

REPORT ON WATER QUALITY IN THE VICINITY OF THE MAVALLIPURA ILLEGAL SOLID WASTE DUMP NEAR BANGALORE

SPECIAL FOCUS ON HEAVY METALS IN WATER

Background:

In recent times, in the context of growing environmental consciousness in India, Solid Waste Management (SWM) has gained a lot of attention. A couple of important judgments regarding scientific Solid Waste Management -- *Dr. B. L. Wadehra vs. Union of India and others* and *Almitra Patel vs. Union of India* -- led to the enactment of the Solid Waste Management Rules (2000) by the Ministry of Environment and Forests. With the passage of these SWM Rules, Solid Waste Management, that was until then perceived as an essentially municipal function, came under the regulatory powers of state and central pollution control authorities. This shift also signaled the importance of appropriate Solid Waste Management vis-à-vis the Environment. The significance lies in the fact that, when effectively done, SWM can reduce the spread of diseases drastically as well as prevent environmental pollution.

In addition, these judgments also propelled activity in the direction of setting up of solid waste management facilities based on country wide standards. In these judgments, the Supreme Court ruled that for Class I cities (cities with population of over 100,000), scientifically designed landfills had to be established December 2003, and that a failure to meet this deadline would be interpreted as Contempt of Court.

Judgments and rules are one thing, reality is another matter altogether.

Garbage dumping in Mavallipura:

About 20 kms north of Bangalore city, close to Yelahanka town and the Yelahanka Air Force Base, there is a village called Mavallipura. With the tacit approval of Bangalore Mahanagara Palike (BMP), every day since May 2003, about 200 truckloads of municipal solid waste from some of the northern wards of Bangalore are being dumped on 20 acres of land belonging to one Mr. Bylappa from Mavallipura. On average, each truckload of waste weighs about 2.5 to 3 tons. The leachate from the dump is allowed to stagnate in a ditch next to the dump and slowly finds its way into surface and ground water aquifers. Over the years all drinking water sources in the vicinity have been adversely affected, and the threat looms large of contaminating the Arkavathy river, a major drinking water source of Bangalore. It is in this river basin that the Mavallipura dump is located.

Note that a dump is different from a landfill in the way the waste is disposed off. A landfill is a constructed by digging out the earth to form a very large ditch which is provided with an impermeable lining and a leachate collection system to prevent ground water contamination. An outlet for gases formed during decomposition is also provided. A dump in contrast does not have any of these provisions and therefore causes serious air, soil and water pollution.

Water pollution is the far more serious problem because the leachates (containing all kinds of toxic material given the composition of waste generated by a city like Bangalore) seep into the ground and possibly reach the aquifers that are likely to be used as a source of drinking water (among other purposes) by people residing in the area. Theoretically, while the water from the aquifers could be treated for making it potable, in reality, the treatment processes are expensive and therefore it may not be an economically viable option to treat the water and the aquifer may have to be abandoned if the contamination is too high for the safety of those who consume the water.

In Mavallipura, the dumping is carried out next to a forest area and a Eucalyptus plantation. Adjoining the dumping site is agricultural land where crops like *ragi* (finger millet), *avarekaalu* (field beans) and flowers are cultivated. Dogs, cattle, cats, crows are some of the animals seen in the vicinity of this area. Vultures are recent additions to the bird population of this area. Additionally, in the vicinity of Mavallipura, there are a few tanks (which are large surface water bodies created to harvest rain in an interlinked pattern) which are part of a chain of lakes/tanks that join the Arkavathy river. Two of these tanks, the Mavallipura Tank and the Koramana Kunte tank, are downstream from the waste dump and hence are polluted by the leaching of pollutants and toxic material from the dump.



Leachate pond next to the Mavallipura dump

As can be expected, this open dumping (and burning) of garbage has resulted in serious environmental pollution including contamination of water bodies here. The villagers of Mavallipura rely on groundwater in this area for their drinking water and cooking needs and face serious health consequences.

This report is an analysis of the water quality in this area (based on water samples taken here), and the health hazards posed by the contaminants present in this water. The principle objective of water quality testing undertaken by us is to examine if there has been a contamination of groundwater sources due to the all the waste that is being continuously dumped on Bylappa's land.

This examination is necessary because the villagers use water from underground reservoirs for drinking and the contamination of these sources could pose a health hazard. The water quality test gives an estimate of the level of contamination in the ground water sources of drinking water and this is useful in assessing the risk of health hazard to the villagers of Mavallipura.

Sampling

Six grab samples of water around the Mavallipura waste dump were tested for various parameters including bacteriological characteristics, heavy metals, pH, Hardness and Total Dissolved Solids among others. The samples include three borewell water samples one of which has been used as the control (reference sample which is indicative of the natural water quality in the absence of contamination), one from an open well, one leachate sample and one from a tank. The distances of the samples from the dump are given below.

Sampling points

1. Borewell water from Muniswamappa's Gladiolus flower farm located ~500 m at lower terrain w.r.t. to the waste dump.
2. Borewell water from Anand's farm ~200m from the dump at similar to lower terrain w.r.t. to the dump.
3. Open well from Hanumanthrayappa's farm ~300 m from and at lower terrain w.r.t. to the dump.
4. Sample from leachate pond next to the municipal solid waste dump (~100 m from the dump).
5. Mavallipura lake/tank at Devraj's field ~300 m from and at lower terrain w.r.t. to the dump.
6. Borewell water from FRLHT campus (from a tap near the security room at the gate) – CONTROL from ~500 m at higher terrain from the dump.



Open well rendered useless because leachate overflow from waste dump

Methodology:

The samples were collected in new 5 litre jerry cans (though the requirement was only 2 lt for analysis). The cans were rinsed with the sample before collecting the sample. For the leachate pond sample, the sample water was transferred to the can using a new funnel and a mug while using gloves for the hands.

The samples were collected and submitted to Essen & Co., Bangalore by 2 pm on the 1st of June, 2006. The samples were submitted for analysis of 31 parameters including physical, chemical, biological, and heavy metal analysis. The parameters are in accordance with those listed under IS 10500 for drinking water. A copy of the list of parameters and the limits for the same has been obtained.

Parameters tested:

- | | |
|---|--------------------------------|
| 1. Colour, Hazen Units, Max | 18. Mercury as Hg, mg/L, Max |
| 2. Odour | 19. Cadmium as Cd, mg/L, Max |
| 3. Taste | 20. Arsenic as As, mg/L, Max |
| 4. Turbidity | 21. Cyanide as CN, mg/L, Max |
| 5. pH Value | 22. Lead as Pb, mg/L, Max |
| 6. Total Hardness as CaCO ₃ , mg/L, Max | 23. Zinc as Zn, mg/L, Max |
| 7. Iron as Fe, mg/L, Max | 24. Chromium, Cr+6, mg/L, Max |
| 8. Chloride Cl, mg/L, Max | 25. Alkalinity, mg/L, Max |
| 9. Residual Free Chlorine, mg/L, Min. | 26. Aluminium as Al, mg/L, Max |
| 10. Total Dissolved Solids, mg/L, Min | 27. Boron as B, mg/L, Max |
| 11. Calcium Cl, mg/L, Max | 28. Magnesium as Mg, mg/L, Max |
| 12. Copper as Ca, mg/L, Max | |
| 13. Manganese as Mn, mg/L, Max | |
| 14. Sulphate as SO ₄ , mg/L, Max | |
| 15. Nitrate as NO ₃ , mg/L, Max | |
| 16. Fluoride as F, mg/L, Max | |
| 17. Phenolic Compounds as C ₆ H ₅ OH, mg/l, Max | |

Bacteriological characteristics:

29. MPN Coliform Bacteria, 100 ml, Max
30. Fecal Coliform Bacteria/100ml
31. E.Coli Bacteria per 100 ml

Results of the water quality analysis

The leachate and the control sample have been used as the samples of reference since the leachate would obviously have the highest amounts of contaminants and the control sample the least. The control sample in this case was taken from a ground water source that is at an elevation from the waste dumpsite and all the other samples (4) are at lower terrain from the dump.

For the following parameters, one or more samples had concentrations higher than the desirable limit (according to IS 10500 standard): Odour, taste, turbidity, total hardness, chloride, TDS, Cadmium, Lead, Alkalinity, Magnesium, MPN Coliform

For the following parameters, one or more samples had concentrations higher than the maximum permissible limit (according to IS 10500 standard) or maximum allowable limit (according to other water quality standards): pH, Calcium, manganese, Fluoride, Total hardness, chloride, TDS.

