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Looking forward to receive your manuscript or advertisement,

Yours sincerely,

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HARVESTING RAINWATER WITH A GROUP OF HOUSES TO RECHARGE GROUNDWATER RESERVOIR

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Abstract

Many places in the world face acute scarcity of fresh water in both terms of quantity and quality. The overexploitation of groundwater is a serious global problem. Rooftop rainwater harvesting (RRH) requires connecting the outlet pipe from the roof top to divert collected water to existing well, tube well, bore well or a specially designed well. Urban housing complexes and institutional buildings having large roof area or a group of residential buildings can be utilised for RRH. The Central Groundwater Board of India has suggested several methods of RRH for individual houses and multistory buildings only. We have designed RRH techniques for housing complexes that are useful for a group of residential buildings. Rainwater is the purest form of natural water. It can be used as recharge water without any treatment. The water used for aquifer recharge can be taken from any source but it must be pure like rainwater or drinking water. It should not have even soil, sand and silt in it. Recharge water should be surely silt free. Filters remove particulates. If germs are present in the collected rainwater, it should be UV irradiated or ozonized before using it as recharge water. Strict regulations regarding aquifer recharge are required. Harvest the rain. Wrangle water from the sky for watering, washing and even drinking by using a RRH system.

Keywords: Roof, rainwater, harvesting, houses

INTRODUCTION

Roof rainwater harvesting (RRH) is a process of capturing rainwater off a roof and storing it for future use. It is rainwater capture and storage for reuse as it falls onto a roof surface of a building (Standards Australia 2006). If used for drinking, roof materials must be compatible for contact with drinking water (Colorado Division of Water Resources 2009). Water harvested from a roof catchment can be improved in storage from a natural distillation process. Risk to water quality can be from airborne particles and from man-made air pollution. Rooftop catchment systems gather rainwater from the roofs of houses, schools, etc., using gutters and downpipes (made of local wood, bamboo, galvanized iron or PVC), and lead it to storage containers that range from simple pots to large ferrocement tanks. If properly designed, a foul-flush device or detachable downpipe can be fitted that allows the first litres of runoff from a storm to be diverted from the storage tanks. The runoff is generally contaminated with dust, leaves, insects and bird droppings (Rainwater Fact Sheet 2007). Sometimes the runoff is led through a small filter of gravel, sand and charcoal before entering the storage tank. Water may be abstracted from the storage tank by a tap, hand pump, or bucket-and-rope system (WHO et al. 2003).

RRH requires connecting the outlet pipe from the roof top to divert collected water to existing well, tube well, bore well or a specially designed well (TWDB 2005; WHO et al. 2003; CGWB 2000). Its components are catchment area (roof); conveyance system (guttering, downspouts, and piping); storage (cistern or tank); filtration and distribution. The storage tank can be as simple as directing gutters to a lidded garbage can or as complex as a concrete cistern, roof washer and filtration system (Camilli 2000). So it involves the main cost of the entire recharge system. Retrieving water from the tank can be done by gravity, if the tank is high enough, or by pumping, similar to the method used to withdraw and pressurize water from a well. Taking the process further, runoff could be collected and stored for use in the immediate facilities, thereby reducing city-supplied volumes, or for sending water back to the municipal facilities. If the infrastructure could be created or modified to direct runoff to city storage facilities, that water could be treated and added to the potable supply. Cities that currently have underground drainage systems might continue those systems to direct the flow to wherever they can store the high volumes associated with hard surface runoff (Vani et al. 1997). Urban housing complexes and institutional buildings having large roof area or a group of residential buildings can be used for RRH.

The Central Groundwater Board of India has suggested several methods of RRH for individual houses and multistory buildings (CGB 2000). The present study aims to depict RRH techniques for housing complexes that are useful for a group of residential buildings or a colony. RRH gives pure water at very low cost.

RAINWATER ENDOWMENT AND HARVESTING POTENTIAL

The total amount of water received as rainfall over an area is called the rainwater endowment of that area. Out of this, the amount that can be effectively harvested is called water harvesting potential.

Water harvesting potential = Rainfall (mm) × Collection efficiency

Many factors affect collection efficiency. The amount of rain is the main factor. Three-hundredths to one-tenth of an inch of rain is needed to wet the roof and fill the roof washer, some of the rain overshoots the gutters or spill out of the gutters during heavy downpours. Other factors are capacity of storage tanks, runoff coefficient, the first flush wastage etc. Efficiency is usually presumed to be 75% to 90% depending on system design and capacity.

Volume of rainfall over the rooftop = Area of rooftop × Average annual rainfall × Runoff coefficient

WATER QUALITY

As rainwater may be contaminated, it is often not considered suitable for drinking without treatment. However, there are many examples of rainwater being used for all purposes — including drinking — following suitable treatment.

Rainwater harvested from roofs can contain animal and bird faeces, mosses and lichens, windblown dust, particulates from urban pollution, pesticides, and inorganic ions from the sea (Ca, Mg, Na, K, Cl, SO_4), and dissolved gases (CO_2, NO_x, SO_x) (Magyar et al., 2008). High levels of pesticide have been found in rainwater in Europe with the highest concentrations occurring in the first rain immediately after a dry spell. The concentration of these and other contaminants are reduced significantly by diverting the initial flow of water to waste as described above. The water may need to be analysed properly, and used in a way appropriate to its safety. In Brazil alum and chlorine is added to disinfect water before consumption. So-called "appropriate technology" methods, such as solar water disinfection, provide low-cost disinfection options for treatment of stored rainwater for drinking. Harvested rainwater can be boiled in parabolic solar cookers before being used for drinking.

DECONTAMINATION AND DISINFECTION

Rainwater is the purest form of natural water. It can be used for aquifer recharge without any treatment. The water used for this purpose can be taken from any source but it must be pure like drinking water or rainwater. It should not have even soil, sand and silt in it. Recharge water should surely be silt free. If germs are present, it should be UV irradiated, ozonized or chlorinated before using as recharge water.

There are many filtration methods and roof-wash systems for decontamination that vary according to intended use. One method uses a floating filter connected to a flexible water line inside the tank. This method withdraws water from approximately 30 cm below the surface, considered to be the cleanest water 30 cm in any body of water. The water to be used for human consumption can pass through an inline purification system or point-of-use water purification system such as an ultraviolet filter. Uses other than for human consumption do not require any purification.

Preliminary filtration and a roof-wash system provide the first line of defense against contamination. RH systems supplying potable water also should include measures to treat water before use (Hartsung, 2002). Several treatment options including microfiltration, UV sterilization and ozonation, are available. Many experts agree that filtration and UV treatment provide adequate protection, making ozonation unnecessary.

Most systems use a combination of physical filters which remove particulates, and a UV-light chamber which kills bacteria and other organisms by exposing them to high-energy ultraviolet light.

A less expensive option is to treat water with chlorine or iodine, as is typically done with municipal water. The most common chemical added is chlorine in the form of sodium hypochlorite which is available in liquid form. Household bleach which is 5% sodium hypochlorite, is commonly used. Chlorination spoils the taste of the treated water and harms human health with harmful chemicals that could result from the added chlorine. In the presence of organic matter, chlorinated hydrocarbons may be formed which are suspected carcinogens.

ROOF WASHER

Between rainstorms, various pollutants can settle out of the air and onto the roof. Many RH systems incorporate a roof washer to keep these contaminants from entering the tank. Roof washers capture and discard the first several gallons of rainwater during a storm before conveying the rest to the tank. A very simple roof-wash system can be made out of a 15- or 20-cm vertical PVC or polyethylene pipe installed beneath the gutter with an inlet just above each downspout to the tank.

AWARENESS

Awareness campaign is essential for RRH (Anon 1998). It needs:

- ❖ Educational materials from government agencies, NGOs and the aqiufer communities
- ❖ Aquifer issues to be brought into primary and secondary school classrooms, and to environmental educators at museums, state parks, market places, and soil and water conservation districts.
- ❖ Numerous presentations and workshops
- ❖ Education to landowners, local government officials, utility managers, citizens groups, and the public about source water issues.
- ❖ Printed materials, TV documentaries and a website for wider dissemination about

MONITORING

Regular monitoring of rainwater, harvesting system particularly water in the storage tank and groundwater in the aquifer is required (Agarwal 1998). The following points should be kept in mind:

- *Water parameters:* COD, bacteria, nitrate, fluoride, arsenic, heavy metals, pesticide and excess nutrients
- *Techniques:* Isotopic analysis, antibiotic resistance analysis and general water quality testing
- *Detailed evaluation:* The extent and land use of the recharge area, and surface and groundwater movement in the basin including mobility, persistence and distribution of toxics
- *Environmental compartments:* Water, soil, food, air and biota to obtain baseline values and trends over time
- *Data use:* Validating predictive models like Aquifer Vulnerability Assessment (AVA)

ROOF AS THE MOST COMMON RAINWATER CATCHMENT SYSTEM

The roof of a building is the most common rainwater catchment system, though a separate building designed especially for rainwater harvesting (a "water barn") may be used.

