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Eco-physiological Impact of Industrial SWE Prepared From A Caustic-Chlorine Industry On A Fresh Water Fish and Its Eco-Toxicological Significance.

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Abstract

Industrial solid waste and its leached chemicals cause significant damage to the environment and inhabiting flora and fauna. The solid waste collected from effluent canal, effluent storage pond and effluent treatment ponds were dumped near the Rushikulya river bank. During rainy season, the lechate and washings of the solid waste enter in to the river finally reach Bay of Bengal contaminating the aquatic environment. Hence, the present work was undertaken to study the impact of lechate chemicals on a fresh water fish. The lechate chemical was collected from different dumping sites and tested. A significant difference was noted. The solid waste was sampled, dried, powdered and a lechate chemical was prepared in the laboratory named as solid waste extract (SWE). It was observed that the SWE is almost identical with lechate chemicals collected from the dumping site. In the present study we have selected SWE as the test material. The SWE exposed fish appeared lethargic and the exposed fish showed imbalance in swimming after exposure to the SWE compared to control fish. Prolonged exposure to SWE led to blindness and body bending of the exposed fishes. Control fish remained clinically healthy throughout the experimental period. Significant depletion in respiration rate in exposed fish brain, liver, muscle and gill tissues when compared to control fish tissues was due to residual mercury accumulation in different tissues and its impact on respiratory metabolism. The residual mercury accumulation in fish tissues increased the body burden and impacted severely the respiratory metabolism which was reflected in depletion of whole body oxygen uptake and residual mercury accumulation in brain affected the nervous system leading to erratic swimming, nervous disorders and paralytic movements. In the present case the impact was very high and the behavioral changes were more acute and drastic confirming mercury poisoning in the affected areas at Ganjam. The depletion in AChE enzyme activity in contaminated fishes can be linked to residual mercury impact in fish tissues. Control fish remained clinically healthy throughout the experimental period without showing any signs of toxicity or contamination. The SWE is deadly toxic and can kill all the contaminated plants and animals including fish. Care should be taken and safe disposal of the solid waste originated from the industry. The solid waste should be treated to remove mercury before disposal into the surrounding environmental segments.

Keywords: Caustic-chlorine **i**ndustry, SWE, mercury, fish, respiration, enzyme activity, ions

Introduction

Pollution of the natural water bodies has been a subject of much discussion since the subject pollution came into lime light. Pollution of the water resources at the site close to man's activities is much more hazardous than pollution of the other environmental segments. Once a pollutant (effluent and solid waste) is introduced into an aquatic system for a prolonged time, the impact of the pollutant seriously affect the survivability of the existing flora and fauna of the area. The case is more serious with a stagnant system such as ponds and lakes where the pollutant enrichment occurs with time. However, in dynamic/flowing ecosystems or in ecosystems connected with ocean the pollutants get diluted. In the open environment all the chemicals present in the wastes both liquid and solid gets diluted and instant impact can never be observed. But the fishes living for a prolonged time accumulated the heavy metals from the environment. Solid waste and its leached chemicals cause significant damage to the environment and inhabiting flora and fauna. The solid waste collected from effluent canal, effluent storage pond and effluent treatment ponds were dumped near the Rushikulya river bank. During rainy season, the lechate and washings of the solid waste enter in to the river finally reach Bay of Bengal contaminating the aquatic environment. The first report of Panigrahi (1980) indicated that the leached chemicals can leach to the bottom and neighboring areas contaminating the ground water and peripheral crop fields and water bodies. The observed concentration in the environment was much less than the toxicity values. Availability of mercury in fish tissues sampled from the contaminated site indicated the impact of the heavy metal. Panigrahi (1980) reported significant change in the behavior of the exposed fish in mercurial toxicity, when compared to control fish. Residual mercury in exposed fish tissues depleted the respiration rate of tissues, which ultimately reflected on the whole body oxygen uptake and ventilation rate when compared to control fish tissues as reported by Priyadasan and Panigrahi (2024a,b). The reports of Panigrahi and Mishra (1978a&b) agree with our findings except that we conducted the experiment by taking the solid waste extract containing mercury for our experiment where the impact was synergistic effect of all chemicals present in the extract in addition to mercury. If we compare the impact of our study with the findings of Panigrahi and Misra (1978a&b), the observed effects reported were the impact of mercury as mercuric nitrate, a single chemical on fresh water fishes. The same authors also reported residual mercury accumulation in fish tissues and depletion of tissue slice respiration in different tissues and correlated the impact to be an effect of mercury poisoning. We got similar results and agree with the findings of Panigrahi and Misra (1978a&b) and Panigrahi (1980). Maximum residual mercury was recorded in exposed fish gill filaments. Exposed fish brain accumulated slowly when compared to other fish tissues but higher accumulation during recovery period might be due to transportation from other tissues. The gill filamentsThe above authors conducted the experiments by taking single chemical inorganic mercury and observed mercury symptoms. But in the open environment the synergistic impact of all available pollutants increase the stress load and the impact was severe. The present study was carried out by taking the solid waste extract prepared in the laboratory which is almost equivalent to the lechate chemicals released from the solid waste dumps. During our study we found lethargicity in exposed fishes, loss of equilibrium, erratic movement, loss of vision, bending of exposed fish body, depression in active metabolism and significant decrease in respiration rate when compared to control fish. After careful observation of the observed data, it was planned to understand the role of ions responsible for different metabolic activities in the present piece of investigation.