Composition of water contaminated by waste dump leachate

Typically, water contaminated with leachate from household waste has high sulphate, chloride, ammonia, BOD, TOC and suspended solids from fresh wastes.

The sources of contaminants and potential health impacts on humans and the animals and the impact on plants of these parameters are discussed below:



Rag pickers scouring for recyclables

Colour, Odour and Taste:

These physical characteristics are important for aesthetic reasons. Although they do not cause any direct harmful health effects, most people would object to drinking water that offends their sense of sight, smell or taste. The water may be coloured due to the presence of dissolved or suspended colloidal particles. In natural waters, the colouring is primarily due to decaying leaves, microscopic plants, or suspended soil particles. Surface waters may have colouring due to highly-coloured waste-waters like dye wastes and wastes from pulping operations⁴.

Odour is measured in terms of threshold odour number. Decaying organic matter imparts the smell of rotten-eggs because of Hydrogen sulphide gas that is produced during decomposition.

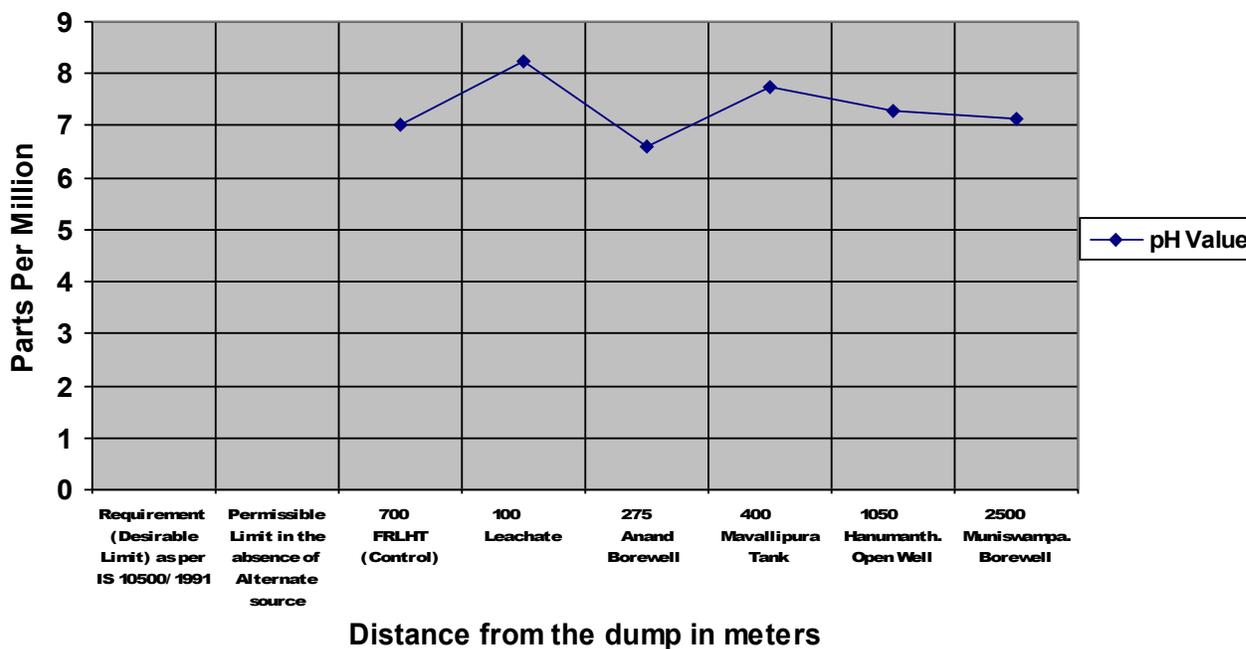
Two water samples have colour above permissible limit. One sample is the leachate sample to which the permissible limit is not applicable and the other is the Mavallipura tank sample. The color in this sample could be because of the suspended soil particles since the tank is very shallow and the sample was collected after rain. None of the other samples show disagreeable colour.

pH:

pH is the term used to express the intensity of the acid or alkaline condition of a solution. It is a measure of the hydrogen ion concentration. The pH scale contains values ranging from 0 (strongly acidic) to 14 (strongly basic)¹. Hydrogen ions are formed when water dissociates into hydrogen and hydroxyl ions. The allowable concentration range for the survival of most biological life is quite narrow⁶.

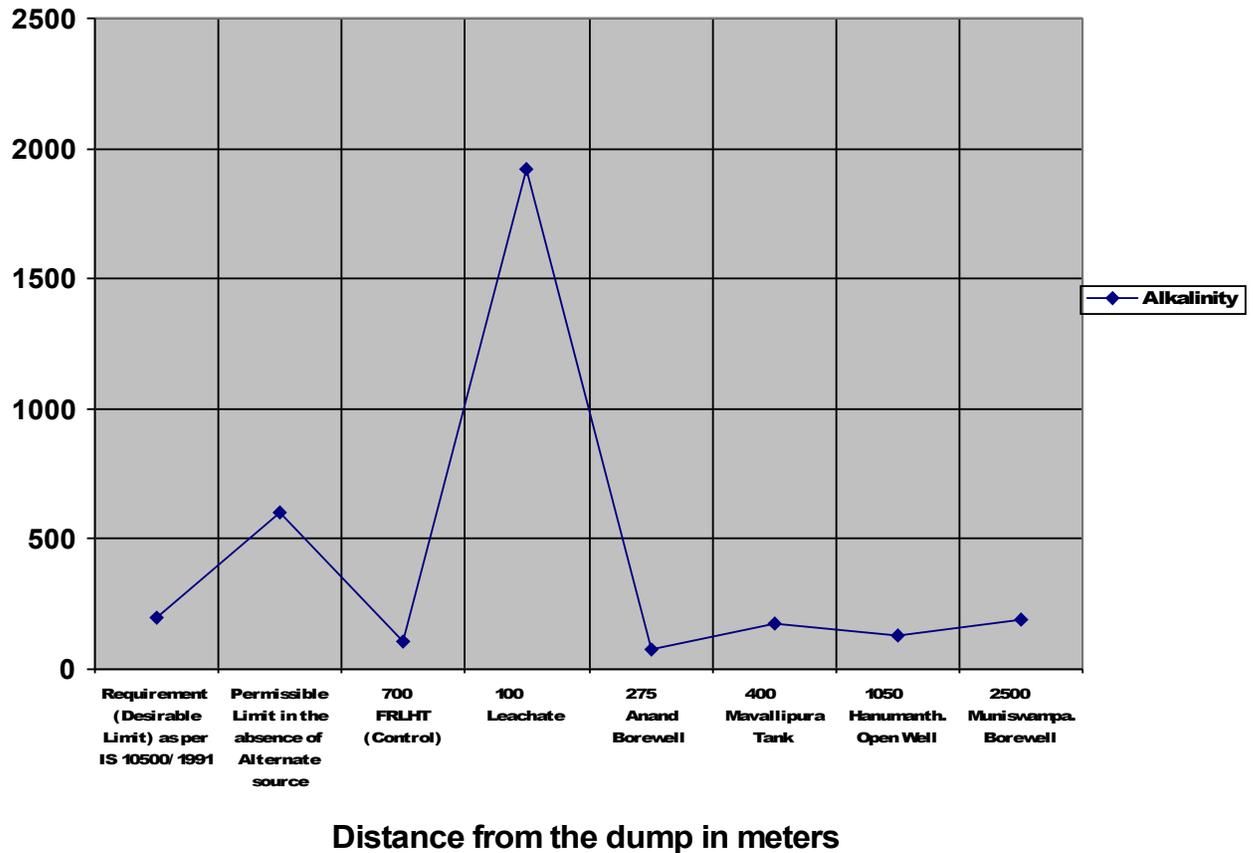
All samples but one are slightly alkaline but within the desirable limit.

Mavallipura Water Test Results- pH



Mavallipura Water Test Results- Alkalinity

Parts Per Million



Alkalinity

Alkalinity is the capacity of a water sample to neutralize an acid. The main reason for alkalinity of a water sample is the presence of carbonate, bicarbonate and hydroxides. Alkalinity buffers fluctuations in pH and is therefore important to aquatic life which is sensitive to pH especially organisms that use external fertilization for reproduction.