The best roofing material for rainwater catchment is uncoated stainless steel or factory-enameled galvanized steel with a baked-enamel, certified lead-free finish. With any metal coating, the manufacturer must be asked whether the coating contains heavy metals. Red paint used on metal often contained lead in the past. Any existing metal roof being used for a potable water catchment system should be tested for lead.

Wood shakes, concrete or clay tiles, and asphalt shingles are more likely than other materials to support the growth of mold, algae, bacteria and moss which can potentially contaminate water supplies. Treated wood shingles may leach toxic preservatives, and asphalt shingles may leach small amounts of petroleum compounds. In addition to the health concerns, a porous or rough roof surface holds back some of the water that would otherwise make it into the cistern. Asphalt roofing has a "collection efficiency" of about 85% while enameled steel has a collection efficiency of more than 95%. With asphalt roofing, more of the rainwater stays on the roof in a typical rainstorm (i.e., the roof stays wet), though the actual percentage depends on the duration of the storm.

To be most effective, the roof should be fully exposed and away from overhanging tree branches. This reduces the risk of contamination from rotting leaves or droppings from birds and insects in the trees. If possible, avoid using roofs of buildings that rely on wood heat, as the smoke particles and soot deposited on the roof may contain PAHs and other hazardous materials.

RRH METHODS FOR AQUIFER RECHARGE

RRH for an individual house or a group of houses requires connecting the outlet pipe from roof-top to divert collected water to existing well, tube well, bore well or a specially designed well (Hartsung 2002; Gould and Nissen-Petersen 1999). Rooftop rainwater collected may be used to recharge groundwater reservoir through any one of the following proven techniques:

1. Abandoned or Running Well

This method can be used for a colony provided hydrogeological parameters permit. For a group of houses the recharge well should be so deep that it can saturate water of the entire area.

2. Settlement Tank

It is used to remove silt and other impurities from rainwater. It can have an unpaved bottom surface to allow standing water to percolate into the soil. It has provision for inflow, outflow and overflow. It holds excess of water till it is soaked up by the recharge structure. Any container masonry or concrete or underground tank, old disused tanks may be used as settlement tanks.

3. Recharge Pit

Recharge pits are constructed for recharging shallow aquifers. 1 to 2 m wide and 2 to 3 m deep recharge pit is generally constructed. After excavation, the pit is refilled with boulders and pebbles at the bottom followed by gravel and then course sand at the top. The collected water from the rooftop is diverted to the pit through a drain pipe. Recharge water is filtered through the pit.

4. Soakaway

It is a bored hole of upto 15 cm in diameter, drilled in the ground to a depth of 6 to 10 m. It can be left unlined if the soil is stable and clayey. It is filled with filter matter like brickbats and is lined with PVC pipe to prevent collapse. A small sump is made at the top of the soakpit where the runoff can be retained before it infiltrates through the soakaway.

5. Recharge Trench

A recharge trench is constructed when permeable strata of adequate thickness is available at shallow depth. It is constructed across the land slope along the boundary walls. It may be 0.5 to 1 m wide, 1 to 1.5 m deep and 10 to 20 m long depending on the availability of land and roof-top area. It is filled with boulders at the bottom followed by pebbles and by course sand at the top. The collected water from the roof is diverted through the drain pipe to the trench. The trench should be periodically cleaned. The method is suitable for a building having the roof-top area of 200 to 300 m^2. For a much bigger area a bigger trench is required or several trenches may be required.

6. Recharge Shaft

A recharge shaft is dug manually or drilled by the reverse/direct rotary drilling method. Its diameter varies from 0.5 to 3 m depending on the availability of water to be recharged and its depth varies from 10-15 m below groundwater level. It is back filled with boulders, gravel and coarse sand. The bottom of the shaft should end in permeable strata, i.e., course sand. It should be constructed to 10 to 15 metres away from the buildings for their safety. It should be cleaned regularly by scraping the top sand layer and refilling it periodically. It is constructed where shallow aquifer occurs below clay layer.

7. Defunct Borewell

A defunct borewell can be used for recharging the aquifer under for a group of houses (Fig. 1). A circular pit of 1 m diameter for a depth of 0.6 m below ground level is dug around the borewell. The bore and the pit are filled with broken bricks. The top 0.3 m portion of the pit is filled with sand. The circular pit is covered with perforated slab at the top. The slab requires regular cleaning so as to keep its holes open to receive water.

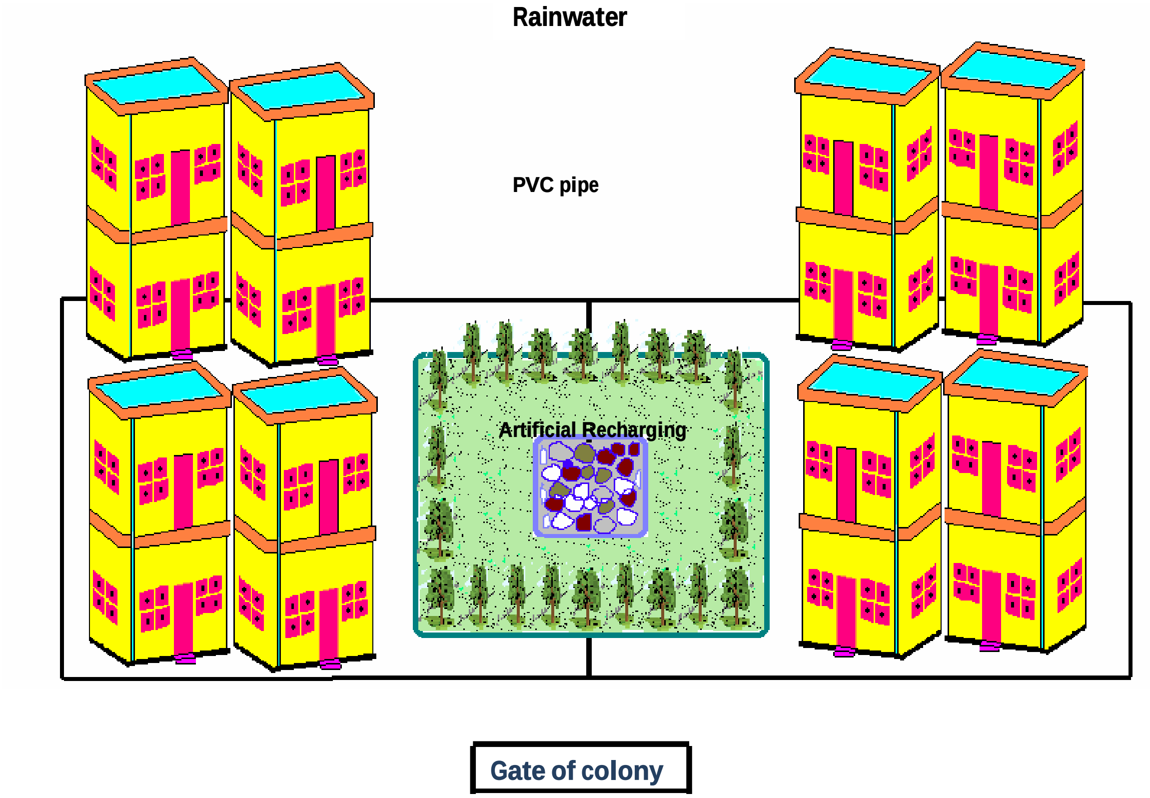

Fig. 1. Recharge through borewell for a group of houses or a colony (Rainwater from the roof top is directed to the recharge borewell or pit in the centre of the park through PVC pipes)

BENEFITS OF RRH

Collecting and using rainwater has numerous benefits, ranging from improved water quality to reduced stress on underground aquifers (Table 1). RRH is a good option for aquifer recharge in urban areas where natural recharge is very low due to compaction, and not much land is available for implementing any other artificial recharge measure. Rainwater can be used for potable water (drinking, cooking, bathing) or nonpotable uses such as landscape irrigation, livestock watering and washing (Geerts and Raes 2009; Cluff 1981). Rainwater typically has very low hardness levels. High hardness reduces the use of soaps and detergents, and eliminates the need for a water softener. Fewer minerals also save wear and tear on plumbing fixtures. Stored rainwater also is a good standby in times of emergencies such as power outages or during periods of extreme drought when wells dry up; or where water supplies are not available, dependable or cheap. Rainwater harvesting reduces the impact on aquifers, lessening the demand on ecologically sensitive or threatened aquifers. Collecting some of the rainwater falling on impervious surfaces also minimizes erosion and flooding. Rainwater is pure. It is free from germs and organic matter, and is soft in nature. Because it doesn't have to be treated, pumped or distributed through a complex network, harvested rainwater saves energy and the use of chemicals. Some municipal water users sometimes switch to harvested rainwater as a way to avoid chlorination and fluoridation treatments. Rain runoff which otherwise flows into sewers and storm drains and is wasted, is harvested and utilised. RRH reduces strain on municipal water supply. It improves groundwater level, yield and quality. For example, the water level in the Panchsheel Park area, considered one of Delhi's posh colonies, was declining rapidly. Keeping in view the growing water problems, the Resident Welfare Association established a rainwater harvesting system for the entire colony, which improved groundwater level and quality.