Materials and Methods

Location of the industry and study sites: The Chlor-alkali industry M/S Jayashree Chemicals Pvt. Ltd. is situated on the side of National Highway-16 at Ganjam. The industry is located very close to Ganjam Township; district Ganjam, Odisha state, India. The industry is located on the Bank of River Rushikulya discharging its effluent into the river directly (initially) and the solid waste collected from the effluent canal was dumped near the banks of Rushikulya river. The sediments collected from the effluent canal containing huge amount of mercury was removed periodically and dumped in and around the industry as huge deposits. During rainy season, flood water carries the dumped solid waste in to river Rushikulya contaminating the river water, Rushikulya estuary and Bay of Bengal. The discharged untreated effluent enters into the River, Rushikulya. The industry is located at 84^0 53'E longitude and 19^0 16'N latitude.

(Arc GIS explore expanded photograph showing the area and site map of the industry located near Rushikulya River and Estuary at Ganjam near Bay of Bengal showing solid waste dumping site on the bank of River Rushikulya)

The industry manufactures sodium hydroxide and HCl as main product by electrolysis procedure, where metallic mercury is used as cathode. Mercury escapes into the environment from electrolytic cells during electrolysis by evaporation. Due to high heat generated during electrolysis, mercury evaporates and escapes from mercury cells. Mercury also escapes during washing and cleaning of cells, cell house, compression chamber and hydration chamber. All the washings along with mercury escape through liquid waste, which is called as effluent. This effluent waste is discharged into environmental segments via effluent canal and effluent stocking pond. Periodic cleaning of treatment ponds, effluent canal and effluent storage pond by way of periodic mud removal and dumped nearby. This mud contained significant amount of metallic mercury, which is ultimately dumped as solid waste on the bank of the River which leeches contaminating ground water, neighboring areas and the river. This solid waste contained highly significant amount of mercury raising alarm for environmentalists. .

Maintenance of fish in the aquarium:

Test fish, *Oreochromis mossambicus*, Peters of medium size (12-18 g) (popularly known as *Tilapia* fish) were collected from the local nursery of the Fisheries Department of Berhampur (Ganjam), Odisha, India. The fish were allowed to grow in the laboratory reservoirs for acclimatization at least for 15 days before starting the experiments. The fish were maintained in aquarium of 60x60cm containing 50L of water. Chlorine-free tap water was used in both control and experimental aquarium. The water was changed daily. Air was bubbled through water of the aquarium to maintain the dissolved oxygen at 85±5% air saturation value. The physico-chemical quality of the water of both control and exposed

aquarium were measured during the experimental period and maintained at the same level during the entire period of experimentation. Living earthworms from garden showing no contamination by any toxicant were collected and fed daily to both control and exposed fish initially and slowly the diet was changed to toxicant-free chopped goat liver and then to small slices of boiled eggs during holding and through out the experimental exposure period. After acclimatization, the fish were washed thoroughly with 1% dilute Potassium permanganate ($KMnO_4$) solution, so as to prevent any infection (Panigrahi, 1980; Priyadarsan, 2024).

Experiment solution: The solid waste was collected from the solid waste dumping sites and also from the dried sediments collected from the effluent canal and brought to the laboratory in glass jars and kept in the refrigerator for experimental use. The solid waste was air dried in shade, powdered and sieved. One kg of solid waste powder was mixed with 2liters of distilled water and stirred for 12hrs and allowed to rest for 12hrs. This process alternate stirring and rest was repeated for 15 days. After 15days the mixture was allowed to rest and the supernatant extract was carefully decanted and the extract was preserved in the fridge for use. This decanted extract is known as SWE (solid waste extract). The control and SWE exposed fishes were not disturbed or stimulated. They were allowed to remain undisturbed. All the obtained values were statistically analyzed (Priyadarsan, 2024).

