from 8.8 to 9.8 from the outlet point to discharge point. The depletion in pH was also due to the other waste water joining the effluent canal at mid point. The hardness ranged from 481.8±17.4 to 265.4±11.4 as $CaCO_3$ in mg l^{-1} from the initial point to the end point of the effluent canal. The chlorinity ranged from 1127.6±48.4 to 862.8±17.2mg l^{-1}. The dissolved oxygen was 2.3±0.6mg l^{-1} at the outlet point of the effluent canal and the value increased to 3.12±0.9mg l^{-1} due to atmospheric mixing and also due to fall in effluent temperature due to cooling and mixing of other waste water joining the effluent. A strong decline in BOD and COD was also noticed when we compare the effluent collected from two different points of the effluent canal. Suspended solid load decreased from 146.3±34.5 to 104.2±6.5mg l^{-1} from the initial point to discharge point. This depletion was probably due to settlement of suspended particles during travel from initial point to end point of the effluent canal. The total nitrogen content and phosphorus content was significantly low in the effluent at both the stations and the value depleted from the initial point to end point of the effluent canal. We have observed a significant amount of mercury in the effluent canal at the outlet point to the tune of 3.12±0.13mg l^{-1} and the mercury content depleted to 0.19± 0.08mg l^{-1} at the end of discharge point. The depletion of mercury content was due sedimentation of mercury in the course of movement of effluent from the outlet point to discharge point. The settled mercury accumulated in the sediment of the effluent canal where, we found very high amount of elemental mercury. Fig.A11 showed significant amount mercury presence in the effluent which comes out from the industry and later precipitation takes place in the settling tank. Less amount of mercury was recorded in the effluent at end discharge point.

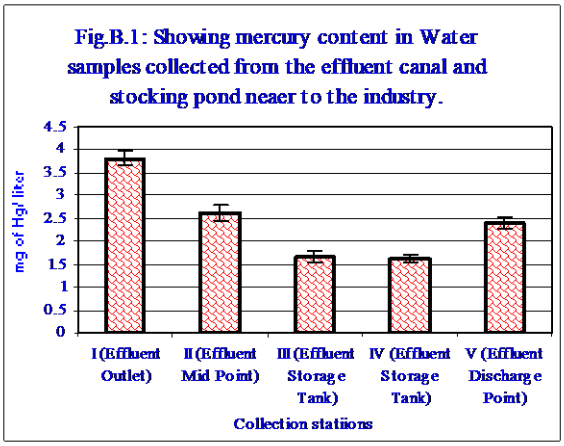


Fig.B.1: Showing mercury content in Water samples collected from the effluent canal and stocking pond neaer to the industry.

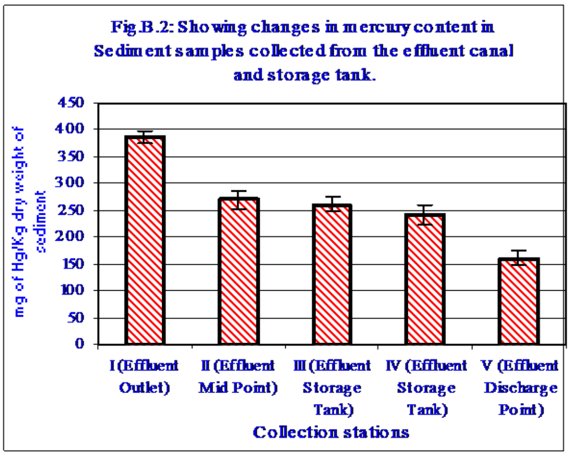


Fig.B.2: Showing changes in mercury content in Sediment samples collected from the effluent canal and storage tank.