Table 1. Assessment of quantity of rainwater harvested

	Individual Houses	**Multistoried building**	**Group of houses/Colony**
Roof top area	100 m^2	500 m^2	2500 m^2
Total quantity available for recharge per annum	50 m^3	250 m^3	1250 m^3
Water available for a 5- member family	100 days	500 days	2500 days

Direct capturing of rainwater significantly reduces our reliance and pressure on water sources such as rivers, dams, canals etc. It helps in reducing the flood hazard by improvement in infiltration and reduction in run-off. It improves groundwater quality through dilution, specially for hardness, fluoride and nitrate. It can reduce groundwater pollution by 80-90%. Rainwater may be harnessed at place of need and may be utilised at the time of need. The structures required for harvesting rainwater are simple, economical and eco-friendly.

LEGISLATION

Currently, there are no defined regulations regarding aquifer recharge in developing countries like India except RRH system is mandatory for new building constructions at some places, but certain rules do exist in developed nations such as USA (Colorado Division of Water Resources 2009). For example, Texas does not regulate rainwater collection for indoor or outdoor household use unless the system is backed up by publicly supplied waterlines. If there is a backup system, there must be an air gap between the public water lines and the rainwater lines. This air gap must exceed two diameters of the city line in width. The only other regulation regarding rainwater collection relates to physical maintenance of cisterns. This regulation is directed at public safety. To date, the primary governmental interest in rain and related runoff has been in pollution prevention. As more and more people begin to look to rain as a source of drinking water, the need for adequate regulation grows. The necessary regulations, whatever they may be, need to be started now while public implementation is still minimal. Legislations should seriously consider the following items: Distance from cistern to any source of contamination such as a septic tank, cistern height in relation to level of roof washer to ensure proper function, requirement of roof washer to capture the first flush, inclusion of overflow pipe directed to non-flooding area, sanitization minimum standards, filtration standards, application of drinking water standards to cisterns intended for potable supplies (regardless of number of people supplied), general health and quality standards for operation (prevention of mosquito breeding grounds), and structural standards to ensure proper design and installation.

SUGGESTIONS

Ensure the roof surface is of a suitable material for collecting quality rainwater. Analyze water samples from the storage tank to ensure If they are free from contaminants. Ensure the roof gutters are installed to building standards and have fall to outlets to prevent ponding and sludge build up. Install gutter mesh to prevent leaves and debris from blocking gutters and mosquito mesh to seal the storage from insects and vermin. Fit gutter outlets to underside of gutter to reduce sludge build up. Fit rain heads to down pipes to ensure the maximum discharge is delivered to the storage. Fit a first flush bypass system to separate debris and sludge before storage. Draw water from the aerobic zone in the storage. Ensure the roof catchment is maintained and cleaned on a regular basis.

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WATER DEFLUORIDATION

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FLUORIDE IN GROUNDWATER

Fluoride in groundwater is mainly due to leaching from F^- bearing soils and rocks. Industrial sources include fertilizers, petrochemicals, aluminium, refrigeration, steel, pottery, plastic, glass, pharmaceutical, tooth paste, chemical industries, welding, automobile etc.

A high fluoride content in groundwater has been reported from 25 countries like North and South American countries, India, China, Sri Lanka, Pakistan, Bangladesh, Argentina, United States of America, Morocco, Middle East countries, Japan, South African Countries, New Zealand, Thailand, West Indies, Spain, Holland, Italy, Norway, Mexico *etc.* In India, its occurrence in the upper aquifer system is endemic in 17 states such as UP, AP, Bihar, Gujarat, Rajasthan, Punjab, Haryana, TN, Karanataka, Kerala *etc.* Out of those 5 are hyper endemic, where 50-100% districts are affected viz. Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Gujarat and Rajasthan. Fluorosis was first detected in India among the cattle by farmers of Nalgonda district, AP during early 1930's. Excess fluoride, wherever present in groundwater in India, is in the range of 1.5 to 6.5 mg/l against its desirable limit (DL) of 1 mg/l and maximum permissible limit (PL) of 1.5 mg/l in drinking water. **Very high fluoride value about 90 mg/l has been observed in Nagaur district of western Rajsthan and above 5.0 mg/l is quite common**. Agra region has been high fluoride in groundwater, for example upto 22 mg/l in Akola Block, 18.3 in Bichpuri Block and 8.9 mg/l in Shamsabad Block.

FLUORIDE TOXICITY

Low amount of fluoride (0.3-1.0 mg/l) in drinking water is helpful in the prevention of dental caries and in treatment of osteoporosis. However, high intake of fluoride (>1.5 mg/l) in drinking water for a prolonged period is known to cause damage to the teeth enamel and eventually leads to skeletal complications that result in fluorosis (dental, skeletal and non-skeletal, or combination of these). Fluoride is also known to induce ageing and no amount of medicine can cure or improve the damage. **Fluorosis is prevalent in many parts of the world. Fluorosis is desease without cure. > 90 m people suffer in China and India.**

Excess fluoride in water causes dental fluorosis (mottling of teeth), skeletal fluorosis (loss of weight, anorexia, anaemia, wasting and cachexia), thyroxine changes, kidney damage, respiratory failure, fall in blood pressure and paralysis. High fluoride inflicts plants also, and reduces productivity and biomass.

Exposure dose, mg/l	**Disorder**
1.0-2.0	Dental fluorosis
3.0-6.0	Skeletal fluorosis (SF)

7.0-10.0	Crippling SF
>10	System failure

WAYS TO REMOVE FLUORIDE FROM WATER

1. Reverse osmosis filtration: **This is used to purify several types of bottled water (not all), so some bottled waters are unfluoridated. Reverse osmosis systems are generally very expensive.**
2. **Activated alumina defluoridation filter:** These filters are used in locales where fluorosis is prevalent. They are relatively expensive and require frequent replacement, but do offer an option for home water filtration.
3. **Distillation filtration:** Commercially available distillation filters can be purchased to remove fluoride from water. When looking at bottled water, keep in mind that 'distilled water' does not imply that a product is suitable for drinking water and other undesirable impurities may be present.

THESE DO NOT REMOVE FLUORIDE

1. **Brita, Pur and most other filters:** Some websites about fluoride removal state otherwise, but I checked the product descriptions on the companies' websites to confirm that fluoride is left in the water.
2. **Boiling water:** This will concentrate the fluoride rather than reduce it.
3. **Freezing water:** Freezing water does not affect the concentration of fluoride.

STEPS TO REDUCE FLUORIDE EXPOSURE

1. Don't take fluoride supplements.
2. Consider using unfluoridated toothpaste.
3. Avoid drinking black tea.
4. Black tea usually contains high amounts of fluorine.
5. Be wary of tinned fish and canned food items.
6. Fluoride may be used as a preservative.
7. Avoid black or red rock salt or items containing black or red rock salt.
8. Avoid using chewing tobacco.
9. Avoid long term use of medication that contains fluorine.
10. Certain antidepressants and medications for osteoporosis contain fluorine

DEFLUORIDATION METHODS

Removal of excessive fluoride from drinking water is difficult and expensive. The preferred option is to find a supply of safe drinking water with safe fluoride levels. Where access to safe water is already limited, de-fluoridation may be the only solution. Methods include: use of bone charcoal, contact precipitation, use of Nalgonda or activated alumina (Nalgonda is called after the town in South India, near Hyderabad, where the aluminium sulfate-based defluoridation was first set up at a water works level). Since all methods produce a sludge with very high concentration of fluoride that has to be disposed of, only water for drinking and cooking purposes should be treated, particularly in the developing countries.