Table-1: Water quality of control and solid waste extract (SWE) exposed aquarium during holding and experiments in the laboratory controlled conditions. (Transparency was measured in terms of optical density (OD) at 540 nm taking double glass distilled water as standard). (Priyadarsan, 2024)

Water Quality	Control	Exposed (SWE)
Colour	Transparent	Light Gray
pH	7.1 ± 0.3	7.7 ± 0.2
Temperature, ^oC	26 ± 2	26 ± 2
Illumination, Lux	2200 ± 200	2200 ± 200
Total hardness, mg l^{-1}	76.5 ± 3.4	115.1 ± 8.5
Specific conductivity,	2.54 x 100µmho	4.52 x 100µmho
Transparency, at 540nm	0.01 - 0.025 (OD)	0.05 - 0.095 (OD)
Hg in the medium, mg l^{-1}	00	0.195±0.024

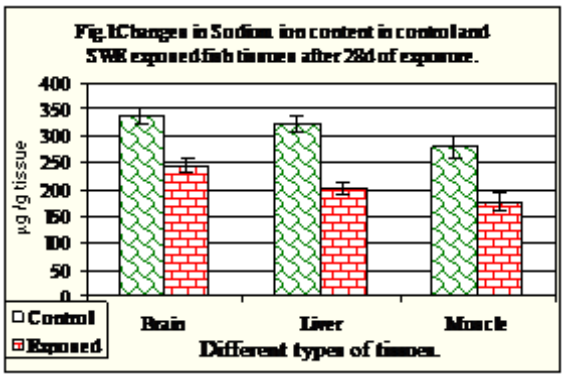
Methodology:

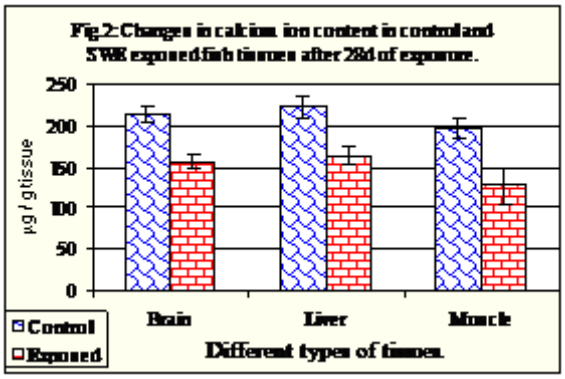
Physico-chemical analysis of water, effluent, SWE was carried out by following the protocol of APHA, 1995. The dissolved oxygen of all experimental flasks was determined according to the modified Winkler's method (Ashby, 1973 and Panigrahi, 1980). Residual mercury concentration measurements were made in a Mercury Analyser (ECIL**,** MA5800A). Fishes were sacrificed and dissected after 28 days of exposure. Brain, liver, muscle and gill tissues of each fish were taken out, properly washed and weighed. Contamination of these tissues was avoided during autopsy. Soaking in Whatman filter paper, the tissues were then transferred to Kjeldahl flasks continuing Nitric acid (BDH, Analar grade) and Sulfuric acid (HNO_3, H_2SO_4 = 1:1) and digested to a nearly colourless solution. The total volume of the solution was diluted to an appropriate volume with double distilled water. The amount Na^+, K^+, Ca^{++}, were determined by a flame photometer taking NaCl, KCl and $CaCl_2$ as standards. For magnesium determinations, the procedure followed by Orange and Rhei (1970) was adopted. The concentration of

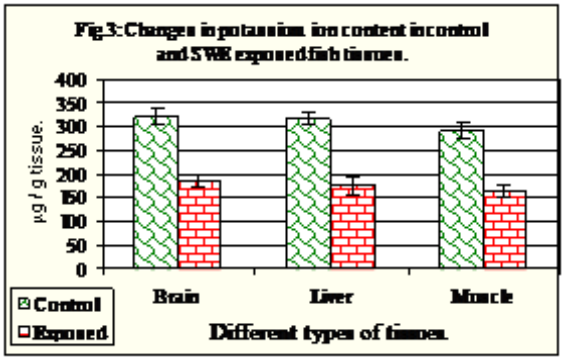
Mg^{++} was calculated from the standard curve. The obtained data was statistically analyzed using different tests as per requirement.

