



*A COMMERCIAL APPLICATION OF
VIROFLOW™ TECHNOLOGY*

**CASE STUDY
SOLID WASTE TREATMENT,
JEDDAH, SAUDI ARABIA**

The application of ViroFlow™ Technology was effective in destroying the sources of objectionable odour in waste materials, binding heavy metals into a nonleachable form, neutralising acid, and destroying pathogens.



Aerial view of the salination plant in Jeddah

BACKGROUND

The city of Jeddah, in the Kingdom of Saudi Arabia, extends 45 kilometres along the eastern Red Sea coast. About 2.5 million inhabitants live in the city. Municipal sewage collection and disposal and industrial solid waste management have been long-term problems in Jeddah, with few waste treatment plants in the city. It has been estimated that only 25% of raw sewage is treated in the city and the use of cesspools is still common.

Despite Saudi Arabia generating a gross national product of US\$380 billion per year, the provision of sanitary sewage treatment and disposal systems in the city has been slow in coming. The problem was compounded by an outbreak of dengue fever in Jeddah during 2006, at which time the entire city completely closed down to outsiders while the disease was contained. Images of raw sewage in the middle of the city (e.g. Figure 1) are commonplace.

The dumping site for Jeddah's municipal sewage and industrial solids is located at the east side of the city, in a valley surrounded by medium to low relief mountains that create an artificial dump called "Briman Lake" (see Figure 2), about one kilometre by one and a half kilometres in area. The city is adjacent to the dump in the west and south. The location of the dump is particularly unfortunate, because the general topography means there is a slope from north to south and from east to west, with leachate from the waste flowing back toward Jeddah.

It has been shown that the water table under Jeddah is rising at 50cm/year, and much of that is attributed to the inflow of untreated sewage. As the only dump site for municipal sewage and industrial waste, Briman Lake is continuously increasing in size, constantly moving towards the south, and now only three kilometres from city houses.

It is estimated that around 50,000 m³ of wastewater and solids, transported by 800 dump trucks, is dumped into Briman Lake every day, and the containment reservoir has no surface outlet. A portion of the contaminated groundwater from both Briman Lake and the rising water table is therefore believed to be entering the Red Sea.

In-situ studies along the periphery of Briman Lake have included soil analyses, permeability tests, and soil density and toxicity tests. These studies have shown there are two main sources of contaminated water leaching from the site: 1) under the dump through the valley soils, and 2) from the abutments of the dump through rock fracture systems. The studies demonstrate the unsuitability of the site as a sewage and industrial dumping area, and the resulting environmental hazards are obvious and well documented.



Raw sewage in creeks, streams and lakes is common in Jeddah.

In January 2007, Arab News announced that the Jeddah municipality was seeking ways to reclaim the dump site and turn it into a forested zone. In parallel with that effort, the municipality is in the process of developing the city's sewage treatment infrastructure to double its capacity. However, the current infrastructure is incapable of handling the output of raw sewage, leading to the continued storing untreated sewage at Briman Lake and dumping the remaining portion directly into the Red Sea.

The project to increase the municipality's capacity to treat raw sewage entails constructing a 13 kilometre pipeline to proposed new facilities. The location of the new dump site has, however, not been chosen. According to Arab News, the city is currently installing a sewage piping system, but had not yet established precisely when the system would be operational.

The lack of a sewage system results in urban flooding during high rainfall events and this rainfall can also cause Briman Lake to overflow, allowing a toxic mixture of raw sewage and floodwater to inundate some eastern suburbs. Briman Lake has also caused some groundwater wells to become poisoned by raw sewage leaking into the aquifer.

In addition to problem's associated with municipal biosolids, Briman Lake is also the deposition site for industrial solids. These solids come from various sources, including desalination plants along the Red Sea, power plants, oil refineries, and other industries within Jeddah. It is estimated that there are more than 10 million cubic metres of untreated waste at Briman Lake with a separate, but significantly large amount of solid waste being discharged directly into the Red Sea.

The desalination plant at Jeddah is linked to a cogeneration power plant at the site (Figure 3); fly ash from the power electric plant, used to fire the multi-stage flash distillation process, is dumped into the Red Sea. However, due to the prevailing wind system, much of this ash is blown back onto the beaches of Jeddah and is a source of significant pollution along the foreshore of the city to the north. Moreover, much of this ash is contaminated with oil from the Suez region and when this oil is mixed with fly ash, it produces a sticky, smelly and contaminated solid waste that pollutes the beaches of Jeddah.



Figure 3: Aerial photograph of a desalination plant in Jeddah (centre). The Red Sea is to the west of the plant and the city is one kilometre to the north and immediately east of the plant. Note the co-generation power plant adjacent to and immediately east of the plant (centre right).



Aerial photograph of Briman Lake. Trucks enter the site from the north (top right) with seepage running to the west and south of the dump (centre bottom); the city of Jeddah is three kilometres to the west.