There are many methods for defluoridation of water such as reverse osmosis, electrodialysis, ion exchange and adsorption. However, indigenous chemicals and minerals offer cheap, viable and effective techniques of defluoridation.

Boiling a brushite/calcite suspension rapidly converts the two salts to apatite which incorporates fluoride if present in solution, and that this process may be exploited to defluoridate drinking water.

Fluoride in groundwater can be controlled by blending, artificial recharge, efficient irrigation practice and proper well construction to be bright.

A new method based on the coacervation induced by electrolysis using an aluminum anode, can be developed to remove excess amounts of floride from potable water. The method is easier, safer, and less expensive than use of activated alumina.

Protein constituent of tamarind has been concluded to be the active component interacting with fluoride.

Excess fluoride concentration can be removed by using chemicals like lime, magnesium and aluminum sulphate and adsorption methods like activated carbon, strong base anion exchange resins, tricalcium phosphate and activated alumina. The following methods can be used to remove excess fluorides in drinking water.

1. Addition of lime
2. Defluoron - 2 process (synthetic carbonaceous sulphonated materials used in the process)
3. ANDCO process (USA)
4. Filtration through bone media
5. Fluoride removal by fish bone charcoal
6. Use of clay pots
7. Dilution method
8. Nalgonda technique (most widely used in India, which involves addition of aluminum salt, lime and bleaching powder)
9. Prashanthi technique (Activated alumina techniques) *etc.*

All the methods for fluoridation of water are based on basically and mainly two approaches: flocculation and adsorption.

Flocculation: The Nalgonda technique (named after the village in India where the method was pioneered) employs this principle. Alum (hydrated aluminium double salts) - a coagulant commonly used for water treatment - is used to flocculate fluoride ions in the water. Since the process is best carried out under alkaline conditions, lime is added and bleaching powder can also be added to disinfect the water. After a thorough stirring, the chemical elements coagulate into flocs that are heavier than water and settle to the bottom of the container. The operation can be carried out on a large or small scale, and the technique is suitable for both community or household use. One household version uses a pair of 20-litre buckets, with a settling time of one hour and not more than two hours, after coagulation and settling are complete, the treated water is withdrawn through a tap 5 cm above the bottom of the first bucket, safely above the sludge level, and stored for the day's drinking in the second bucket.

Adsorption: The other approach is to filter water down through a column packed with a strong adsorbent such as activated alumina (Al_2O_3), activated charcoal or ion exchange resins.

This method, too, is suitable for both community and household use. When the adsorbent becomes saturated with fluoride ions, the filter material has to be backwashed with a mild acid or alkali solution to clean and regenerate it. The effluent from backwashing is rich in accumulated fluoride and must therefore be disposed off carefully to avoid recontaminating nearby groundwater. Both the community and household defluoridation systems have pros and cons. Defluoridation equipment connected to a community handpump is theoretically cheaper per capita than a household unit because of economies of scale; but ensuring proper maintenance of a commonly owned facility is often problematic, so good community organization is necessary. The household units are more convenient for filtering the small amounts of water intended for drinking only, and people usually take better care of them; but an extensive and efficient service system is required to ensure that the filters are replaced or regenerated at the right time. Technology is only part of the issue, local capacity building, including entrepreneurial capabilities, can be a far more critical and difficult task.

Evaluation and Selection of Method

We do not have a universal method which can be sustained under all kinds of social, financial, environmental and technical constraints. This is in agreement with the fact that none of the methods have been implemented successfully at a large scale in many parts of the world. This oddity is probably because available defluoridation methods do have disadvantages. Some of these are what may be designated as killer disadvantages, in the sense that the methods turn out to be unsustainable under the given socio-economical conditions. Such killer disadvantages of defluoridation include:

1. **High cost-tech:** Either the price and/or the technology is high, demanding imported spare parts, continuous power supply, expensive chemicals, skilled operation or regeneration and the like. Reverse osmosis, ion exchange and activated alumina may thus be categorised as high cost-tech methods.
2. **Limited efficiency:** The method does not permit sufficient removal of the fluoride, even when appropriate dosage is used. As in the Nalgonda technique, the residual concentration would often be higher than 1 mg/l, unless the raw water concentration itself is low.
3. **Unnoticeable break through:** The fluoride concentration in the treated water may rise gradually or suddenly, typically when a medium in a treatment column is exhausted or even when the flow is out of control. As in the case of bone charcoal and other column filters, these techniques necessitate continuous monitoring of fluoride, or at least the rate and the volume of treated water, if the unnoticeable breakthrough or the loss of removal capacity are to be avoided.
4. **Limited capacity:** While the removal capacity of bone charcoal or activated alumina may be about 2 mg fluoride per g of medium, much higher amounts of e.g. calcined clay or Nirmali seeds, has to be used in order to obtain appropriate removal.
5. **Deteriorated water quality:** Some methods like the activated magnesia would by nature result in excessively high pH values, normally above 10. The water quality may also deteriorate due to poorly prepared medium (bone charcoal) or due to medium escaping from the treatment container e.g. ion exchange, alumina, Nalgonda sludge *etc.*

Table 1. Comparison of advantages of the promising defluoridation methods

	Defluoridation methods				
Advantages	**BC**	**CP**	**Nalg**	**AA**	**CC**
1. No daily dosage of chemicals i.e. no daily working load	+	-	-	+	+
• Dosage designed for actual F^- conc. independent of unit or plant	-	+	+	-	-
• No risk of false treatment due to break point	-	+	+	-	-
• Removal capacity of medium is independent of F^- concentration	-	+	-	-	-
• No regeneration or renewal of medium is required	-	+	+	-	-
• High removal efficiency can be ensured	+	+	-	+	--
• Easy to construct, even by the users	+	+	++	+	+
• Construction materials are cheap and widely available	+	+	++	+	+
• Can be sized for one or several families or e.g. a school	+	++	+	+	-
• No risk of medium/chemicals unacceptability	-	-/+	+	+	-
• No risk of deterioration of the original water quality	-/+	+	-/+	-/+	-

Notes: BC = Bone charcoal; CP = contact precipitation; Nalg = The Nalgonda technique of aluminium sulfate and lime; AA = activated alumina; CC = calcined clay. "Risk" means in some cases. + indicates advantage; - indicates potential disadvantage.

6. **Taboo limitations:** In particular, the bone charcoal method is culturally not acceptable to Hindus. Bone charcoal originating from pigs may be questioned by Muslims. The charring of bones has even been reported to be repulsive to villagers in North Thailand.

On the other hand, all the methods mentioned do have advantages and have been shown to be capable of removing fluoride under certain conditions. Four criteria are essential and may contribute to the success of fluorosis prevention through treatment of drinking water at a decentralised level:

1. The right method has to be selected to deal with given water quality and social acceptability. Table 1 may be useful in selection of the method.
2. Proper design and process understanding are required at least among the monitoring officials.
3. Media and unit spare parts have to be made available though an infrastructural set-up, such as village communities and social and health workers.
4. **Motivation and training of users has to be continued through the same or a similar infrastructure.**

GENERAL ADVICE

Perhaps the best general **advice that can be given in relation to local conditions is that, at a** minimum, the fluoride level in local water supplies should be monitored and the population examined for signs of excessive fluoride exposure **(e.g. moderate and/or severe dental fluorosis and crippling skeletal fluorosis). Laboratory methods for fluoride determination, based on** fluoride ion specific electrodes or colorimetric methods or even test kits**, can be used for measuring fluoride concentrations but it is preferable to have on-line monitoring of the fluoride concentration using a continuous instrument.**

A Final Word

Awareness should be created to use defluoridated water where there is a problem. Policy makers, scientists, doctors, public health engineers and NGOs should be involved in finding suitable methods to control fluoride pollution in general and fluorosis in particular.

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MANAGEMENT OF SCRAP FLUORESCENT LAMP IN TAIWAN

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Abstract

The fluorescent lamp is most commonly used in Taiwan for lighting purpose. Even though application of the fluorescent lamp has illuminated our daily lives, the mercury contained within the fluorescent lamp tubes brings a hidden hazard to our environment. The Environmental Protection Administration (EPA) of Taiwan announced on January, 2002 for scrap fluorescent lamps to be recycled and disposed of by fluorescent lamp tube manufacturers and importers in accordance with the Waste Disposal Law (WDA). Thus, under current regulations of the WDA, the fluorescent lamp's manufacturers and importers have to pay the scrap lamp processing fee to EPA in support of the implementation of scrap fluorescent lamp recycling in Taiwan. Currently, there are three eligible scrap fluorescent lamp recycling plants existed in Taiwan. The main process adopted by these recycling plants for scrap lamps comprises of removing the aluminum cap and lead containing glass on both end of straight tube by cutting, blow off fluorescent powder contained in the open straight tube, the collection of mercury vapor and fluorescent powder, crushing and separation of aluminum cap, crushing of tube glass, distillation of fluorescent powder to recover mercury etc. According to EPA's report, from 2002 to 2008, the average amount of scrap fluorescent lamp recycled by the eligible recycling plants in Taiwan is approximately 4.5 million kg for each year. This paper will introduce the related information on the management of scrap fluorescent lamp in Taiwan.