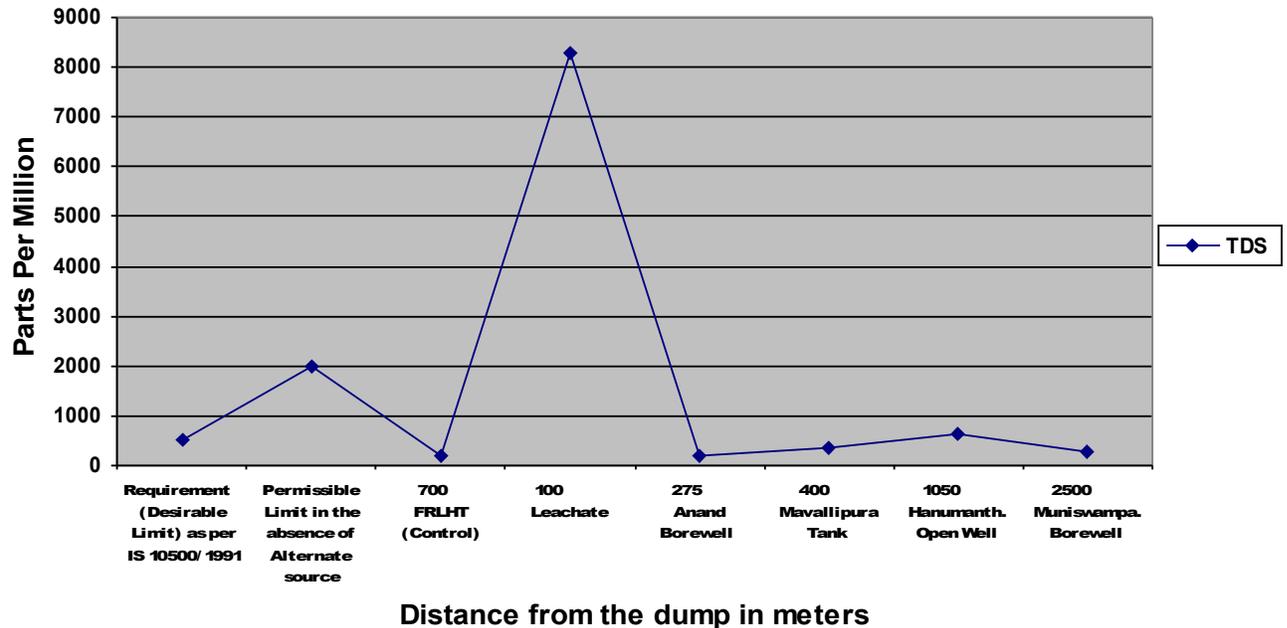
Total Dissolved Solids

The total solids in a water sample consist of total dissolved and total suspended solids. Total dissolved solids are materials in the water that will pass through a filter with a 2.0 μm or smaller nominal average pore size. The material retained by the filter is the total suspended solids. In potable waters, most of the dissolved matter consists mainly of inorganic salts, small amounts of organic matter, and dissolved gases. The hardness increases with total dissolved solids.

The amount of dissolved solids present in water is a consideration in the water's suitability for domestic use. In general, water with a total-solids content of less than 500 mg/L is most desirable for such purposes. Higher total solids content imparts taste to the water and often has a laxative and sometimes the reverse effect upon people whose bodies are not used to higher levels. Water with high dissolved solids content has an adverse impact on irrigated crops, plants and grasses.

The total dissolved solid content in the leachate is well above the permissible limit. The open well sample has dissolved solid content more than the desirable limit.

Mavallipura Water Test Results - Total Dissolved Solids

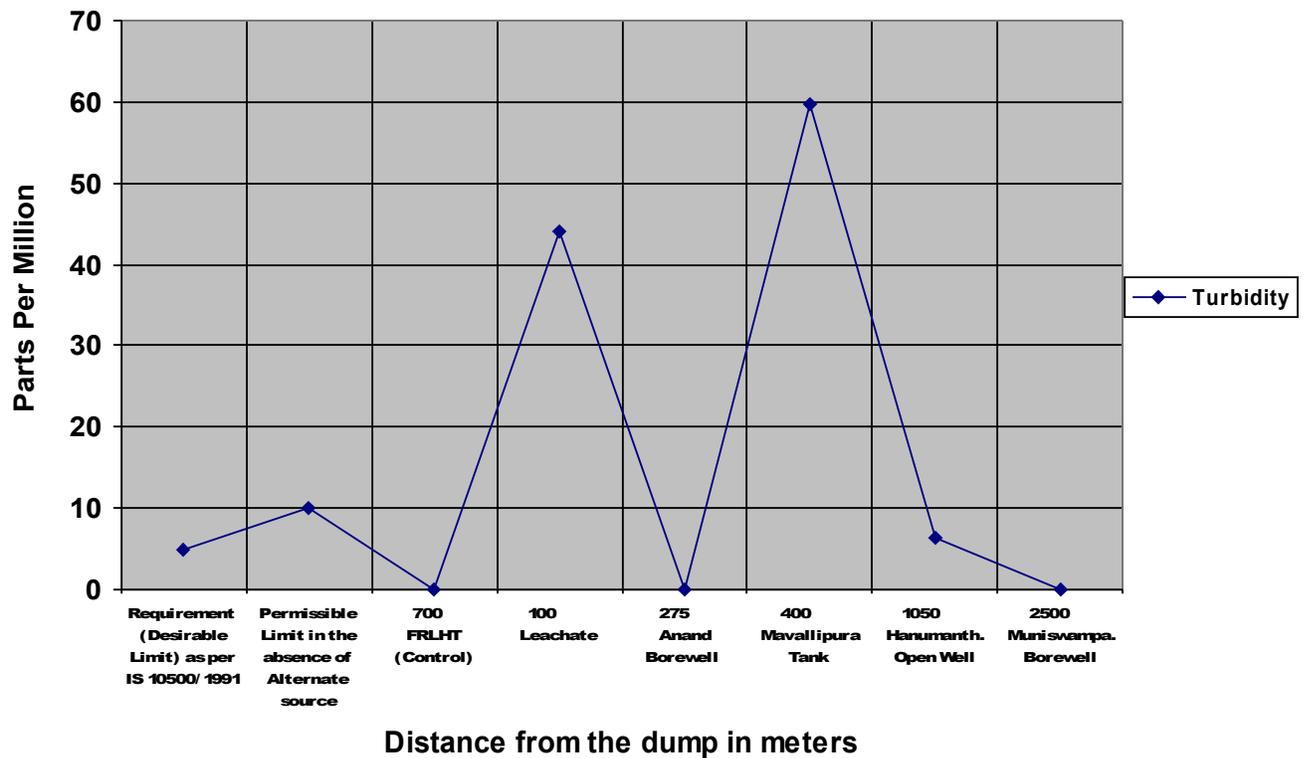


Turbidity:

Turbidity in water is caused by suspended particles that absorb light. Clay, silt tiny fragments of organic matter and microscopic organisms are some of the substances that cause turbidity. Suspended particles can provide hiding places for harmful micro-organisms and thereby affect the quality of water. Turbidity hampers the disinfection process in a waste treatment plant. Turbidity is also unacceptable for aesthetic reasons⁵. Filtration of water is rendered more difficult and costly when turbidity increases⁴.

As can be expected the turbidity is very high in the leachate since it is the water that percolates through a soil and that carries substances in solution or suspension. The Mavallipura tank sample is also turbid beyond the permissible limit. This sample could be turbid because the sample was collected after rains.

Mavallipura Water Test Results - Turbidity



Total Hardness:

Hardness is caused by bicarbonates, chlorides and sulphates (mainly of Ca, Mg and Na) dissolved in water. The hardness caused by bicarbonates is called carbonate hardness or temporary hardness; it cannot be removed by heating. The hardness caused by sulphates and chlorides of Ca and Mg is called permanent hardness since it cannot be removed by heating. Hardness in water hinders lathering of soap/detergent. Salts present in hard waters get deposited alongside water pipes, cooking utensils and water heaters causing inconvenience and maintenance problems. Water with a total hardness greater than 500 ppm is considered hazardous to human health.