The amount of mercury present in the settling tank is transferred along with mud as sediment deposited as solid waste.Fig.B1 and Fig.B2 showed presence of mercury in effluent collected from 5 stations of the effluent canal initiating from effluent outlet effluent canal and effluent stocking pond located outside the industry and very nearer to Rushikulya river. The sediments were periodically removed and dumped as solid waste out side the industry premises and on the bank of river Rushikulya. The mercury concentration of the effluent significantly decreased from 2.68±0.25mg l^{-1} at mid point of the effluent canal to 2.04±0.11mg l^{-1} in the storage tank. The effluent which when released from the factory finds its way in to the Rushikulya river estuary, was found to contain very high amount of mercury. The effluent analyzed throughout the year contained much higher levels of mercury than the stipulated limit of 0.01mg l^{-1} set by Central Board for the Prevention and Control of Water Pollution, India. The effluent contained 3.82 ± 0.16 mg of Hg l^{-1} at the first outlet point, the place from where the effluent comes out from the industry. The mercury content depleted at mid point of the effluent canal for sedimentation of mercury in the effluent canal (Fig.B1 & 2). The mercury content in the storage tank ranged between 1.65 ± 0.13 - 1.61 ± 0.09mg of Hg l^{-1} and the effluent at final discharge point contained 2.41 ± 0.12 mg of Hg l^{-1}, which was much more than stipulated guidelines by Pollution Control Board. The above table indicated the variation in mercury concentration in water and sediment of different sites in the effluent channel and at three spots inside the effluent storage tank. In station III and IV little amount of water was available hence the sediment samples were taken for residual mercury analysis. Significant amount of mercury was recorded in the sediment samples (III, IV and V) when compared to site I and II. The amount of mercury available in water and sediment was much more than the prescribed levels to be available in the environment. To study the impact of lechate on seed germination and seedling viability laboratory experiments were conducted taking rice crop seeds. The concentration of mercury was maintained in all the experiments. Solid waste was taken and air dried, powdered. The solid waste powder (1kg) was taken mixed with distilled water (2L) and stirred for 15days at 2hrs interval. After 15 days of stirring the whole content was allowed to sediment and the extract was decanted and kept in the fridge for experiment. Healthy and uninfected rice seeds were hand shorted and arranged in coupling Petri plates at equal distances.

Table-1: Changes in morphological variables of a crop plant, *Oryza sativa*, L. CV Satari in different concentrations of solid waste extract after 144hrs of germination.(data in parentheses indicate percent change of parameters when compared to control. (* Data calculated from the mean of the samples and **, *** showed levels of significance).

Parameters	Different concentrations of solid waste extract (%V/V)							Correlation Coefficient (r)
	Control (0)	0.25	0.5	1.0	1.5	2.0	2.5	3.0	
Shoot length, cm	3.010± 0.232	2.500± 0.231 (-16.9)	2.401± 0.519 (-20.3)	1.990± 0.463 (-33.9)	1.760± 0.568 (-41.5)	0.570± 0.221 (-81.1)	00 (-100)	00 (-100)	-0.951***
Root length, cm	2.620± 1.063	2.130± 0.542 (-18.7)	1.810± 0.635 (-3.9)	1.660± 0.412 (-36.6)	1.410± 0.576 (-46.2)	0.850± 0.292 (-67.6)	00 (-100)	00 (-100)	-0.958***
Shoot fresh wt., mg	87.0±6	79±4 (-9.2)	74±7 (-14.9)	62.±5 (-28.7)	57±3 (-34.5)	22±6 (-74.7)	00 (-100)	00 (-100)	-0.955***
Shoot dry wt., mg	14±03	15±01 (-7.1)	12±02 (-14.3)	12±02 (-14.3)	12±03 (-14.3)	05±02 (-64.3)	00 (-100)	00 (-100)	==
Root fresh	20±2.4	15±1.6	17±2.7	12±1.5	12±1.1	08±0.9	00	00	-0.953***