INTRODUCTION

According to the statistics released by the Environmental Protection Administration (EPA) of Taiwan, R.O.C., the total amount of the waste generated each year in municipal areas is approximately 8 million metric tons. It is well known that the mercury contained within the fluorescent lamp tubes brings a hidden hazard to our environment. The amount of sealed mercury in the fluorescent lamp in Taiwan has been lowered from 25mg/tube in the 1990s to 15mg/tube in 1999, and reaches 12mg/tube at present time. The disposal of such a huge amount of waste presents tremendous challenge for the island due to the scarcity of landfills and incineration facilities available locally. EPA thus takes an active role in promoting waste recycling to reduce the garbage produced in municipalities. In order to efficiently utilize the government‘s human and financial resources used in recycling, EPA has mandated the producer responsibility recycling program for several designated post-consumer products. On August 22, 1990, the scrap fluorescent lamp was declared as a producer responsibility product. It means that the fluorescent lamp's manufacturers, importers and sellers have the responsibility to retrieve the scrap fluorescent lamp and recycle them properly. The purpose of this paper is to give an overview of the scrap fluorescent lamp management system in Taiwan.

SCRAP FLUORESCENT LAMP MANAGEMENT SYSTEM IN TAIWAN

Article 15 of the Waste Disposal Act (WDA) issued by Taiwan's Environment Protection Administration (EPA) states that: If the discarded material, package or container, which is classified as municipal waste has the following properties: It is difficult to be collected and be disposed of It does not contain readily decomposable substances. It contains hazardous substances . It can be recycled and may seriously pollute the environment hence should be recovered and treated properly by its manufacturers, importers and sellers. This means that if discarded post-consumer products have the above properties, then the government is not responsible for the cleaning and disposal of such products. Instead, the manufacturers, importers, and sellers of these products are mandated to properly recover and dispose of their post-consumer products.

According to the principles stipulated in Article 15, Taiwan's EPA declared the scrap fluorescent lamp as a producer responsibility product on January, 2002. This announcement only applies to straight tube fluorescent lamps due to technical difficulties in processing non-straight tubes, and only since 2007 were other types of fluorescent lamps brought into the announcement. Under current regulations of the WDA, the fluorescent lamp's manufacturers and importers have to pay the scrap lamp processing fee to EPA in support of the implementation of scrap fluorescent lamp recycling in Taiwan.

After collection of this processing fee, the EPA is then responsible for the management and recycling of scrap fluorescent lamp in Taiwan. For this purpose, the Recycling Fund Management Board (RFMB) was established by the EPA in order to manage and implement the recycling of scrap fluorescent lamp and other declared producer responsibility products (i.e., computer, car, tire etc,) in Taiwan. RFMB is a semi-official organization directly under the control of the EPA. The main functions of RFMB in the aspect of scrap fluorescent lamp recycling are to: (1) Propose scrap fluorescent lamp processing fee for fluorescent lamp's manufacturers and importers; (2) Propose scrap fluorescent lamp subsidy for scrap fluorescent lamp's recycling plant; (3) Identify responsible fluorescent lamp manufacturers and importers; (4) Establish a scrap fluorescent lamp processing fee collection system; (5). Set up the scrap fluorescent lamp recycling system; (6) Select recycling facilities for scrap fluorescent lamp recycling; (7) Supervise a third party to audit scrap fluorescent lamp recycling work; (8) Subsidize scrap fluorescent lamp recycling related research projects. Currently, the RFMB plays an essential role in the scrap fluorescent lamp management system in Taiwan. Figure 1 presents the current scrap fluorescent lamp management system in Taiwan.

SCRAP FLUORESCENT LAMPS RECYLING IN TAIWAN

To promote the recycling of scrap fluorescent lamp, Taiwan EPA passed the scrap fluorescent lamp (straight tube) recycling subsidy for the recycling plants; where starting from January 1, 2002 the announced subsidy for recycling fluorescent lamp (straight tube) is NTD $44.62/kg. In order to maximize the recovery of valuable material and the hazardous material of mercury from scrap lamps, a new subsidiary plan was issued by EPA on March 1, 2007. Table 1 presents this new subsidiary plan (EPA report, 2007). This table shows that the amount of subsidy depends on the valuable material recovery rate (RT%) and mercury recovery rate (RHg%) obtained by the recycling plant. The valuable material recovery rate (RT%) and mercury recovery rate (RHg%) are defined as below:

RT%= weight of recycled material/weight of scrap lamp processed
RHg%= weight of mercury recovered / (weight of scrap lamp processed × 6.9 mg/100g)

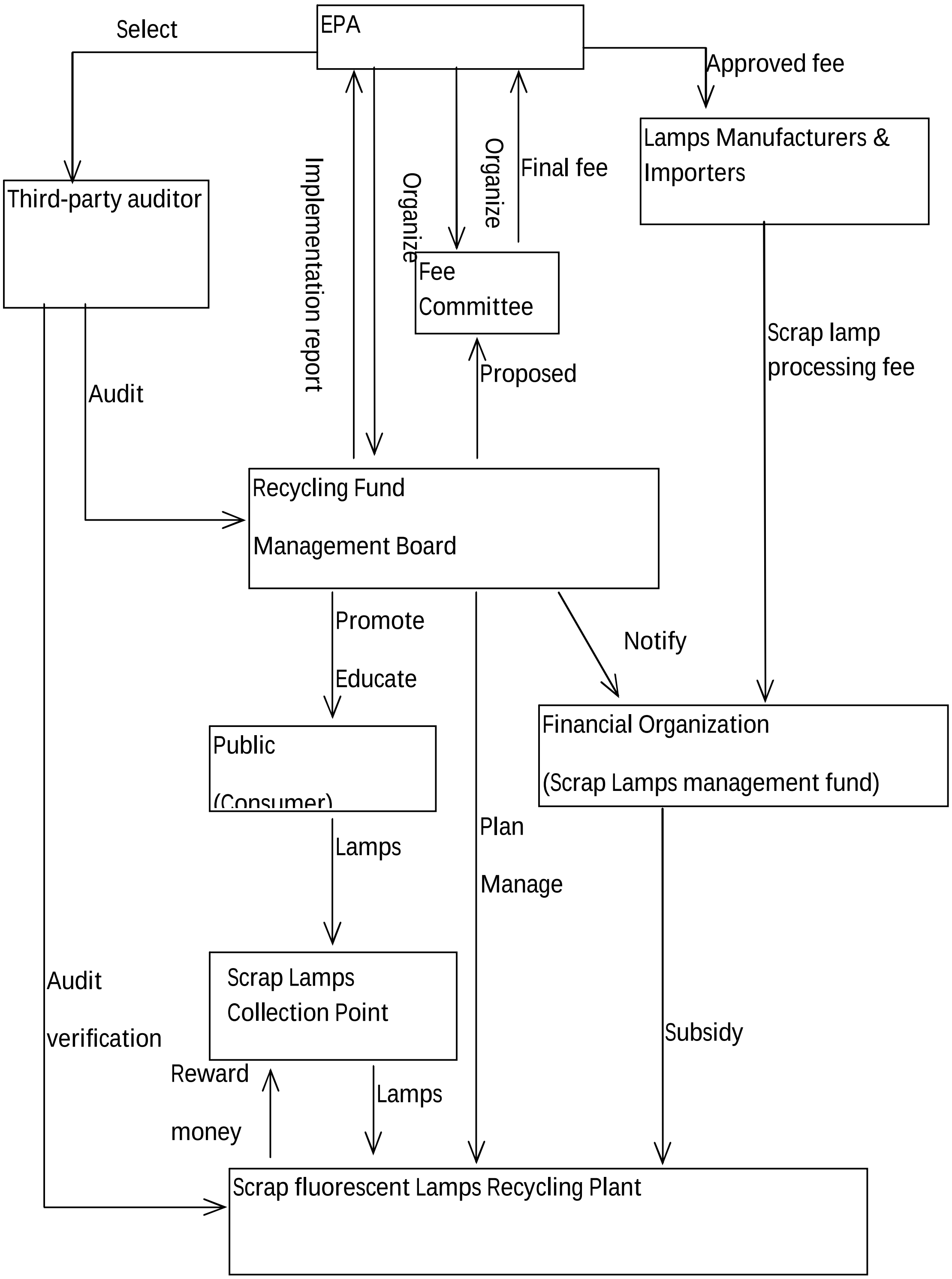

Fig. 1. Scrap fluorescent lamp management system in Taiwan

Table 1. Subsidy for scrap fluorescent lamp recycling plant (EPA report, 2009)