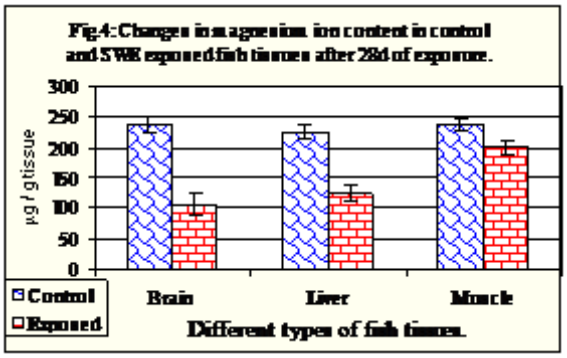
Results:

Analysis of solid waste extract: The temperature of the SWE prepared in the laboratory was 28.2^0C. The pH of the SWE was alkaline and the value recorded was 8.3±0.2. The alkalinity was 241.8±18.5 as $CaCO_3$ in mg l^{-1}. The hardness of the SWE sample was 392.2±12.6 as $CaCO_3$ in mg l^{-1}. The chlorinity was 1018.6±24.6mg l^{-1}; Phosphate-21.6±3.4mg l^{-1}; Chloride-18.2±1.4mg l^{-1}; Calcium- 88±11mg l^{-1}; Magnesium -21.1±3.6mg l^{-1}; Sodium -5.2±0.8mg l^{-1}; Potassium -12.2±16.6mg l^{-1}; Total nitrogen -4.5±1.3mg l^{-1} and Mercury -9.75 mg/liter. The dissolved oxygen content was low and ranged within 2.2±0.4mg l^{-1}. The suspended solids were low but significant and the value was 102.5±6.4mg l^{-1} (Priyadarsan, 2024). Toxicity testing of the SWE revealed the following information. After 24h of exposure the lethal concentration values were, LC_0- 5.4%SWE; LC_{100}-9.7%SWE and after 28days of exposure in chronic poisoning, the LC values were LC_0- 2.85%SWE, LC_{10}-3.11%SWE, LC_{50}-3.95%SWE, LC_{90}-4.68%SWE and LC_{100}-4.95%SWE. The MAC (maximum allowable concentration) value after 28days was 2.8% SWE and all laboratory experiments were conducted. After addition of SWE in the exposed aquarium, the medium contained 0.195± 0.024mg of mercury L^{-1} (Priyadarsan, 2024). The SWE exposed fish showed paralytic movements and the body showed banding with lateral movement. The changes in sodium ion, potassium ion, calcium ion & magnesium ion of both control and solid waste extract (SWE) exposed fish brain, liver, and muscle tissues after 28 day of exposure and percent changes in different ion concentration in different tissues of the SWE exposed fish, when compared to control fish. The sodium ion content in the brain tissue of the SWE exposed fish decreased from 332.8±18.6µg g^{-1} tissue to 231.2±22.6µg g^{-1} of control fish brain tissue; in the liver tissue of the SWE exposed fish decreased from 318.4±15.4µg g^{-1} tissue to 194.5± 1.2µg g^{-1} of control fish liver tissue and in the muscle tissue of the SWE exposed fish decreased from 272.2 ± 11.6µg g^{-1} tissue to 154.6±17.8µg g^{-1} of control fish muscle tissues after 28days of exposure (Fig.1). The ion content depleted by 30.53%, 38.91% and 43.2% in SWE exposed fish brain, liver and muscle tissues when compared to respective control fish tissues (Fig.5). The exposed fish muscle tissue showed the highest percent decrease, when compared to liver and brain tissues of the exposed fish. Significant ($P \leq 0.01$) decrease in potassium ion content in brain, liver and muscle of exposed fish, compared to the control fish, was marked. The potassium ion content in the brain tissue of the SWE exposed fish decreased from 324.6±21.6µg g^{-1} tissue to 206.2±19.4µg g^{-1} of control fish brain tissue; in the liver tissue of the SWE exposed fish decreased from 302.8±18.5µg g^{-1} tissue to 181.4±15.4µg g^{-1} of control fish liver tissue and in the muscle tissue of the SWE exposed fish decreased from 284.1±19.4µg g^{-1} tissue to 121.6±14.8µg g^{-1} of control fish muscle tissues after 28days of exposure (Fig.2). The ion content depleted by 36.5%, 40.1% and 57.2% in SWE exposed fish brain, liver and muscle tissues when compared to respective control fish tissues (Fig.5). The calcium ion content in the brain tissue of the SWE exposed fish decreased from 206.5±11.6µg g^{-1} tissue to 181.4±23.7µg g^{-1} of control fish brain tissue; in the liver tissue of the SWE exposed fish decreased from 211.2±17.8µg g^{-1} tissue to 146.5± 5.4µg g^{-1} of control fish liver tissue and in the muscle tissue of the SWE exposed fish decreased from 194.2 ± 19.2µg g^{-1} tissue to 116.4±21.8µg g^{-1} of control fish muscle tissues after 28days of exposure (Fig.3). The ion content decreased by 12.2%, 30.6% and 40.1% in SWE exposed