Mavallipura Water Test Results - Minerals

Parts Per Million

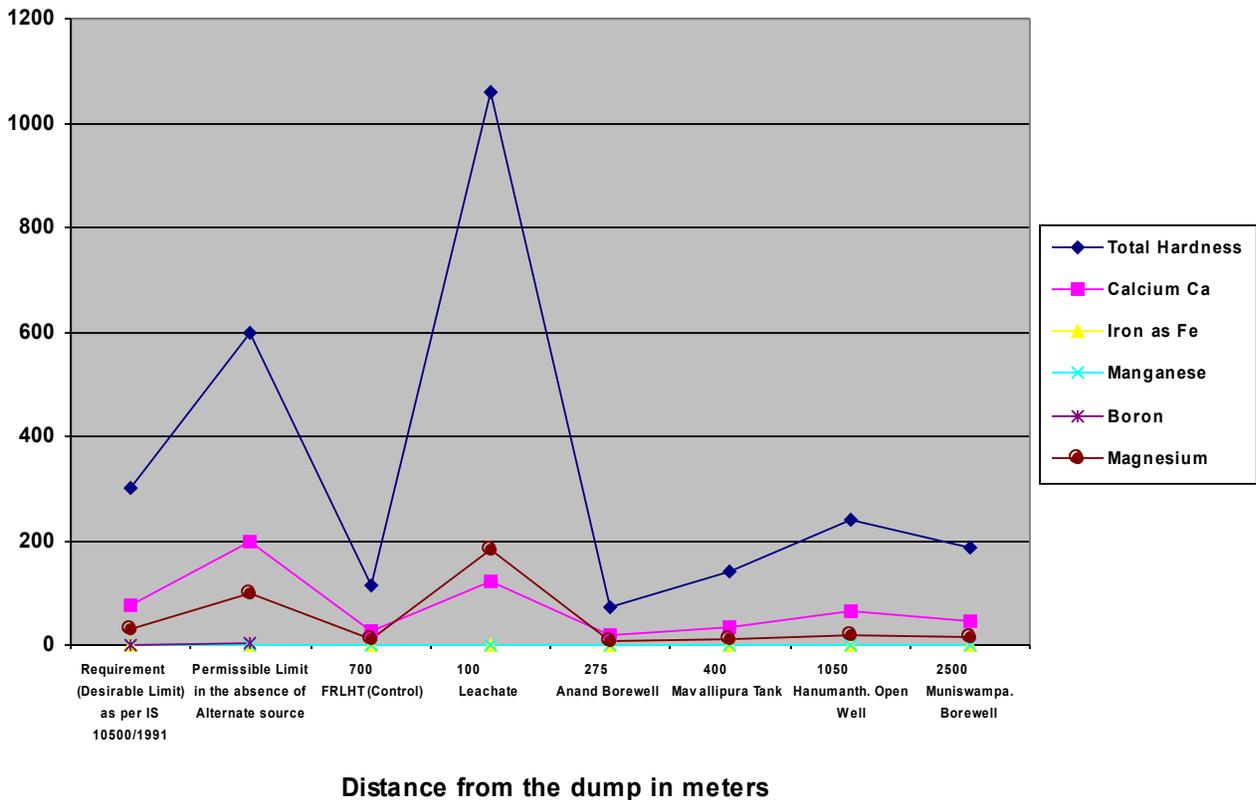


Table I. Classification of water hardness (hardness as calcium carbonate) ²

| | mg/l or ppm | grains/gal |
|-----------------|-------------|-------------|
| Soft | 0 - 17.1 | 0 - 1 |
| Slightly hard | 17.1 – 60 | 1 - 3.5 |
| Moderately hard | 60 – 120 | 3.5 - 7.0 |
| Hard | 120 – 180 | 7.0 - 10.5 |
| Very Hard | 180 & over | 10.5 & over |

Only one sample is above the desirable limit but within the permissible limit. Total hardness in the leachate sample is much higher than the permissible limit but it is not considered as a source of drinking water therefore this limit is not applicable to it.

Iron and Manganese:

Iron exists mainly in soils and minerals mainly as insoluble ferric oxides and iron sulphides (pyrite) It occurs in some areas also as ferrous carbonate (siderite) which is very slightly soluble. Since ground waters usually contain significant amounts of carbon dioxide, appreciable amounts of ferrous carbonate may be dissolved by the reaction shown in the equation



This takes place similar to how calcium and magnesium carbonates are dissolved. However, iron problems are prevalent where it is present in the soil as insoluble ferric compounds. Iron does not dissolve easily in waters with dissolved oxygen even when there are appreciable amounts of carbon dioxide.

As far as known, humans suffer no harmful effects from drinking waters containing iron and manganese. Such waters, when exposed to the air so that oxygen can enter, become turbid and highly unacceptable from an aesthetic viewpoint, owing to the oxidation of iron and manganese to Fe(III) and Mn(IV) state, which can form colloidal precipitates. Oxidation rates may be increased by the presence of certain inorganic catalysts or through the action of microorganisms. Both iron and manganese interfere with laundering operations, impart objectionable stains to plumbing fixtures, and cause difficulties in distribution systems by supporting growths of iron bacteria. Iron also imparts a taste to water supplies which is detectable at very low concentrations.

Manganese exists in the soil principally as manganese dioxide, which is very insoluble in water containing carbon dioxide. Under reducing (anaerobic) conditions, the manganese in the dioxide form is reduced (from an oxidation state of IV to II), and solution occurs, as with ferric oxides.

Manganese is used in ceramics, dry battery cells, electrical coils and iron alloys. Burning of fossil fuels (coal, oil) is the main source of Mn in the environment. The use of manganese in some fertilizers contributes further to air and water pollution¹.

Ground waters that contain appreciable amounts of iron or manganese or both are always devoid of dissolved oxygen and are high in carbon dioxide content. Wells producing good-quality water, low in iron and manganese, start producing poor-quality water when organic wastes have been discharged on the soil around or near the well, thereby creating anaerobic conditions in the soil.

The iron and manganese problem in impounded surface supplies has been correlated with reservoirs that stratify, but occurs only in those, which anaerobic conditions develop in the hypolimnion (the bottom most layer of a thermally stratified lake)⁴.

Both the iron and manganese content in all the samples is much below the permissible limit and desirable limits.

Calcium (Ca) and Magnesium (Mg):

Calcium and Magnesium are the two most common minerals that cause hardness in water. The degree of hardness increases as the amount of Ca and Mg increase in water. Ca and Mg enter water when water passes through soil and water and it dissolves very small amounts and hold them in solution⁴. Even though the human body requires 0.7 to 2.0 grams of calcium per day as a food element excessive amounts can lead to kidney and gall bladder stones. High concentrations of calcium hinder many industrial processes. Calcium also serves an important role in the health of bodies of water. In natural water it is known to reduce the toxicity of many chemical compounds on fish and other aquatic life².

Boron (B)⁹

Borates are widespread, naturally occurring substance found mainly as an inorganic compound in sediments and sedimentary rock. It is released to the environment slowly in low concentrations by weathering processes. Boron is neither transformed nor degraded in the environment, although changes in the specific form of boron and its transport may occur, depending on environmental conditions. Although few data are available quantifying boron releases from industrial sources, it is estimated that natural weathering releases more boron to the environment worldwide than do these industrial sources (Butterwick et al. 1989). Releases of boron to the environment occur from the production and use of boron and boron-related compounds.

Natural weathering of boron-containing rocks is a major source of boron compounds in water (Butterwick et al. 1989). The quantity of boron released varies widely with the geographic variations in boron-rich deposits. Boron compounds are released to water in municipal sewage from perborates in detergents, and in wastewaters from coal-burning power plants, copper smelters, and industries using boron. Borate levels above background may be present in runoff waters from areas where boron-containing fertilizers or herbicides were used (Butterwick et al. 1989; Nolte 1988; Waggott 1969).

Boron has been detected in surface water and groundwater at hazardous waste sites.

Boron is naturally released to soil and water by rainfall, weathering of boron-containing minerals, desorption from clays and by decomposition of boron-containing organic matter. Man-made sources include application of boron-containing fertilizers or herbicides, application of fly ash or sewage sludge as a soil amendment, the use

of waste water for irrigation or land disposal of boron-containing industrial wastes (Butterwick et al. 1989; Hollis et al. 1988; Mumma et al. 1984; Nolte 1988; Rope et al. 1988). No quantitative data were located regarding man-made releases of boron compounds to soil. Landfilling or land application is a common disposal method for sewage sludges.

Environmental Fate

Transport and Partitioning:

Borates are relatively soluble in water, and will probably be removed from the atmosphere by precipitation and dry deposition (EPA 1987c). Boron readily hydrolyzes in water to form the electrically neutral, weak monobasic acid HBO and the monovalent ion B(OH). In concentrated solutions, boron may polymerize, leading to the formation of complex and diverse molecular arrangements. Rai et al. (1986) concluded that because most environmentally relevant boron minerals are highly soluble in water, it is unlikely that mineral equilibria will control the fate of boron in water. Waggott (1969), for example, noted that boron is not significantly removed during the conventional treatment of wastewater. Boron may, however, be co-precipitated with aluminum, silicon, or iron to form hydroxyborate compounds on the surfaces of minerals (Biggar and Fireman 1960). Water borne boron may be adsorbed by soils and sediments. Adsorption-desorption reactions are expected to be the only significant mechanism that will influence the fate of boron in water (Rai et al. 1986). The extent of boron adsorption depends on the pH of the water and the chemical composition of the soil. The greatest adsorption is generally observed at pH 7.5-9.0 (Keren et al. 1981; Keren and Mezuman 1981; Waggott 1969). Bingham et al. (1971) concluded that the single most important property of soil that will influence the mobility of boron is the abundance of amorphous aluminum oxide. The extent of boron adsorption has also been attributed to the levels of iron oxide (Sakata 1987), and to a lesser extent, the organic matter present in the soil (Parks and White 1952), although other studies (Mezuman and Keren 1981) found that the amount of organic matter present was not important. The adsorption of boron may not be reversible in some soils. The lack of reversibility may be the result of solid-phase formation on mineral surfaces (Rai et al. 1986), and/or the slow release of boron by diffusion from the interior of clay minerals (Griffin and Bureau 1974). Partition coefficients such as adsorption constants describe the tendency of a chemical to partition from water to solid phases. Adsorption constants for inorganic constituents such as boron cannot be predicted a priori, but must be measured for each soil-water combination.