Valuable material recovery rate (RT%)	Mercury recovery rate (RHg%)	Subsidy (NT$/kg, 1 US$= 33 NT$)
RT%≧80%	RHg %≧35%	40
	30%≦RHg %<35%	35
	20%≦RHg %<30%	20
	RHg %<20%	0
RT%<80%	-	0

In the calculation of RHg%, EPA assumed that 100 g of scrap fluorescent lamp contained 6.9 mg of mercury. Table 1 indicates that the recycling plant can get the subsidy only if its material recovery rate (RT%) is higher than 80% as well as the mercury recovery rate (RHg%) is higher than 30%. The amount of subsidy is also dependent on the mercury recovery rate. Table 1 presents that the higher the mercury recovery rate the larger amount of subsidy the recycling plant can get. At present time, a maximum amount of subsidy of 40 NT$/kg can be obtained for the recycling plant if its RT%>80% and RHg%>35%. However, only the eligible recycling plants in Taiwan can get this subsidy by recycling and treating the scrap fluorescent lamps properly. It means that the recycling plant has to meet the management requirements issued by EPA before it becomes an eligible plant. Thus, on September 11, 2002 EPA announced the collection, storage and treatment instructions and standards for scrap lighting sources, which clearly defines the recycling standards and management requirements for fluorescent lamp recycling plant. The recycling plant has to be examined and pass the inspection which performed by RFMB to become an eligible scrap fluorescent lamp recycling plant. Since the subsidy is paid by the amount of scrap fluorescent lamp recycled, the RFMB will send a third party to do the daily on-site auditing about the quantity of recycled lamps as well as the environmental performance for each eligible recycling plant.

Current eligible recycling plants in Taiwan certified by RFMB to recycle scrap fluorescent lamps by the EPA include C.T. Recycled Co., LTD.; Perfect Recycling Co., LTD.; Hong Chin Recycling Enterprise Corp. etc. The typical recycling process for scrap fluorescent lamp recycling plants in Taiwan is as indicated in Figure 2. The main recycling process for scrap lamps comprises of removing the aluminum cap and lead containing glass on both end of straight tube by cutting, blow off fluorescent powder contained in the open straight tube, the collection of mercury vapor, fluorescent powder, crushing and separation of aluminum cap, crushing of tube glass, distillation of fluorescent powder to recover mercury etc.

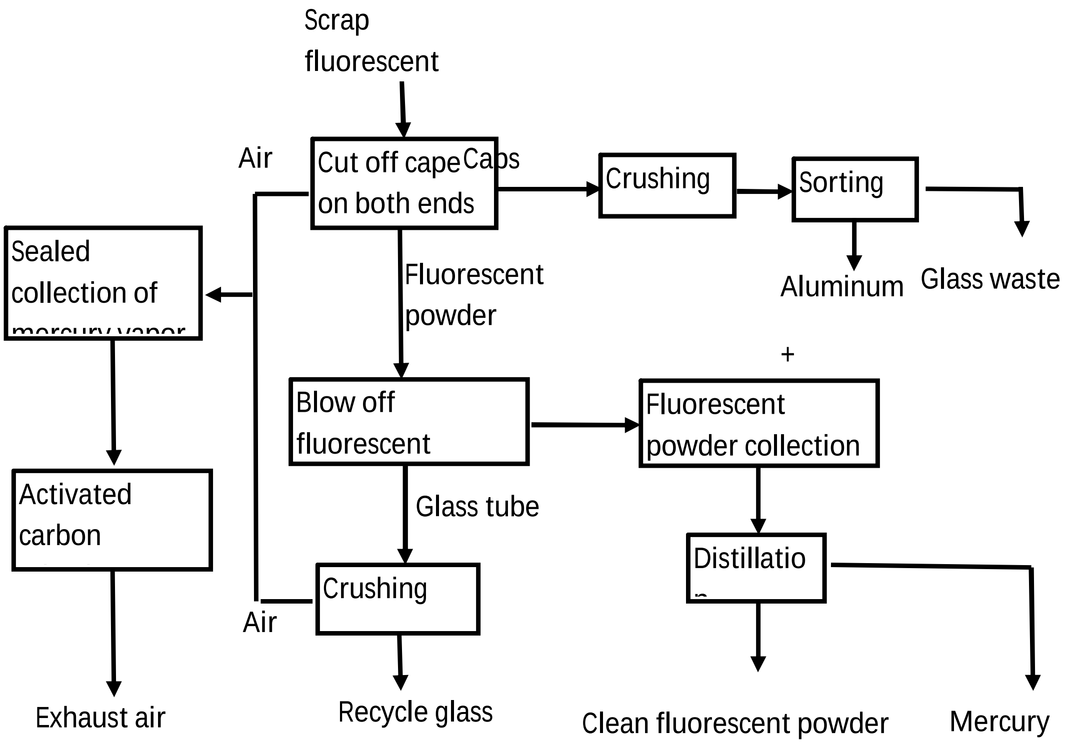

Fig. 2. Scrap Fluorescent Lamp recycling process used in Taiwan

Based on on-site interviews and collected data, materials resulting from a scrap fluorescent lamp recycling plant in Taiwan includes: tube glass, lead containing glass, aluminum containing metal, copper containing metal, iron containing metal, and fluorescent powder etc. On average the weight of a 40W fluorescent lamp is 0.2 kg/tube, the 20W fluorescent lamp is 0.1 kg/tube. The percentage for 40W and 20W fluorescent lamp tubes going through this recycling plant is 50-50, therefore on average this recycling plant handles 0.15kg/tube of fluorescent lamps. Table 2 is the recycled material and the sales price from this scrap fluorescent lamp recycling plant, and if this plant works two shifts every day, a total of 1.6 million tubes of fluorescent lamps can be recycled each month. As shown in Table 2, the materials resulting from the scrap fluorescent lamp recycling plants comprise 85% sodium glass that has been sent to glass tube company as raw material with a charge of NT$ -1.5/kg; 12% lead glass and impurities requires an external solidification process with a charge of NT$ -15/kg; 2% copper and aluminum metals sold for NT$ 10/kg, 0.01% fluorescent powder collected after distillation was landfilled with a charge of NT$ -2.9/kg; 0.006% liquid mercury obtained from distillation was sent to mercury refining company with a charge of NT$ -6500/kg.

According to RFMB's report (RFMB report, 2009), from 2002 to 2008, the average amount of scrap fluorescent lamp recycled by the eligible recycling plants is approximately 4.5 million kg for each year. Table 3 presents the amount of scrap fluorescent lamp recycled each year in Taiwan.

Table 2. Materials resulting from a scrap fluorescent processing plants in Taiwan

Type of material	Weight (%)	Weight (kg/tube)	Production (kg/month)	Target (external, sold, storage)	Price (+) or paid fees (-) (NT$ /kg)
Sodium tube glass	85	0.127	20,400,000	Glass refinery	- 1.5
Copper aluminum metals	2	0.003	480,000	Sold	10
Lead glass and impurities	12.09	0.018	2,880,000	Solidified	-15
Fluorescent powder	0.01	0.000015	2,400	Landfill after distilled	-2.9
Liquid mercury	0.006	0.000009	1,440	Refinery	NT$ -6500/kg

Table 3. The certified amount of scrap fluorescent lamp recycled in Taiwan (RFMB report, 2009)

Year	Recycled amount (kg)
2002	523,500
2003	7,891,706
2004	4,363,711
2005	4,675,873
2006	4,736,784
2007	4,557,818
2008	5,121,063
2009 Jan.~Mar.	January:322,906 Feburary: 497,602 March:466,005 Total:1,286,513

CONCLUSION

On January, 2002, the scrap fluorescent lamp was declared as a producer responsibility products. According to the regulation issued by Taiwan EPA, the fluorescent lamp manufacturers, importer and sellers are responsible for the recycling and disposal of the scrap fluorescent lamp. The Recycling Fund Management Board (RFMB) was established by the EPA in order to manage and implement the recycling of scrap fluorescent lamp. Currently, there are three eligible scrap lamp recycling plants which qualified by RFMB can recycle the scrap lamps in Taiwan. At present time, a maximum amount of subsidy of 40 NT$/kg can be obtained for the eligible recycling plant if its material recovery rate >80% and mercury recovery rate >35%. The data issued by RFMB reveals that the average amount of scrap fluorescent lamp recycled by the eligible rec4ycling plants in Taiwan is approximately 4.5 million kg for each year.