The dumping of municipal and industrial solid waste into the Red Sea has created many environmental problems along the 100 km coastline of Jeddah. Recent research has shown, for example, that the Red Sea is contaminated with Biologic Oxygen Demand (BOD) levels ranging from 51 mg/L to 812 mg/L, total phosphorus levels of 3.81 mg/L, and nitrate levels ranging from 6.9 mg/L to 26.6 mg/L. This contamination has resulted in the destruction of fish habitats and coral reefs, adversely affecting two industries (i.e. fishing and tourism) on which Jeddah relies heavily.

For example, when wastewater is discharged into the Red Sea from the Al-Khomra treatment plant in the southeast of Jeddah, the effects include impairment of habitat for aquatic and marine life by accumulated solids, depletion of oxygen by decomposition of organic material, and marine organisms harmed by toxic substances that may spread to higher organisms through bioaccumulation in the food chain. The discharge entering confined water bodies, such as those near Salman Bay in the north of Jeddah, causes eutrophication with nuisance plant growth disrupting fisheries and recreational

activities.

VIROTEC'S TOTAL SOLUTION

Virotec Global Solutions was asked to demonstrate for the Presidency of Meteorology and Environment (PME) the effectiveness of its ViroFlow™ Technology in treating three different types of hazardous solid waste from Jeddah. The wastes were:

1. Solids from a municipal waste treatment plant;
2. Solid waste washed up on the beach contaminated with fly ash; and
3. Contaminated sediment from Briman Lake.

The four objectives of the application were to:

- a. Destroy objectionable odour (if evident) in the solids;
- b. Bind any heavy metals and neutralise acid in the solids;
- c. Destroy pathogens (if present) in the solids; and
- d. Examine revegetation and reuse option for the solids.

The work included the following steps for each solid waste:

- a. Analysis of the basic chemical properties of the waste solid;
- b. Treatment strategies and results for odour abatement, the destruction of Total Coliforms (TC) and Eschericia coli (E. coli), neutralizing acid and binding heavy metals; and
- c. An investigation into reuse options, including revegetation and brick manufacture.

WASTE DETAILS

> Waste # 1:

Solid waste from a municipal waste treatment plant; a blackish-brown, moist “filter cake” mixed with sandy material (see Figure 4). The waste was spongy or rubbery in texture, and was typical of biosolids previously treated and reused by Virotec.



Solid waste from a municipal treatment plant.



Briman Lake solid waste.

> Waste # 2:

This solid waste was collected from a Jeddah beach after washing up from the Red Sea; a grey, slightly moist, ash-sand mixture (see Figure 5), including shell pieces 10-50 mm long and small sticks. Upon receipt, the waste had a wet, sandy non-offensive odour typical of ash solids previously treated and reused by Virotec.



Solid waste washed up on the beach at Jeddah.

> Waste # 3:

Briman Lake sediment (or “dredge spoil”); a fine, black, dry powder (see Figure 6), typical of dredge spoil previously treated and reused by Virotec.

TREATMENT STRATEGY

Each waste was analysed for pH, odour levels, nutrients, leachable metals (and total metals for Waste #3 as Wastes #1 and #2 were free of heavy metals) using the TCLP test and Total Coliforms (TC) and Escherichia coli (or E. coli), if applicable. After treatment with the appropriate ViroFlow™ Technology solution, wastes were re-analysed for the above parameters and conclusions drawn.

Odour was qualitatively tested using a scale of “0”-“5”, with “0” being no smell and “5” being a smell causing nausea (i.e. extremely offensive). Analysis was conducted by the same independent “odour raters” at each recording interval.

TABLE 1: ODOUR RATING SCALE

TREATMENT METHODS

> Direct Addition Treatment

Each waste was mixed directly with ElectroBind™ reagent (an inert, dry powder) at a predetermined addition rate. The purpose of the direct addition treatments was to assess the ability of ElectroBind™ to bind heavy metals, destroy objectionable odour and neutralise acid.

Odour	Value	Description
Foul	5	Causes nausea in sensitive people, not tolerable to most
Offensive	4	Highly unpleasant to be around, tolerable to some
Unpleasant	3	Unpleasant to be around, tolerable to most
Mildly Offensive	2	Unpleasant to be around, tolerable by all
Non-offensive	1	Not unpleasant regardless of odour, tolerable to all
None	0	No discernable odour

> Revegetation Potential

In order to assess whether treated wastes could be revegetated or used in the revegetation of other infertile soils, each waste was mixed with ViroGrow™ reagent (an inert, dry powder). All mixtures were tumbled for 24 hours and pH recorded. Each treated waste was then planted with grass seeds and assessed at regular intervals.