wt., mg		(-25)	(-15)	(-40)	(-40)	(-60)	(-100)	(-100)	
Root dry wt., mg	12±0.34	07±0.86 (-41.7)	07±0.5 (-41.7)	05±0.2 (-58.3)	05±0.4 (-58.3)	02±0.04 (-83.3)	00 (-100)	00 (-100)	==
S/R length ratio*	1.149	1.174	1.326	1.199	1.248	0.671	==	==	==
S/R dry wt ratio*	1.167	2.142	1.714	2.400	2.400	2.500	==	==	==
% moisture content in shoot*	83.9	81.01	83.78	80.65	78.95	77.27	==	==	-0.889**
Chlorophyll content, mg/l*	0.286± 0.086	0.139± 0.025 (-51.4)	0.20± 0.035 (-30.07)	0.162± 0.019 (-43.4)	0.153± 0.023 (-46.5)	0.088± 0.014 (-69.2)	00 (-100)	00 (-100)	-0.914***
Pheophytin content, mg/l*	0.331± 0.035	0.120± 0.067 (-63.8)	0.240± 0.032 (-27.5)	0.230± 0.054 (-30.5)	0.143± 0.038 (-56.8)	0.070± 0.021 (-78.9)	00 (-100)	00 (-100)	-0.875**
Carotenoid content,mg/l	0.00058	0.00035 (-39.6)	0.00040 (-31.03)	0.00030 (-48.3)	0.00022 (-62.1)	0.00017 (-70.7)	00 (-100)	00 (-100)	-0.937***

For toxicity study, graded series of concentrations of the UV-sterilized lechate (SWE) was prepared and applied to the Petri plates. The first testing range was 1% to 10 SWE concentrations, where no germination was marked beyond 2% effluent concentration. Hence the next selected range of the effluent was from 0.1% to 2.0% effluent dilutions. One control set was maintained without effluent and distilled water was added instead of effluent. The Petri plates were kept inside a seed germinator. After 24h, the seeds were observed and it was observed that within 24h the seeds swelled, outer coat busted and plumule emergence was not seen. In all the Petri plates, emergence of plumule was not marked. Hence, 24h period was considered as a latent period for all control and exposed seeds and hence not counted. From this time period onwards germination time was counted. After 24hrs, emergence of plumule was noticed in the seeds of all the control and effluent exposed Petri plates. The percentage of seed germination and seedling establishment decreased with the increase in solid waste extract concentration. No seeds germinated beyond 2% of the solid waste extract. Seedling establishment significantly decreased and beyond 2% SWE, no seedling was found. The shoot length decreased from 3.010±0.232cm to 2.500±0.231cm showing 16.9% decrease at 0.25% SWE, the shoot length decreased from 3.010±0.232cm to 1.990±0.463cm showing 33.9% decrease at 1% SWE; the shoot length decreased from 3.010±0.232cm to 0.570±0.221cm showing 81.1% decrease at 2% SWE and unfortunately at 2.5%SWE no shoot was observed. The root length decreased from 2.620±1.063cm to 2.130±0.542cm showing 18.7% decrease at 0.25% SWE, the root length decreased from 2.620±1.063cm to 1.660±0.412cm showing 36.6% decrease at 1% SWE; the root length decreased from 2.620±1.063cm to 0.850±0.292cm showing 67.6% decrease at 2% SWE and unfortunately at 2.5%SWE no root was observed (Table-1). Shoot and root fresh weight and dry weight almost followed the same trend like length measurements. The shoot and root length ratio showed higher values in SWE exposed seedlings compared to control seedlings except at 2%SWE where the ratio value was much lesser than the control value (Table-1). The shoot and root dry weight ratio showed much higher values in SWE exposed seedlings compared to control seedlings (Table-1).The decrease in moisture content in the solid waste extract exposed seedling shoots insignificantly less compared to moisture content of control seedling shoots. After 144hrs of germination, highly significant variations were noted in solid waste extract exposed seedlings compared to the pigment content of control seedlings. The total chlorophyll content decreased from 0.286±0.086mg/L to 0.139±0.025mg/L showing 51.4% decrease at 0.25% SWE; total chlorophyll content decreased from 0.286±0.086mg/L to 0.162±0.019mg/L showing 43.4% decrease at 1% SWE; the total chlorophyll content decreased from 0.139±0.025mg/L to 0.088±0.0.014mg/L showing 69.2% decrease at 2% SWE concentration and unfortunately at 2.5%SWE no leaf was available for pigment analysis. The total pheophytin content decreased from 0.331±0.035mg/L to 0.120±0.067mg/L showing 63.8% decrease at 0.25% SWE; total pheophytin content decreased from 0.331±0.035mg/L to 0.230±0.054mg/L showing 30.5% decrease at 1% SWE; the total pheophytin content decreased from 0.331±0.035mg/L to 0.070±0.021mg/L showing 78.9% decrease at 2% SWE concentration and unfortunately after 2.0%SWE no leaf was available for pheophytin pigment analysis (Table-1). The total carotenoid content decreased from 0.00058mg/L to 0.00035mg/L showing 39.6% decrease at 0.25% SWE; total carotenoid content decreased from 0.00058mg/L to 0.00030mg/L showing 48.3% decrease at 1% SWE; the total carotenoid content decreased from 0.00058mg/L to 0.00017mg/L showing 70.7% decrease at 2% SWE concentration and unfortunately after 2.0%SWE no leaf was available for carotenoid pigment analysis (Table-1).