Effects on Plants animals and Humans:

Available data for boron are given elsewhere (Rai et al. 1986). In general, boron adsorption will be most significant in soils that contain high concentrations of amorphous aluminum and iron oxides and hydroxides such as the reddish Ultisols in the southeastern United States. It is unlikely that boron is bioconcentrated significantly by organisms from water. A bioconcentration factor (BCF) relates the concentration of a chemical in the tissues of aquatic and terrestrial animals or plants to the concentration of the chemical in water or soil. The BCFs of boron in marine and freshwater plants, fish, and invertebrates were estimated to be less than 100 (Thompson et al. 1972). Experimentally measured BCFs for fish have ranged from 52 to 198 (Tsui and McCart 1981). These BCFs suggest that boron is not significantly bioconcentrated.

Ingestion of boron from food (primarily fruits and vegetables) and water is the most frequent route of human exposure, but occupational exposures to boron dusts may be significant. Boron is also a component of several consumer products, including cosmetics medicines and insecticides.

Boron in water is completely absorbed by the human system, but it does not accumulate in body tissues (Waggott 1969). No other experimentally measured BCFs were located.

Transformation and Degradation

Water:

Elemental boron is inert in the presence of water. Boron compounds rapidly transform to borates, the naturally occurring form of boron, in the presence of water. No further degradation is possible. Borate and boric acid are in equilibrium depending only on the pH of the water. If dissolved in atmospheric water, the standard borate-boric acid equilibria are established.

Soil:

Lead:

Sources of lead in the environment: Lead is found in natural deposits, is commonly used in household plumbing materials and water service lines. However lead plumbing or soldering in water lines is no more used³. Lead is used in the manufacture of pipes, ceramics with lead glazes and alloys used as accumulator plates in storage batteries. Paints, pigments and varnishes, pesticides, lead-borates (used in plastic industries) contain lead. It is also found in anti-knock agents for petrol as well as in petrol itself. Lead can also be found in air and dust; imported food in lead-soldered cans¹ etc. It is rarely found in natural water because of its low solubility therefore its presence in water indicates a possible exposure of the water source to high levels of lead.

It is a well known poison that affects the liver, kidneys, brain, red blood cells, bones and teeth. It has also been speculated to be a carcinogen. Since growing children absorb any lead consumed faster, young children, infants and foetuses are particularly vulnerable to lead poisoning. An amount of lead that would have little effect on an adult can greatly affect a child. Children's mental and physical development can be irreversibly stunted by lead². In youngsters it may result in mental retardation and even convulsions in later life⁴. At low levels lead may not produce any noticeable toxicity in humans and the symptoms can easily be mistaken for flu or other illnesses². Toxicity of Lead is measured by the levels of diffusible forms in tissues especially in blood rather than the total amount of lead in the body. Most of the absorbed Lead is immobilized in the bones, thus not showing and adverse reactions immediately. Bone-Lead concentrations increases with age and any disturbances in osteolysis, tends to liberate the bound-Lead from the skeleton, thus leading to its toxic actions. Chronic exposure to lead causes weight loss, constipation and loss of teeth. Gums may show a blue line due to the deposition of colloidal Pb (PO₄)₂. Lead interferes with the synthesis of Heme in the blood therefore anemia can be the first symptom of chronic lead poisoning¹. Lead is toxic to the central and the peripheral nervous system. Kidney dysfunction occurs due to the impairment of energy metabolism, leading to expression of Fanconi syndrome characterized by an increased loss of aminoacids, glucose and phosphate in the urine due to the inability of the damaged tubular cells to re-absorb these substances). Iron deficiency or a surplus of vitamin D can markedly increase the adverse effects of Pb toxicity¹.

The small particle size of airborne lead makes it is readily absorbable into the blood stream and the absorption through the gastro-intestinal tract is very low. Considering the high toxicity of lead, even the small amounts absorbed through the GI tract can cause significant damage to the body.

Lead affects soil micro-organisms more among aquatic invertebrates and plants by retarding the heterotrophic breakdown of organic matter. Increase in pH reduces the concentration of available Pb in water, which in turn decreases its toxicity to the aquatic biota. Most of the water samples collected around the Mavallipura dump showed slightly more basic pH so that unless the water is exposed to high levels of lead it is not likely to have a proportionally high concentration of Pb.

Leafy vegetables such as lettuce, spinach, potatoes and beans are likely to absorb more lead, whereas fruiting crops such as tomatoes, corn, beans, brinjal and chilli do not pick up any appreciable amount of lead through their root systems at all. The organic content in the soil has been found to be inversely proportional to the rate of uptake of lead in soil. It has been found that in soils containing large quantities of organic matter i.e., >40-50%, the lead uptake is nil even when the Pb concentration is as high as 3000 ppm. Therefore it is advisable to use organic manure in places that are exposed to high levels of lead¹.

Cadmium:

Cadmium is almost always found as an impurity with Zinc ore. It is usually a by-product from mining, smelting, electroplating, pigment, and plasticizer production can contain cadmium that makes its way into water through effluent discharge from these industries. Cadmium makes gets into the water supplies as a result of deterioration of galvanized plumbing, industrial waste or fertilizer contamination⁵. Cadmium in the air comes from emissions from fossil fuel use. Cd is used in the manufacture of alloys, electroplating, Ni-Cd batteries and paint pigments. Other sources of Cd in water are Cd –containing industrial wastes.

Even at low levels of exposure over prolonged periods, it causes high blood pressure, sterility among males, kidney damage and flu-like disorders. About 1-2% of ingested and 11% of inhaled Cadmium is retained in the body. There is an inverse relation between the amount of Ca in the body and the absorption of Cd. Since a third of the absorbed Cd is stored in the kidney it is the organ that is affected the most. Cd is a potent enzyme inhibitor and is known to interact with sulph-hydryl (-SH-) groups of several enzymes. Hypertension, respiratory disorders, damage to liver and kidney are the symptoms of Cd poisoning. Cd is also known to be teratogenic in many animal species and carcinogenic to humans.

Two samples, the leachate and the Mavallipura tank water show concentrations that are higher than permissible limit. The Mavallipura tank is down stream from the leachate pond and therefore the presence of high levels of cadmium is an indication that the leachate may have contaminated this surface water body which is one of the nearest to it.

Copper (Cu):

Copper is an essential trace metal that is ubiquitous in the earth's crust. It occurs primarily as its sulphide or oxide ores. Water pollution by copper results from the discharge of mine tailings and flyash, which also forms a major source of solid Cu-contamination). Fertilizer production and disposal of industrial/municipal sewage wastes represent minor sources of copper in the environment.

Copper is necessary for the normal biological activities of amine oxidase and tyrosinase enzymes. Amino oxidase is involved in the formation of two proteins—elastin and collagen; elastin is the major protein constituent of the walls of large blood vessels and collagen is the proteinaceous component of tendons and bones. The latter Cu-containing enzyme, tyrosinase, is required for the catalytic conversion of tyrosine to melanin, the pigment located beneath the skin protecting it from radiation injuries. People lacking tyrosinase cannot produce melanin and thus would be extremely sensitive to sunlight and probably be prone to early death. The recommended daily intake of copper ranges from 2 to 3 mg. The impairment of daily ability to absorb copper resulting in its deficiency is called Menke's disease whereas Wilson's disease is its opposite (i.e., excessive accumulation of copper).

Ingestion of 15-75 mg of copper causes gastrointestinal disturbances. The intake of large quantities of copper salts may cause hemolysis, hepatotoxic and nephrotoxic effects. Copper toxicity could be aggravated by low dietary molybdenum or zinc¹.