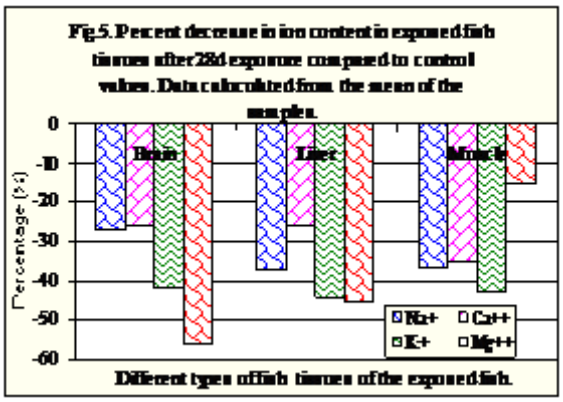


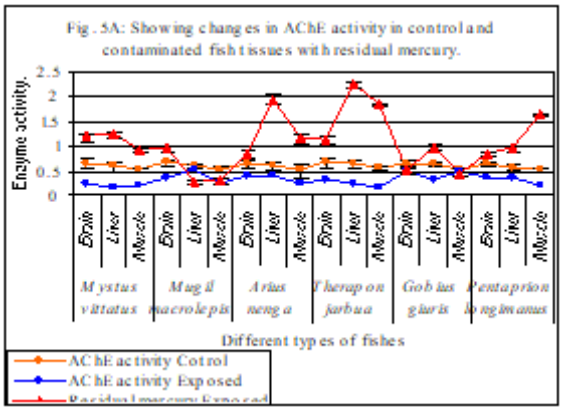






fish brain, liver and muscle tissues when compared to respective control fish tissues (Fig.5). The magnesium ion content in the brain tissue of the SWE exposed fish decreased from 232.5±26.2µg g^{-1} tissue to 184.6±17.4µg g^{-1} of control fish brain tissue; in the liver tissue of the SWE exposed fish decreased from 210.2±14.8µg g^{-1} tissue to 146.2±18.6µg g^{-1} of control fish liver tissue and in the muscle tissue of the SWE exposed fish decreased from 218.6± 22.2µg g^{-1} tissue to 187.4±19.2µg g^{-1} of control fish muscle tissues after 28days of exposure (Fig.4).





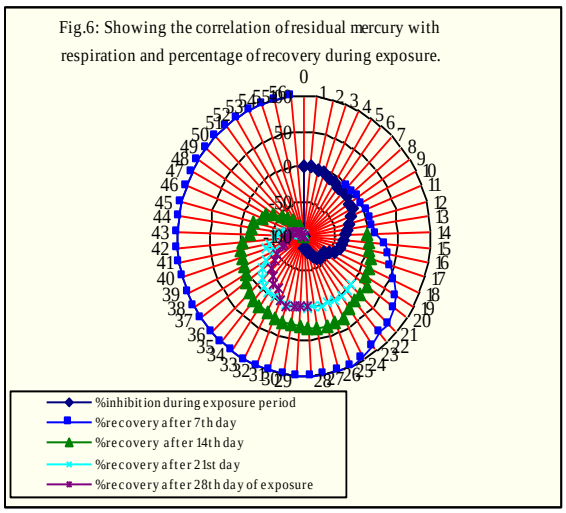
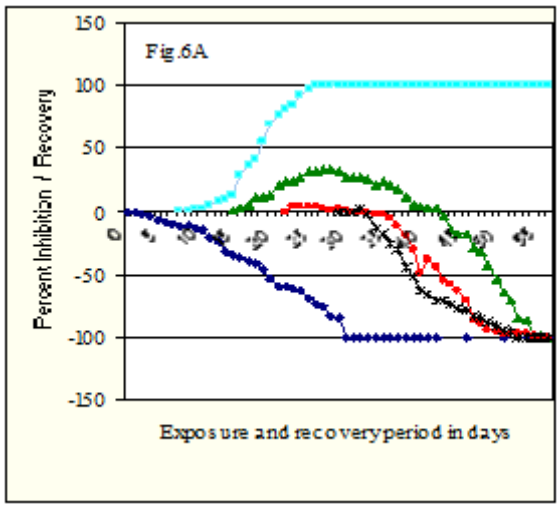


Fig.6: Showing the correlation of residual mercury with respiration and percentage of recovery during exposure.