The presented data showed significant variation as evinced from statistical analyses of obtained data. No analysis was carried out for calculated data.

Discussion:

The eco-toxicological assessments of toxic chemicals depend on two basic items of information. First, the environmental available concentrations of the chemical which occur as a result of discharge and distribution in the natural environment and secondly, the toxicological properties of the chemical at that concentration and its possible impact on the biota including humans. Environmental concentrations and toxicological properties also include the concentrations of by-products or transformation products as well. Different methods and procedures were used to draw all the available eco-toxicological information's together to arrive at an assessment. The basic requirements for such procedures are the pattern of use of chemicals; their disposal and release; physico-chemical characteristics; degradation and bioaccumulation; and biological factors such as growth inhibition, toxicity testing etc. Thus, the eco-toxicology of chemicals is an important aspect of environmental management and the management of pollution. From the observed results, it can be inferred that the earlier effluent discharged by the industry was deadly toxic. The solid waste discharged by the industry was equally toxic. The industry has now changed the technology and no more mercury cell was used for production of NaOH, rather now they have employed the membrane technology for production of NaOH. At present the effluent does not contain mercury. Even we could not trace any mercury in the effluent channel. Interestingly, after two clear washes by flood in the Rushikulya River, the area where solid waste was dumped found to contain huge amount of mercury. Mercury was also found in deep layers of the soil at the dumping sites. Hence, at this point, it was planned to carry out some experimental work to test whether the effluent, SWE and lechate are toxic or not and whether the leached chemicals can affect the biota or not. Hence, the effluent collected from the end discharge point was used as the test chemical and impact analysis was carried out on a crop seed. Here, we have selected *Oryza sativa,* L. CV satari as the test seed as experimental material, as most of the farmers of the area cultivate rice crop. . Some of heavy metal such as Cd, Hg and As, etc are strongly poisonous to metal sensitive enzymes, resulting in growth inhibition and death of organisms. An alternative classification of metals based on their coordination chemistry, categorizes heavy metals as class B metals that come under non-essential trace elements, which are highly toxic elements such as Hg, Ag, Pb, Ni (Nieboer and Richardson, 1980). Plants are stationary and roots of a plant are the primary contact site for heavy metal ions. In aquatic systems, whole plant body is exposed to these ions. Heavy metals are also adsorbed directly to the leaves due to particles deposited on the foliar surfaces. Urbanization and traffic, industrial and agricultural activities, waste incineration and mining have significantly contributed to the entry of heavy metals through inhalation in human body. Heavy metals such as cadmium, mercury, lead, Nickel, Arsenic and Chromium pose a number of hazards to humans. Heavy metals are also potent carcinogens. Some of heavy metals (Fe, Cu and Zn) are essential for plants and animals (Wintz *et al.*, 2002). The availability of heavy metals varies in different medium of the environment. Some of these heavy metals such as Cu, In, Fe, Mn, Mo, Ni and Co are called micronutrients (Reeves and Baker, 2000), and are only toxic when taken in excess of requirement (Monni *et al.