Copper is essential for the synthesis of chlorophylls and for the functioning of certain enzymes. At the same time, at slightly higher levels it can be more toxic to plants than any other heavy metal except mercury; inhibition of growth occurs even at <0.1 mg/L, regardless of test conditions and plant species. Plants generally absorb high amounts of copper in the presence of Ca⁺⁺ and Mg⁺⁺ ions, but the uptake is suppressed when H⁺ ions are present in the soil solution. Bluegreen algae are particularly susceptible to copper because copper at high levels inhibits the nitrogen-fixing properties of these algae¹.

Concentrations near 1.0 mg/L can be toxic to some fish. It tends to be much more of an environmental hazard than human hazard.

None of the samples show significant amount of copper and the copper concentrations are well within the permissible limit.



Waste being burned causing serious air pollution and releases toxins into the atmosphere

Mercury (Hg):

Mercury is a rare element and constitutes less than 0.00003% by weight of earth's crust. Mercury is used in the manufacture of vinyl chloride, chlor-alkali (used in the manufacture of chlorine and caustic soda), electrical (in making electrical switches, batteries and fluorescent light bulbs) and electronic (in the manufacture of "long life" alkaline batteries) industries¹. It is also used in the manufacture of electric apparatus, industrial control instruments, agricultural and industrial poisons, catalysts, preservatives, antifouling paint in thermometers, barometers, manometers, mercury vapour lamps, boiler, turbines and in the manufacture of explosives⁸.

Inorganic mercury released into the environment is converted to more toxic methyl mercury compounds by the action of certain anaerobic bacteria; this transformation occurs in the sediments and bottom muds of flowing waters¹.

Mercury in its inorganic form attacks mainly liver, kidneys whereas organo-mercurials traverse through the biological membranes and concentrate especially in the brain. Alkyl mercurials are much more toxic than inorganic forms. Alkyl mercurials tend to accumulate when taken in small quantities and eventually attack the nervous system. A concentration of 6 pm in the brain cells can cause irreversible brain damage. The biological half-life (the time required for something to fall to half its initial value (in particular, the time for half the atoms in a radioactive substance to disintegrate) ethylmercury is much longer (70-74days) than that of inorganic forms (5days). Mercury is a teratogen (any agent that interferes with normal embryonic development thereby causing birth defects), capable of inducing abortions and embryonic defects¹.

Grain seeds dressed with agrochemicals accumulate mercury via translocation. Hens fed with mercury pretreated crop-seeds could concentrate the metal in their livers and eggs. Mercury is concentrated up through the food chain; hence even amounts only slightly above those ordinarily found on sediments could be potentially dangerous.

The Minimata outbreak in the Minimata bay of Japan during the 1950s made the world aware of the poisonous effects of mercury⁴. Minimata is a neurological disorder caused by the consumption of methylmercury compounds¹.

None of the samples show significant amount of mercury and the mercury concentrations are well within the permissible limit.

Arsenic (As)

Arsenic exists mainly as its sulphide ore, arsenopyrite. Arsenous oxide (As_2O_3), known as white arsenic, is generated as a by-product of in the smelting of lead, copper and gold ores¹. It is also used as an alloying agent for heavy metals in special solders; doping [Deliberately adding a very small amount of foreign substance to an otherwise very pure semiconductor crystal. These added impurities give the semiconductor an excess of conducting electrons or an excess of conducting holes (the absence of conducting electrons) which is crucial for making a working transistor] agent, in silicon and germanium solid state products, smelting of ore, hardening of Pb for battery grids, manufacture of pottery glass, rodenticide, insecticide, wood preservative pigments, tanning and pharmaceuticals⁸. It constitutes about 97% of all the arsenic produced and used in end-product manufacturing. Copper acetoarsenate, another ore known as Paris green is used to a lesser extent as a feed additive.

Arsenic occurs in natural water in the form of Arsenous acid (H_3AsO_3) and its salts. Arsenic is quite widely distributed in natural waters (occurring at levels of $5\mu\text{g/L}$ or more in approximately 5 percent of those tested). Arsenic gains access to the water environment through mining operations, the use of arsenal insecticides, and from the combustion of fossil fuels, where part of the fallout occurs on aquatic areas. Arsenic poisoning (arsenicosis) can range from pigmentation (white or dark spots on the skin), skin hardening and development of raised wartlike nodules (keratosis), and skin cancer. Other resulting problems are peripheral vascular disease (blackfoot disease), resulting in gangrene, hypertension and ischemic heart disease, liver damage, anemia and diabetes mellitus⁴.

The worst arsenic-related drinking water problems have occurred in West Bengal in the late 1980s. Because of dense populations and lack of access to safe drinking water, 4 million tubewells were installed in the 1970s in Bangladesh to tap better-quality groundwater sources. While this resulted in halving a high infant mortality rate, in 1993 the tubewell water was found to contain high levels of arsenic, at places reaching up to $3000\mu\text{g/L}$. Around 5000 patients were identified with arsenic-related health problems in West Bengal⁴.

None of the samples show significant amount of arsenic and the arsenic concentrations are well within the permissible limit.

Zinc (Zn)

Zinc is used in the manufacture of dry batteries, construction materials, pigments and printing processes. It is also used for protective coatings on iron, steel, brass and alloys. Municipal refuse and automobiles (tire wear, fuel additives, brake linings and motor oils) serve as additional pollution sources. Agricultural use of $ZnSO_4$ – containing pesticides and fungicides may be yet another source of zinc in the environment.

Zinc is an essential trace metal to all organisms, as it is necessary for the functioning of various enzymes. It is normally present in the body in metallo-enzymes and other enzymes that take part in the synthesis of DNA, proteins and insulin. Thus zinc is necessary for the normal functioning of the cell, including protein synthesis, carbohydrate metabolism, cell division and growth. 15mg and 10mg of zinc is the recommended daily allowance for an adult and a child respectively. Large doses of zinc salts (220-440 mg of Zn as $ZnSO_4$) cause gastrointestinal disorders including vomiting and diarrhea.

Fishes exposed to zinc generally accumulate it in the gills, gut and liver. Older fishes seem to be highly resistant to zinc poisoning compared to the young ones. Accumulation does not occur in many invertebrates. Under most conditions Zn is less toxic than Hg, Cd, Cu, Cr, Ni or As to aquatic invertebrates¹.

Zn plays a very important role in plant nutrition, it being a component of a number of metallo-enzymes¹ (enzymes in which metals may be a co-factor or may be incorporated into the molecule as a metallo-enzyme).

None of the samples show significant amount of zinc and the zinc concentrations are well within the permissible limit.

Chromium (Cr+6)

Chromium is an ingredient of many of stainless steel but also of other alloys. It is used in leather tanning, explosives, ceramics, paint pigments, photography, wood preservation¹. Wastes from these industrial units can be a source of water pollution by soluble chromate salts. It is used in the manufacture of alloys, refractories, catalysts, chromic oxide, and chromate salts (used in paints and to produce “cleaning solution” in laboratories)⁴. Fertilizer materials, which at times contain as much as several thousand ppm of Cr, are additional sources of water pollution.

Chromium in its trivalent [a property of atoms or radicals; their combining power given in terms of the number of hydrogen atoms (or the equivalent)] form is essential to humans and animals. Since it plays an important role in the insulin metabolism as the GTF (Glucose Tolerance Factor), supplementation of Cr helps normalize or improve glucose tolerance in diabetes, older people and malnourished children. There is no conclusive evidence on the toxic effects of chromium in the trivalent state.

The adverse effects of Chromium are mainly associated with the hexavalent forms, which are highly toxic to humans. Exposure to hexavalent chromium causes dermatitis, allergic skin reactions and gastro-intestinal ulcers. Cr (IV) is a teratogen and a carcinogen (a substance capable of inducing cancer in an organism). The toxicity of Cr(=6) to aquatic organisms is generally low; chromium is relatively less toxic than Cd, Cu, Pb, Hg, Ni or Zn effects of Chromium than older aquatic species, especially invertebrates. Though the rate of uptake is very high in young fishes, Cr burdens progressively decline with age of fishes through elimination from their bodies. Chromium does not occur as a contaminant of concern in plant tissue except at site-specific discharge points. The algae are generally susceptible to the toxicity and accumulation of Cr. Chromium at 10ppm levels in water is considered to be lethal to several species of algae¹.

Aluminium (Al)

Aluminium is produced in the largest quantities in India. Aluminium is used extensively for canning, food packaging, and as a foil for covering and preserving foodstuffs. Contamination of the environment with aluminium may result from the indiscriminate disposal of aluminium products and wastes.