The ion content depleted by 20.6%, 30.5% and 14.3% in SWE exposed fish brain, liver and muscle tissues when compared to respective control fish tissues (Fig.5). Out of the three tissues studied the liver was the most affected and the least affected was brain for some ion and for the rest of the ions the muscle was least affected. The analysis of variance ratio test for ions like Na^+, K^+, Ca^{++} and Mg^{++} in brain, liver and muscle of the control and SWE exposed fish showed significant difference between rows and significant difference between columns. The analysis of variance ratio test for percent decrease in ions like Na^+, K^+, Ca^{++} and Mg^{++} in brain, liver and muscle tissues of the control and SWE exposed fish showed significant difference between rows and non-significant difference between columns. Significant differences in ion content of different tissues of the exposed fish when compared to control fish clearly indicated the nature of the toxicant and effects caused by the SWE toxicant on the nervous tissue, synaptic transmission, nerve impulse generation, ionic balance and membrane transport system of the exposed fish. The exposed fishes did not recover when transferred to SWE free medium. The enzyme activity showed no recovery in liver, brain and muscle tissues but little variation during recovery was not statistically significant. Exposed liver tissues showed the highest damage when compared to brain and muscle tissues of the exposed fish, when compared to control fish tissues. Fig. 5A represent the changes in AChE activity of brain, liver and muscle of control fish collected from Gopalpur sea and exposed fish collected from contaminated estuary. In case of *Mugil macrolepis*, the AChE activity significantly declined in exposed fish brain, liver and muscle tissue, when compared to its respective control tissue. Muscle tissue showed the highest depletion in the AChE activity, when compared to brain and liver tissues of the contaminated fish. Brain tissue showed 43.3% decrease, liver tissue showed 16.4% decrease and muscle tissue showed 55.6% decrease, when compared to its respective control tissues. In *Arius nenga*, the AChE activity significantly declined, muscle tissues showed the highest depletion in the AChE activity, when compared to liver and brain tissues of the contaminated fish. Brain tissues showed 36.4% decrease, liver tissues showed 33.9% decrease and muscle tissues showed 54.9% decrease, when compared to its respective control tissues. Fig.5A indicate the changes in AChE activity in *Mystus vittatus* , the AChE activity significantly declined in exposed fish brain, liver and muscle tissues, when compared to its respective control tissues. Liver showed the highest depletion in the AChE activity, when compared to muscle and brain tissue of the contaminated fish. Brain tissues showed 63.6% decrease, liver tissues showed 69.5% decrease and muscle tissues showed 64.2% decrease, when compared to its respective control tissue. In *Pentaprion longimamus*, the AChE activity significantly declined in exposed fish brain, liver and muscle tissues, when compared to its respective control tissue.