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HEALTH HAZARDS OF E-WASTE RECYCLING AND HOSPITALS' ROLE PLAY IN INDIA

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Abstract

E-Waste Management is one of the major areas of concerns today. Researchers are trying to find new ways to reduce, recycle and reuse the E-Waste and governments are trying to find methods of implementations of e-waste management schemes. Developed nations are trying to cope up with this startling problem and the result is the dumping of e-waste into the developing countries like India. New health problems are emerging due to the unmanaged E-Waste industry. As the electronic recycling is an unregulated industry in India, the recycling process is dangerous to the health of its employees A study of the related health studies in China has shown the impact of e-Waste recycling on health of workers. Such studies are important for India as these will help in designing better policies of E-Waste Management. In this paper, we present the problem of e-waste with the focus on the health. A study about the role of hospitals in dealing with this problem is also being presented with a focus of new initiatives that can be taken by hospitals in this regard.

INTRODUCTION

It is a major area of concern today that the wealthy countries are dumping large quantities of e-waste into the developing world. According to (Rachel Kesselman, 2007), currently, companies export 80 percent of the world's electronic trash to Asia, and 90 percent of this flows into China, according to a BBC report. The article (Toxic Links, 2008) besides discussing the problem of e-waste recycling in India and the economies involved expresses the urgent need for educating consumers and the general public regarding the potential threat to public health and the environment posed by their products and for raising awareness for the proper waste management protocols.

E-WASTE RECYCLING IN INDIA

According to (Rachel Kesselman, 2007), The Indian government estimates that the country generates approximately 146,000 tonnes of e-waste annually, and that another 150,000 tonnes of used PCs, printers and other IT devices enter its ports illegally.

Greenpeace International released a report (GreenPeace International, 2005) in August 2005 about the hazardous chemicals found in scrap yards in India that include tin, lead, copper, cadmium and antimony in the soil and local rivers around scrap yards where the electronic waste is recycled. It also emphasized the fact that all stages in e-waste processing could release substantial quantities of toxic heavy metals and organic compounds into the workplace environment.

HEALTH HAZARDS

The e-waste recycling and disposal operations found in developing countries are extremely polluting and likely to be very damaging to human health (Robert Bortner, 2008).

According to (Habib Beary, 2005), computers, refrigerators, televisions and mobiles contain more than 1,000 different toxic materials. Chemicals such as beryllium, found in computer motherboards, and cadmium in chip resistors and semiconductors are poisonous and can lead to cancer. Chromium in floppy disks, lead in batteries and computer monitors and mercury in alkaline batteries and fluorescent lamps also pose severe health risks.

The author (Mike Mcphate, 2004) writes about the patients suffering from problems such as bleeding from the throat and breathlessness, lung ailments including asthma, bronchitis and chronic lung infections, relating these to e-waste recycling methods used, burning of wires and handling of green circuit boards such as the task of recovering copper from printed circuit boards (PCBs). The author also shows the concern to the use of a brew of nitric acid, a toxic substance during the recycling process that releases copper as well as cancer-causing lead and mercury.

According to (Emmanuel K. Dogbevi, 2007), plastics used to house computer equipment and cover wire cables to prevent flammability often contain poly-brominates flame retardants, a class of dangerous chemicals. Studies have shown that ingesting these substances may increase the risk of cancer, liver damage, and immune system dysfunction. The chemicals contained in e-waste are a cocktail of dangerous pollutants that kill both the environment and humans slowly. The recycling units are mostly in the residential areas, where children play with trash. This can lead to further health hazards.

The example, as in (Andrew Pollack, 1984), specifies - As batteries have become smaller, especially with the introduction of button-shaped versions, infants have started swallowing them. A swallowed battery can burn holes in the intestines and cause inflammations.

SOLUTIONS FOR INDIA

It is not that there is no solution for this problem. There are various articles such as (Intersindia.com, 2007), where the authors give suggestions to keep a check on this seemingly uncontrolled problem of recycling. However, to give importance to such ideas and to implement these, there is a need to understand the health hazards of this unwatched process of recycling. There is also the need of bringing health awareness to masses regarding this issue. As this recycling industry contributes to the economics of the country, the need is also to study the health impacts and to relate these directly to the recycling process. Such studies will not only help in designing controlled, supervised and monitored processed of recycling e-waste but will also help in cautious reduction of e-waste.

RELATED RESEARCHES

The research conducted by (Xia Huo et. Al, 2007) found that the lead contamination from e-waste processing appears to have reached the level considered to be a serious threat to children's health around the e-waste recycling area, and that the elevated Blood Lead Levels in Guiyu children are common as a result of exposure to lead contamination caused by primitive e-waste recycling activities. Another important research, (Annao. W. Leung et. Al, 2007), is the human health risk assessment study conducted concerning dust exposure at an uncontrolled e-waste recycling site and the results can serve as a case study for similar e-waste activities in countries such as Africa, India, and Vietnam where e-waste is becoming a growing problem. COEH, Center for Occupational and Environmental Health is also involved in e-Waste management research projects and claims to be the only such center out of the 240 Medical Colleges in India (T. K. Joshi and Neeraj Gupta, 2008).

HOSPITALS' PROJECTS AND NEW INITIATIVES

In recent years, some U.S. hospitals have taken proactive measures to not only minimize or eliminate the impact of hazardous e-waste on their nation's environment, but also for saving the valuable dollars as well.

One such hospital (Premier, 2009) in New England, Hartford, CT-based Saint Francis Care entered into an agreement with WeRecycle!, in 2005. The combined effort was not to allow hazardous e-waste to be sent to solid waste landfills, incinerators, prison recycling operations or developing countries.

In India, it is needed that hospitals should get involved in such life saving initiatives for people of India and the 'Mother Earth'.

Hospitals in India can come up with different initiatives to help in this regard, such as

To conduct the public health awareness programs on dangers of uncontrolled e-waste recycling.

To find the impact on health on people working in E-waste recycling units in India.

To find the impact on health on people living near the E-waste recycling units in India, specially the pregnant women and children.

To relate to specific health problems and their increase to e-waste recycling issues.

In paper (Violet N. Pinto, 2009), the table 1, specifies E-Waste Component, the process needed for dismantling, the related potential occupational and environmental hazards. Such studies should be used by the hospitals to create mass awareness. The hospitals can take the initiatives of keeping a check or recording the patient's health history if it is suspected to be related to E-Waste mismanagement. The hospitals can also further publish reports, based on such recordings for making the government alert on the increase of health problems of people in a given location, which is suspected to be related to E-waste.

DEVELOPMENT OF HEALTH MONITORING SYSTEM AS PART OF E-WASTE RECYCLING MANAGEMENT

Hospitals in India can provide a real measure of problem severity, may it be the rate of increase of stress and suicides, the criminal offences, the domestic fights, even the impact of mosquito-bites. However, this is only possible if hospitals play a pro-active role in monitoring, recording and analysis of factors related to life and death, even those that are seemingly not directed related to the diagnostics and treatments. Hospitals' role play had been considered related to E-Waste Management only to the extent of hospital or bio-waste management. However, as the sufferers of the E-Waste recycling processes also come to the hospitals for treatment, the track of recycling processes, impacts, health hazard and possible treatments can be kept easily by hospitals.

Figure 1. A health monitoring framework

CONCLUSIONS

This paper has presented the areas of Health Monitoring System, which can be further elaborated and embedded in the daily processes of hospitals. The E-waste Management Systems with health monitoring frameworks can lead to results in only the health improvement of patients but also in public thought and views related to E-waste recycling.