Aluminium at levels 15 µg/ml in water causes anorexia, decreased activity, gill hyperplasia (an abnormal increase in tissue growth caused by excessive cell division) and mortality in fishes. Aluminium in its dissolved form is more toxic than the suspended form.

Aluminium is injurious to plants, when the soil pH is less than 5 Aluminium in soil injures crop roots, making them stubby and brittle The affected roots are thick and lack fine branching, thus cannot efficiently absorb water or nutrients seedlings are more susceptible to the toxic effects of aluminium than are more toxic than suspended form.

INORGANIC COMPOUNDS

Cyanide (CN)

Cyanide occurs as free cyanide (CN⁻), cyanide salts (e.g., NaCN) or other complex cyanides (e.g., metalocyanides)

Principal sources of cyanides in the environment are the metallurgical and ore extraction industries. Sodium and Potassium cyanides are used in the extraction of gold and silver ores. Calcium cyanide is used as a fumigant. Gold mines and iron and steel manufacturing units are the main contributors of cyanide in the environments. Other sources include petrochemical, metal electroplating & finishing, photographic processing and combustion from various solid wastes.

Cyanide radicals (radical: two or more atoms bound together as a single unit and forming part of a molecule) are produced by numerous plants. Only free cyanide has toxicological effects. At acutely toxic levels, cyanide is respiratory poison. Cyanide is toxic to enzyme systems. Cyanide causes problems in the oxidation of nitrogen in the anaerobic conditions in wastewaters that contain large amounts of organic matter or nitrogenous wastes. In the presence of cyanide, nitrogenous substances are incompletely oxidized to nitrite rather than completely to nitrate. Nitrate is a potent inducer of methemoglobinemia (A condition of the blood in which there are large amounts of methemoglobin which is an altered hemoglobin which does not carry oxygen.) in humans; this condition leads to the reactions in the red blood cells that reduce their oxygen-carrying capacity. The same condition causes physiological stress in animals¹.

Cyanide gains access to water environment through the discharge of rinse waters from plating operation and from refinery and coal coking waste waters. The cyanide ion has a relatively short half-life (The time required for the amount of a reactant to decrease to half its initial value) because it can serve as a source of energy for anaerobic bacteria, provided the concentration is kept below its toxic threshold to them.

Sulphate as SO₄:

The sulphate ion is one of the major anions (positively charged ions) occurring in natural waters. It is important in public water supplies because of its cathartic (strongly laxative) effect on humans when it is present in excessive amounts. Sulphate is important even in industrial water supplies because of the tendency of water containing appreciable amounts of sulphate to form hard scales in boilers and heat exchangers. Sulphate poses odour problems because of the formation of hydrogen sulphide with water in the absence of oxygen (anaerobic conditions) and nitrate. It tends to corrode sewers as well.

Chloride (Cl):

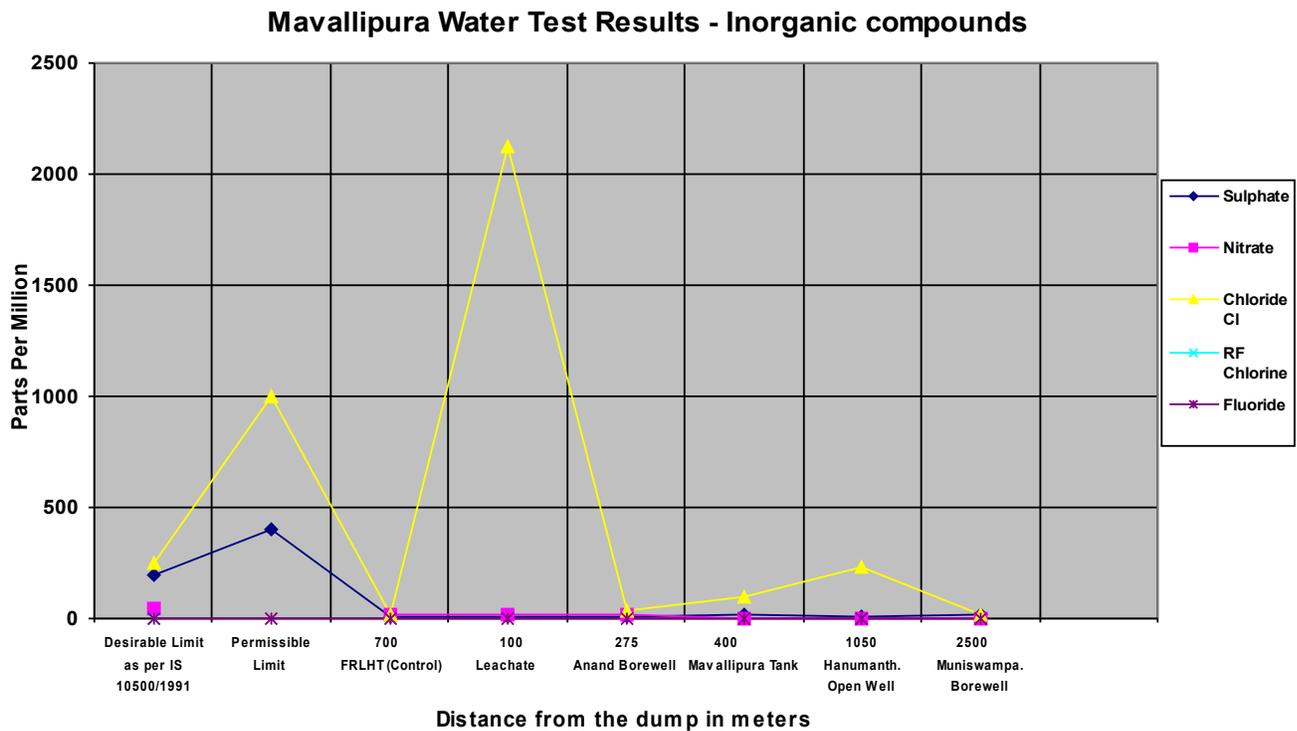
Chloride occurs in all natural waters in widely varying concentrations. The chloride content of water increases with increase in the mineral content of the water. River and ground waters usually have high concentrations of chloride whereas upland and mountain water sources have very low concentrations of the same. There are many ways in which chloride salts gain access to natural waters. The water with its high solubility dissolves chloride from topsoil and deeper formations. Spray from the ocean is carried inland as is carried inland as droplets or as minute salt crystals, which result from the evaporation of the water in the droplets. These sources constantly replenish the chloride in inland areas where they fall⁴. The presence of relatively high chloride

concentration in fresh water (about 500 mg/L or more) may be an indication of sewage pollution. Salt (NaCl) used in foods, is excreted with body wastes; sewage carries these chlorides into the receiving waters. Chlorides from roadway deicing salts may enter the groundwater as well as streams and lakes⁵.

Chloride in reasonable concentrations is not harmful to humans. At concentrations above 250mg/L it gives a salty taste to water, which is objectionable to many people.

The chloride content of waters used for irrigation of agricultural crops is important since chloride content along with salinity at the root zone of irrigated plants makes it difficult for crops to take up water due to osmotic pressure differences between the water outside the plants and within the plant cells⁴.

The chloride content in the leachate is very high and above the permissible limit and another sample, which is from an open well, is above the desirable limit as per IS 10500 standards for drinking water.



Residual Free Chlorine:

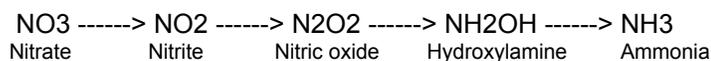
Chlorine, Cl₂, does not occur naturally in water. It is however one of the most common chemicals added to water and wastewater, primarily for disinfection⁵. Chlorine is to disinfect water prior to it being discharged into the distribution system. When chlorine is fed into the water, it reacts with any iron, manganese, or hydrogen sulphide that may be present. Any chlorine remaining is called residual chlorine. Residual chlorine reacts with organic materials, including bacteria. This amount is usually adjusted to make sure there is enough chlorine available to completely react with all organics present. The chlorine concentration decreases with distance from the source, until it reaches the point where the chlorine level can become ineffective as a disinfectant. Bacteria begin to grow in distribution systems when very low levels of chlorine are encountered. Therefore it is important to make sure there is enough chlorine to effectively disinfect even at the far ends of the distribution system. Chlorination can kill many pathogenic microorganisms such as *E.coli*, but others like *Cryptosporidium* and *Giardia*, are very resistant to chlorine and require other measures to properly remove them⁷.