Muscle tissue showed the highest depletion in the AChE activity, when compared to brain and liver tissues of the contaminated fish. Brain tissues showed 40.6% decrease, liver tissue showed 37.9% decrease and muscle tissue showed 58.8% decrease, when compared to its respective control. In case of *Gobius giuris*, the AChE activity significantly declined in exposed fish brain, liver and muscle tissues, when compared to its respective control tissues. .Liver tissue showed the highest depletion in the AChE activity, when compared to brain and muscle tissue s of the contaminated fish. Brain tissues showed 25.8% decrease, liver tissues showed 46.9% decrease and muscle tissues showed 9.4% decrease, when compared to its respective control tissues. In case of *Therapon jarbua*, the AChE activity significantly declined in exposed fish tissues. Muscle tissue showed the highest depletion in the AChE activity, when compared to liver and brain tissues of the contamination fish. Brain tissues showed 53.7% decrease, liver tissues showed 59.4% decrease and muscle tissues showed 67.3%decrease, when compared to its respective control tissues (Fig.5A). The changes in AChE activity of brain, liver and muscle of control fish collected from Gopaslpur Sea and exposed fish collected from contaminated estuary .In case of *Trachinocephalus myops*, the AChE activity significantly declined in exposed fish brain, liver and muscle tissues, when compared to its respective control tissues. Brain tissue showed the highest depletion in the AChE activity, when compared to liver and muscle tissues of the contaminated fish. Brain tissues showed 55.1% decrease, liver tissue showed 46.0% decrease and muscle tissues showed 24.1% decrease, when compared to its respective control tissues. Experiments were conducted to find the impact of mercury contained SWE on the fish respiration and possible recovery. It was observed that once the fish is exposed mercury based toxicant, the fish showed depression in active metabolism and drastic depletion in respiration rate (Fig.6 and 6A). These exposed fishes were transferred to toxicant free medium for recovery studies after 7, 14, 21 and 28days of exposure. It was observed that the 7d exposed could recover to its pre-test level showing 100% recovery. In case of 14d exposed fish, the exposed fish could recover partially but after around 18days the recovery fishes started dying. In 21d exposed fish, little improvement was noted for first 7days but afterwards no recovery rather significant depression leading to death was noted. In case of 28d exposed fishes, no recovery was noted. All the 28d exposed fishes died within 7days of recovery. The data indicated that in short term exposure recovery can be a possibility but prolonged exposure the toxicant caused irreversible damage leading to death.

Discussion

In Minamata Bay mercury contamination of fish and sediments still continues though discharge of Hg from the acetaldehyde plant was completely stopped in 1971 (Nishimura and Kumagaii, 1983**).** Powell (1983**)** reported presence of mercury in river system which had received mercurial discharge from a chlor-alkali plant some years before. Thus pollution of an aquatic system gives a more persistent effect than pollution of a terrestrial system. The Chlor-alkali industry was dumping its solid wastes on the riverside (bank of the river) and effluents initially directly for around 60years and later indirectly for around 20years, contaminating both aquatic and terrestrial ecosystems. Heavy metal contamination caused by either natural processes or by human activities is one of the most serious eco-toxicological problems (Reedy and Prasad, 1990). Chlor-alkali industries adopting mercury as cathode in the mercury cell process discharge significant amount of mercury in to the environment in the effluent. The effluent collected from the cell house, washings of the cell house, electrolysis cells, hydration chamber and compression chamber are canalized as effluent and stores in treatment chamber-1 for treatment. The effluent is generally never treated except pH neutralization and sedimentation. The sediments were

collected periodically from treatment point-1 & 2 and the effluent canal and dumped nearby. These dumped sediments known as solid waste contained metallic mercury. The surface mercury when gets exposed evaporates and joins air. During rain the same evaporated mercury returns to water bodies and land masses. The industry discharges its effluents through effluent canal. The sediments collected from effluent canal, treatment pond-1 and treatment pond-2, were dumped nearer to the Rushikulya River bank. Lechate chemicals and rain washed chemicals from solid waste dumps enter into the river and finally reach to the estuary and ultimately enter into the Sea (Priyadarsan & Panigrahi, 2024a, b). Panigrahi, (1980**)** reported presence of huge amount of mercury in the solid wastes and sediments dumped by the industry people. The photographs clearly indicated that the solid waste dumping site is not a safer place, as most of the domesticated animals graze in that area (Priyadarsan, 2024). All grazing plants contained mercury absorbed from the dumping site. These grazing animals also drink the effluent water as no fresh water was available in the vicinity. Earlier Panigrahi (1980) reported presence of mercury in the milk of the cows roaming in the contaminated site. This mercury ultimately finds a way to enter into human body. Hence, this project was planned to study the impact of SWE prepared from the solid waste which is equivalent to the solid waste lechate of a Chlor-alkali industry on the changes on the physiological parameters of the exposed fish tissues and to find out the impact of mercury on the analyzed parameters of the SWE exposed fishes. It was observed that the grazers graze grasses in the contaminated site where solid waste was dumped. The whole day these grazers graze, drink the water from effluent storage tank and rest. These grazers accumulate mercury in their bodies. It was reported that the cows and goats accumulated mercury from the surrounding contaminated environment. Mercury was found in the milk of the cows and liver & muscle tissues of goats grazing in the contaminated area. The rapid absorption of the SWE along with mercury through the gill, skin and gastro-intestinal tract of fish is well evident (Panigrahi, 1980). The lechate chemical was collected from different dumping sites and tested. A significant difference was noted. The solid waste was sampled, dried, powdered and a lechate chemical was prepared in the laboratory named as solid waste extract (SWE). It was observed that the SWE is almost identical with lechate chemicals collected from the dumping site. In the present study we have selected SWE as the test material. The SWE exposed fish appeared lethargic and the exposed fish showed imbalance in swimming after exposure to the SWE compared to control fish. Prolonged exposure to SWE led to blindness and body bending of the exposed fishes. Control fish remained clinically healthy throughout the experimental period. The depression in active metabolism in exposed fishes might be due to depletion in respiratory metabolism and the erratic behavior of the contaminated fishes can be related to depletion in enzyme activity induced by residual mercury absorbed from the environment. Significant depletion in respiration rate in exposed fish brain, liver, muscle and gill tissues when compared to control fish tissues was due to residual mercury accumulation in different tissues and its impact on respiratory metabolism. The residual mercury accumulation in fish tissues increased the body burden and impacted severely the respiratory metabolism which was reflected in depletion of whole body oxygen uptake and residual mercury accumulation in brain affected the nervous system leading to erratic swimming, nervous disorders and paralytic movements. In the present case the impact was very high and the behavioral changes were more acute and drastic confirming mercury poisoning in the affected areas at Ganjam. The depletion in AChE enzyme activity in contaminated fishes can be linked to residual mercury impact in fish tissues. Control fish remained clinically healthy throughout the experimental period without showing any signs of toxicity or contamination. The toxicity of SWE becomes more apparent in a very shorter period in aquatic animals. Panigrahi (1980)