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SOIL CONTAMINATION AND IMPORTANCE OF ITS REMEDIATION

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SOIL CONTAMINATION

Soil has enormous surface area and catalytic activity plus a supply of O_2 & H_2O to deactivate pollutants. It degrades most wastes much more quickly than air and water and returns the components to their natural cycles. So, naturally occurring contaminants are rare in soil except widespread Al^{3+} phytotoxicity in acid soils. But there is limit for everything. Soil contaminants are anthropogenic from domestic, urban, industrial, agricultural, mining and automobile traffic activities. Major anthropogenic organic soil pollutants with their important oxidation states are Be(II), F(–1), Cr(III-VI), Ni(II-III), Zn(II), As(III-V), Cd(II), Hg(0-I-II) & Pb(II-IV). Fertilizers and pesticides applied to crops are largely retained as recalcitrant contaminants by the soil. A few of contamination problems are outlined below :

- Only a fraction of fertilizers applied are consumed by plants. The remainder is left in the soil and become nonrecoverable forms. Unless some future technology frees these ions for plant uptake, P & K will, over geologic time, eventually leach from the soil once more. Not one atom is lost by this consumption but availability, chemical states, concentrations and locations of the atoms are often changed markedly.
- The average use of pesticides in India is 457 g/ha. Pesticides applied to crops are also largely retained by soil. Thus they pollute land and cause toxicity to crop yields. Among the most important are the chlorinated organics like 2,4-D and organophosphates like malathion. In addition to their toxicity, they are persistent to biodegradation. So, some of these have been already banned as DDT in 1985, yet their residues may be detected in the soil, groundwater, crops, honey, breast milk *etc*. Pesticides affect CNS and so DDT residues can cause even paralysis.
- Industrial & urban soils may be more contaminated due to decreased plant cover and intensive human activities. About 50% of the raw materials ultimately become waste products in industries and 20% of these are extremely deleterious. Urban wastes compose both commercial and domestic wastes consisting of dried sewage sludge. Urbanization also increases runoff by paving, compaction and destruction of natural contours. Soil reactions are major determinants of trace gas concentrations like CO_2 & SO_2. Soil ecosystems support much higher urban population with O_2 through plants. So, city soil should be well investigated.
- Road side soil becomes enriched with Pb from leaded petrol having concentrations in the order of 1000-4000 mg/kg on busy streets. 81% As is used in agricultural chemicals as wood preservatives, feed additives, insecticides, fungicides & herbicides. Its order of toxicity is arsines(As^{3+}) > arsenite (As^{3+}) > arsenate (As^{5+}) and arseni-organic acids (As^{5+}). Rubber tyres can contain 0.09 μ/g of Cd due to use of ZnO & zinc dialkylcarbamates in the vulcanization process and Cd occurs with Zn in nature. The abrasion of tyres on the road adds Cd to street dust that comes to soil by wet and dry deposition processes. Though Cd^{2+} movement and plant availability in soils are small, its extreme toxicity can be a serious problem in soils. Pb, Cd & Hg are used in batteries. Cd, Cr, Cu & Zn are used in metal plating. Hg is used chloralkali industry, electrical apparatus and fungicides for seed dressing. Hg(0), Hg(I), Hg(II) & Cd(II) are retained

less strongly by soils than the other toxic cations, and hence pose a more serious problem. Hg(II) can be reduced to Hg(I) and more significantly to Hg(0) that is volatile and can diffuse as a gas through soil pores. Thus Hg is the most mobile toxic metal in soils.

IMPORTANCE OF SOIL REMEDIATION

Remediation refers to removal of contaminants so that the natural quality of soil is maintained for its proper use in agriculture, construction, industry, chemistry and environment.

I. Agriculture

The major reason of studying soil chemistry is to benefit plant production. One goal of soil chemistry is to explain why ions in soils vary widely in their degree of plant availability. The availability of cations generally decreases with increasing time after contamination and with increasing *p*H and clay content. Ions such as Ni^{2+}, Zn^{2+}, Hg^{2+} & Pb^{2+} are less responsive to *p*H than Al^{3+} & Be^{2+}. The availability of toxic anions (Se, V, As & Cr) decreases with soil Al & Fe hydroxide content and increases with *p*H because anions retention by soils decreases as the *p*H increases. The *p*H effect for anions, however, is generally less marked than for cations. Hg, Hg^{+}, Hg^{2+}, & Cd^{2+} are retained less strongly by soils than the other toxic cations, and hence pose a very serious problem of movement and plant availability. Cd^{2+} is rather soluble transition metal that behaves like Ca^{2+}. Though Cd^{2+} movement and plant availability in soils are small, its extreme toxicity can be a serious problem in soils used as waste dispersal sites. CrO_4^{2-} moves readily through well aerated soils of moderate to high *p*H. Though it is a strong oxidant and hence easily reduced at high concentration, its stability increases at increasing *p*H in it dilute (10^{-6} M) soil solution.

Toxics tend to remain within a few centimetres of where they first contact the soil unless the soil is stirred by cultivation (also by wind or rain). If retained at the immediate soil surface, they are above the most active portion of the root zone. Grazing animals confined to contaminated areas show the most serious effects of toxic metal concentrations in soils. Contaminants may reach human body through food and cause long term health hazards. Thus remediation improves both quantity and quality of our crops.

II. Construction

Soil chemistry is also important to the nonagricultural uses of soil for earthfill dams and roads and is being rediscovered in industrial nations as a good building material for homes, mud huts and adobe houses. The physical stability of soil structure depends in part on their soil chemical status. The longevity of mud adobe & wattle construction depends on the high Ca & low salts concentrations. The temples at Ankorwat have high Fe & Al oxides in building blocks, so persisted for many centuries.

III. Industry

A. Ceramics

Ceramic is a product manufactured by the action of heat on earthy raw materials in which silica and silicates dominate. The major groups of ceramic industry are :

1. Structural clay products such as brick, tile, terracotta, glazed architectural brick
2. Whitewares such as dinnerware, sanitary ware, floor tile, chemical and electrical porcelain, *e.g.,* spark plugs
3. Glass products of all types
4. Porcelain enamels
5. Refractory materials that withstand high temperatures
6. Portland cement, lime, plaster and gypsum products
7. Abrasive materials such as fused alumina, silicon carbide and related products

8. Aluminum silicates fibres
9. Ceramic foams with ultra fine particles (10-150 μ)

B. Cermets

Cermet (*ceramic + metal*) is a semisynthetic product consisting of a mixture of ceramic and metallic components having physical properties not found solely in either one alone, *e.g.,* metal carbides, borides, oxides and silicates. They combine the strength and toughness of the metal with the heat and oxidation resistance of the ceramic material. The composition may range from predominantly metallic to predominantly ceramic *e.g.,* SAP (sintered aluminum product) contains 85% Al and 15% Al_2O_3. The most important industrial cermets are titanium carbide based, aluminum oxide based and special uranium dioxide types. Cermets are made by powder metallurgy techniques, involving use of bonding agents such as Ta, Ti & Zr. Properties concerning high stress to rupture operate continuously at 982^{o}C, for short periods at 2200^{o}C.

Uses : Gas turbines rockets motor parts, turbojet engine components, nuclear fuel elements; coatings for high-temperature resistance sensing elements in instruments, seals, bearings, *etc.* in special pumps and other equipment.

C. Silicates

Silicic acids (hydrated silicas) may be represented by the general formula $SiO_2.nH_2O$. Salts corr. to orthosilicic acid [H_4SiO_4 or $Si(OH)_4$ or $SiO_2.2H_2O$], metasilicic acid (H_3SiO_3 or $SiO_2.H_2O$) and disilicic acid ($H_2Si_2O_3$ or $2SiO_2.H_2O$ or $SiO_2.½\ H_2O$) are definitely known. Metasilicates are often called simply silicates and hence H_2SiO_3 is known as silicic acid.

Like clays most rocks (except limestone and dolomite) and many mineral compounds are silicates. Typical natural silicates are gemstones (except diamond), beryl, asbestos, talc, feldspar, mica, *etc.* Portland cement contains a high percentage of calcium silicates. Best known of the synthetic (soluble) silicates is sodium silicates or water glass whose composition may vary due to an excess of silica from $Na_2SiO_3.SiO_2$. to $Na_2SiO_3.3SiO_2$.

Silicates are used in fillers in plastics and rubber, paper coatings, antacids, anticaking agents and cements.

IV. Chemistry

Soil clays are being investigated as catalysts for industrial and chemical reactions. Smectic clays that form in soils have large surface area to hold reactant molecules and can catalyse cracking of petroleum into gasoline and other organic reactions like polymerization. Smectite can also support other catalysts on its surface such as Cu^{2+}, Al^{3+}, $N(CH_3)_4^+$ and rhenium phosphine and rhenium phospho organic complex ions. At the end of the reaction, the clay catalyst is simply removed by filtration.

V. Environment

Green plants release oxygen which we breath in. Afforestation is the best possible solution to save man from natural threats of flood, draught and soil erosion. Green belts reduce all types of pollution. Soil quality determines the nature of plants in an area. Several soil samples showing activity against drug resistant bacteria or are noval antifungal or can be used in waste treatment.

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