Nitrate as NO₃:

Nitrates are nitrogen-bearing molecules that are essential for the formation of proteins in plants since plants other than legumes cannot absorb free nitrogen from the atmosphere. Proteins are made up of carbon, hydrogen, oxygen and nitrogen and are necessary for growth and development and for various metabolic

processes. Hormones, enzymes and haemoglobin in humans are made up of proteins. Nitrates are added to the soil as fertilizers (ex: sodium nitrate and ammonium nitrate) to increase crop yield. Plants accumulate and retain the excess available nitrate in the soil in their tissues.

In doses between 5 to 10 mg/kg of bodyweight does not produce any significant toxic effects in humans. But at levels of 20mg/kg of bodyweight could be lethal. Rather than nitrate itself, the metabolic products of nitrates produce toxicity.



Nitrite and Hydroxylamine are inducers of Methemoglobinemia. It is a condition wherein ferrous iron in the blood is oxidised and thereby loses its oxygen-carrying capacity which leads to hypoxia and death. Monogastric animals have relatively high tolerance to nitrate since reduction to nitrate in their bodies is minimal. Human babies are at a high risk of nitrite toxicity because they do not have free HCl in their stomach and therefore nitrate is readily reduced to nitrite by the bacteria in the stomach and the duodenum¹.

Sources of nitrate water apart from fertilizers are sewage, soil and mineral deposits⁵.



Smoke emanating from the dump

Fluoride as F:

Fluorides such as HF, SiF₄ and H₂SiF₆ are emitted by phosphatic fertilizer manufacturing plants and aluminium reduction processes. Fluoride-containing minerals are often used in and thus may be released from brick steel, glass, pottery, tile and ferro-enamel works. Fluoride as a particulate and HF as a gaseous air pollutant are highly toxic and irritating. Only a fraction of the fluoride entering the body is excreted and the a larger amount of it is retained in the body. Fluorides are mainly deposited in the body in bones and teeth. As soon as the skeleton is saturated with fluoride, it starts to accumulate in the soft tissues as well. Overdose of ppm fluorides i.e., 2 ppm levels in drinking water in temperate regions and 0.4-0.7 in tropical regions may lead to mottling of enamels and bones.

Fluorides cause respiratory failure, fall in blood pressure and general paralysis. Continuous ingestion of non-fatal doses of fluorides causes permanent inhibition of growth.

A few cases of 'crippling fluorosis' have been reported in China and India at places where the surface water have been contaminated upto 10 ppm of fluoride. This type of fluorosis is characterised by hypermineralization of the skeleton, body outgrowths (exostoses) and calcification of ligaments. These conditions are followed by painful joints and immobilisation.

Many plants apricot, gladiolus, peach and prune are extremely sensitive to HF even at concentrations as low as 0.02-0.05 ppm. Orange and lemon trees exposed to fluoride emissions produce smaller yields while gladiolus turn brown or die on exposure to fluorides. More than 2 dozen plants are known to synthesize fluoroacetate which is a highly toxic and is used in rodenticides.

Livestock have been the main victim of fluoride poisoning as a result of ingestion of contaminated vegetation.

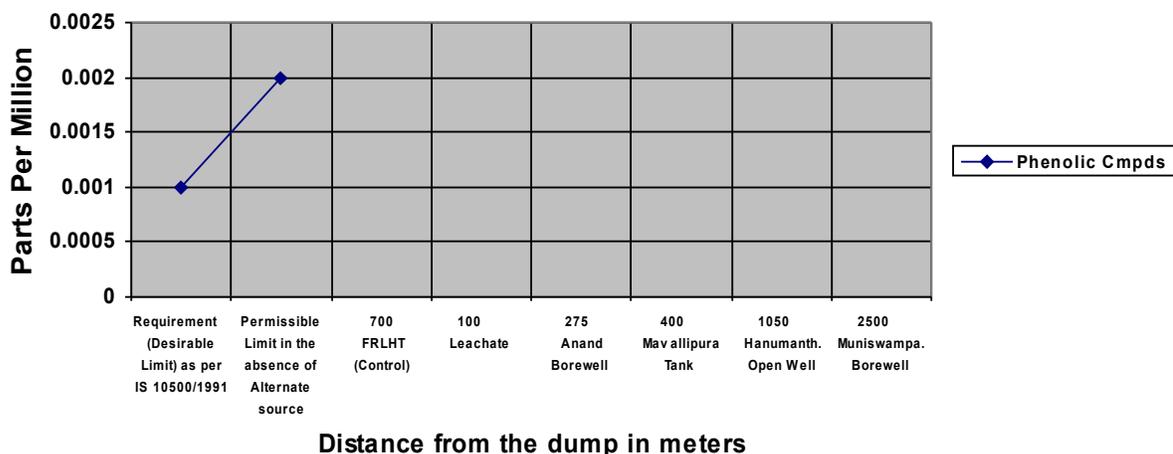
Natural background levels of fluorides in most freshwater streams are in the range of 0 to 0.2 ppm while other data show levels as high as 2-3 ppm may fairly be common in waters contaminated by human activities¹.

The fluoride concentrations in the water sample are well within the permissible limit in all samples except the leachate where it is above the permissible limit.

Phenolic Compounds as C₆H₅OH:

Phenolic compounds are a class of chemical compounds consisting of a hydroxyl group (-OH) attached to an aromatic hydrocarbon group. Common examples of Phenolic compounds or phenols are phenol, BHT (butylated hydroxytoluene, cresols, Xylenols, 4-Nonylphenol, picric acid, polyphenols etc.

Mavallipura Water Test Result - Phenolic compounds



Transport of contamination in ground water:

The sub-surface movement of a contaminant is influenced by the moisture of content of the unsaturated zone. Non-reactive contaminants are transported by advection and hydrodynamic dispersion. Advection is the component of solute movement attributed to transport by the flowing ground water. Hydrodynamic dispersion occurs as a result of mechanical mixing and diffusion. A continuous pollution source will produce a plume whereas a single point source will produce a slug that grows with time as the plume moves in the direction of groundwater flow. The chemical and biochemical reaction that can alter contaminant concentration in groundwater are acid-base reactions, solution-precipitation reactions, oxidation-reduction reactions, ion pairing or complexation, microbiological processes and radioactive decay. Adsorption attenuates or retards a dissolved contaminant in ground water.

Coliform bacteria:

The presence of *E.coli* in water is used as an indicator of fecal contamination originating from the intestine of warm-blooded animals, which includes humans. *E.coli* belongs to a class of bacteria called the coliform bacteria. The term Coliform bacteria includes the genera *Escherichia* and *Aerobacter* some of which are found even in soil. Therefore there is a presumptive and a confirmed test for the presence of the broad category of total coliforms and fecal coliforms respectively and a completed test for the presence of *E.Coli*. The MPN or

Most Probable Number Test gives us an approximate number of coliform organisms present in a volume of water thereby indicating the extent of fecal contamination.

All the samples tested, except the control sample, show higher than permissible numbers of total coliform bacteria. As per standards under the IS 10500 only 10 coliforms per 100ml and those under US Water Quality Act (1965), only water with less than 50 coliforms per 100ml is suitable for drinking. This indicates the contamination of the water source by an outside source. However, all samples are negative for the presence of fecal coliforms and E.Coli. The contamination could be an indicator for the probable presence of other pathogenic bacteria.



Solid waste segregation and processing unit under construction next to the dump

Further study:

The health problems faced by the residents of Mavallipura (since the dumping began) as found during the health camps conducted by FRLHT need to be studied more thoroughly. An epidemiological survey is immediately required in parallel with a thorough analysis of environmental parameters such as water quality, air quality and soil quality. Soil quality is important to plant life and soil microbiology. The consequences of heavy metal contamination can be felt not only through consumption of contaminated water but also by consuming plants that take up heavy metals.

The dump has brought with it flies and other insects that have disturbed the ecology in the area and crop plants suffer the lack of pollinators. Large doses of pesticides have to be used so that crops can grow normally. Vultures and kites have also been introduced newly into the local ecology. How the dumping of waste has affected the ecology in the area and whether this change can cause a permanent damage needs to be studied.

Conclusion:

There are many contaminants that can potentially contaminate the water sources as indicated by the very high levels of certain parameters in the leachate sample since it is through the leachate that the contaminants from the waste dump is likely to reach the water sources. In the report, such parameters that are above the permissible limits in one or more samples and those that can pose a serious health risk, such as bacterial infection and heavy metal contamination, are discussed in greater detail.

It is evident from the test results that there is contamination of ground water as surface water shown by the level of Cadmium in Mavallipura tank which is down stream from the leachate pond. The ground water samples as well as an open water sample that are used for drinking show only high coliforms numbers but do not show the presence of E.coli which implies that there is no contamination with sewage.



Agricultural productivity has dramatically dropped due to the waste dump

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