documented the detail behavioral changes in relation to inorganic-mercury intoxication. The observed depression in active metabolism in SWE exposed fish were indicative of damage to nervous tissues, inhibition of enzymes or a vital system, was totally in agreement with Panigrahi (1980). Fry (1957) demonstrated the depression in active metabolism directly reduced "scope for activity". This in turn may result in decreased growth, impaired swimming ability with erratic out burst at times. The mortality percentage for any fixed period increased with the increasing concentration of the SWE. There was an increase in mortality percentage with the increase in exposure period, also. The proportion of these animals that died in a fixed time increased with the increase in the SWE concentration and the median tolerance limit value decreased with the exposure period (Hodson *et al*., 1977; Das and Misra, 1982 and Panigrahi, 1980). The close response approach to assessment of pollutant toxicity involves several assumptions. The route of entry of the SWE is generally agreed to be via the gills (Holden, 1962; Ferguson *et al*., 1966) and thus enters directly into the circulatory system. This caused damage to tissues as a result of which there is depression in active metabolism (Macleod and Passah, 1973). Depression in active metabolism that directly reduced scope of activity was demonstrated by Fry (1957). Probably this has relevance with the impaired swimming ability, erratic movements, paralysis, and ataxia which were observed in all test fish at higher exposure periods. No initial disturbance was caused by the swe but later on the fishes were destabilized and did not performed normal activity. High percentage mortality of fish due to the action of SWE might be due to the pathological changes, as Mathur (1969) pointed out that fish subjected to insecticides such as lindane, dieldrin, DDT and BHC die due to pathological disorders. Ray and David (1962) concluded that deficiency of dissolved oxygen concentration caused by decomposition of algae or bottom deposits was mostly the cause of the fish kills in ponds and impounded water. Inorganic ions can equally prove fatal by limiting oxygen intake causing respiratory and circulatory failure influencing smooth osmotic exchange of gases caused by flocculation of iron on gill filaments. David *et al*., (1976) showed that of the metals tested, silver and mercury were the most toxic i.e., silver was 95% toxic at 0.086ppm and mercury at 0.150 ppm, while LC_{50} values were 0.033ppm for silver and 0.089ppm for mercury. During the experimental period temperature, hardness, time of exposure size of the test-fish and all such factors were monitored since the interference of one of these factors will alter the TLM values and MAC values. Hence, with the recognition that all types of SWEs are potentially lethal to fish even at relatively low concentrations. Residual mercury in exposed fish tissues depleted the respiration rate of tissues, which ultimately reflected on the whole body oxygen uptake and ventilation rate when compared to control fish tissues as reported by Priyadasan and Panigrahi (2018a). The reports of Panigrahi and Mishra (1978a&b) agree with our findings except that we conducted the experiment by taking the solid waste extract containing mercury for our experiment where the impact was synergistic effect of all chemicals present in the extract in addition to mercury. It is high time to take care of the effluents and solid wastes generated from the industry and dumped as waste without any biological treatment. The industry should ensure 100% removal of heavy metals from the wastes.

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