*, 2000; Blaylock and Huang, 2000). Like all organisms, plants are often in a state of dilemma that some heavy metal ions are essential micronutrient, while the same at higher concentrations and even more ions such as Cadmium, Mercury, Arsenic, etc are strongly poisonous to the metabolic activities. Researches have been conducted throughout the world to determine the effects of toxic heavy metals on plants (Reeves and Baker, 2000; Fernandez and Henariques, 1991). Several heavy metal ions are reported to cause preoccupation of membrane lipids (plasma and chloroplast membrane). For example Cd modified the lipid composition of root plasma membrane of *Pisum sativum* (Hernandez and Cooke, 1997).Sahu & Panigrahi (2002, 2003) reported that the effluent and solid waste coming out from the chlor-alkali industry is deadly toxic. Shaw et al, 1985 and 1986 reported that the effluent of the industry is toxic all biosystems living in the contaminated sites. Among metals, increased level of lipid peroxidation has been reported under Cd stress in *Oryza sativa* (Ros *et al.*, 1990; Shah *et al.*, 2000), *Holcus lanatus* (Hendry *et al.*, 1992) and *Phaseolus vulgaris* (Somasekharaiah *et al.*, 1992; Chaoui *et al.*, 1997). Increased lipid peroxidation is also reported under Ni stress in *Oryza sativa* (Ros et al., 1990), Al stress in *Glycine max* (Cakmak and Horst, 1991) and tobacco (Yamamoto *et al.*, 1997), In stress in *Phaseolus vulgaris* (Chaoui et al., 1997; Weckex and Clijsters, 1997) and rice (Panda and Khan, 2003), Cu stress in *Silene cucubalus* (DeVos *et al.*, 1991, 1993), *Avena sativa* (Luna *et al.*, 1994) and *Lycopersicum esculentum* (Mazhoudi *et al.*, 1997), Pb stress in *Oryza sativa* (Verma and Dubey, 2003), and Cr stress in rice and wheat (Panda and Khan, 2003). Studies on heavy metal tolerance in plants indicate that root growth is particularly sensitive to heavy metals (Punz and Sieghardt, 1993). Copper and Cadmium in combination have affected adversely the germination, seedling length, and number of lateral roots in *Solanum melongena* (Neelima and Reddy, 2002). Reduction in root growth due to heavy metals has also been reported in wheat seedlings (Oncel *et al*., 2000). The number of leaves and branches, root and shoot length and biomass decreased as concentration of Cr increased in egg plant and tomato (Purohit *et al*., 2003) and in barley (Aery and Rana, 2003). The dry matter and yield of many higher plants such as pea, wheat, rape seed and maize have been reported to decrease under multiple heavy metal stress. Presence of Zn at higher concentrations retarded the growth and development of plants by interfering with certain important metabolic processes (Alia et al., 1995). The length of root and shoot were smaller for plants growing in Cd polluted soil. Significant reductions in length of *Solanum melongena* (Mehindirata *et al*., 1999) and plant height and fresh and dry matter in *Brassica juncea* (Singh and Tewari, 2003) at higher Cd concentration have also been reported. The younger plants and particularly seedlings absorb metals faster than old plants. With the increase in age, the absorption and retention capacity decreases significantly. The absorbed chemicals can be excreted out but it depends on the translocation routes and site of accumulation. Wide species variations are recorded for the accumulative efficiency for different heavy metals. The difference in metal accumulation is not correlated with tolerance to the heavy metal. Heavy metals pose a number of hazards to human health. Therefore their concentration in the environment and their effects on human health must be regularly monitored. More researches are required to understand the mechanisms involved in heavy metal tolerance in plants. Metal induced defense response at molecular level need to be worked out for understanding the cascade of chemical mechanisms of heavy metal tolerance.

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