> Brick and Road Base Manufacture

Each waste was mixed to form a sand plus ElectroBind™ slurry, and cured to determine the feasibility of using the waste as a fill, a road base or as other construction materials. A base mixture, consisting of two parts screened sand, one part ElectroBind™ reagent #1 and one part 40% ElectroBind™ reagent #2 slurry, was generated. Each waste was added and mixed into the base mixture at various proportions and poured into molds. Waste solids were left overnight to dry.

Initial evaluations were based solely on observation of the mixtures to see if the manufacture of bricks or road base might be practical. Compressive strength tests, dimensional stability (including drying shrinkage and moisture induced expansion), chloride penetrability, carbonation, efflorescence, acid resistance, and abrasion resistance were the subject of a later assessment.

RESULTS

The work found that all three solid wastes from Jeddah have some form of contamination, and that each waste could be effectively treated with a direct addition of ElectroBind™. It was found that all direct addition treatments successfully destroyed objectionable odours when present, destroyed coliforms when present, neutralized acid when present, and bound heavy metals. The treatments resulted in the creation of inert, dry and safe solids, free from any odour and disease-causing agents, leachable heavy metals or other contaminants.

The work also showed that the treated solids could support plant growth and could be used in revegetation projects. Several viable reuse options were identified that would allow the solids to be used in agricultural, construction or other industrial or municipal applications. These included reuse as road base, use as a beneficial soil additive, and use as an ingredient in brick manufacture.

> Direct Addition Results

TABLE 2: MAJOR COMPONENT CONCENTRATIONS IN RAW AND TREATED WASTE FOR WASTE #1

Parameter	Unit	Raw Waste	Treated Waste
pH	-	7.6	8.3
Total Coliforms	cfu	25,000	250
E. coli	cfu	15,000	0
Odour*	0 - 5	5	1 (like compost)
Calcium	mg/kg	NA	85
Magnesium	mg/kg	NA	46
Potassium	mg/kg	NA	180
Total Phosphorous	mg/kg	NA	3,125
Total Nitrogen	mg/kg	NA	10,260

NA indicates not analysed. * Odour data based on the scale summarised in Table 1.

TABLE 3: MAJOR COMPONENT CONCENTRATIONS IN RAW AND TREATED WASTE FOR WASTE #2

Parameter	Unit	Raw Waste	Treated Waste
pH	-	8.6	8.0
Odour*	0 - 5	2	0
Sodium	mg/kg	3,000	3,000
Calcium	mg/kg	100	750
Magnesium	mg/kg	100	350
Potassium	mg/kg	NA	150
Total Phosphorous	mg/kg	NA	11
Total Nitrogen	mg/kg	NA	515

NA indicates not analysed. * Odour data based on the scale summarised in Table I.

TABLE 4: MAJOR COMPONENT CONCENTRATIONS IN RAW AND TREATED WASTE FOR WASTE #3

Parameter	Unit	Raw Waste	Treated Waste
pH	-	1.9	7.3
Odour*	0 - 5	1	0
Calcium	mg/kg	NA	120
Magnesium	mg/kg	NA	50
Potassium	mg/kg	NA	50
Total Phosphorous	mg/kg	NA	3
Total Nitrogen	mg/kg	NA	880

NA indicates not analysed. * Odour data based on the scale summarised in Table I.

TABLE 5: TOTAL HEAVY METAL CONCENTRATIONS IN RAW WASTE #3

Parameter	Unit	Total Metals
As	mg/kg	10
Cd	mg/kg	5.0
Cr	mg/kg	5.0
Cu	mg/kg	6.0
Hg	mg/kg	10
Ni	mg/kg	755
Pb	mg/kg	10
Se	mg/kg	10
Sn	mg/kg	10
Zn	mg/kg	14

TABLE 6: LEACHABLE HEAVY METAL CONCENTRATIONS IN WASTE #3 AFTER TREATMENT

Parameter	Unit	Total Metals
As	mg/L	<0.05
Cd	mg/L	<0.02
Cr	mg/L	<0.1
Cu	mg/L	<0.1
Hg	mg/L	<0.05
Ni	mg/L	0.12
Pb	mg/L	<0.2
Se	mg/L	<0.05
Sn	mg/L	<0.5
Zn	mg/L	<0.1

> Revegetation and Growth Assessment

The following photographs (Figures 7, 8, 9, 10, 11 and 12) show the growth of grass in the three treated wastes seven days after treatment with ViroGrow™ reagent, and compare this growth to grass growth in the untreated waste solids.

Figure 7



Grass growth in treated Waste #1 seven days after planting and germination.

Figure 8



Grass growth in untreated Waste #1 control seven days after planting and germination.

Figure 9



Grass growth in treated Waste #2 seven days after planting and germination.

Figure 10



Grass growth in treated Waste #2 control seven days after planting and germination.

Figure 11



Grass growth in treated Waste #3 seven days after planting and germination.

Figure 12



Grass growth in untreated Waste #3 control seven days after planting and germination.

> Brick and Road Base Manufacture

The following photographs (Figures 13, 14 and 15) and data (see Table 7) present the results from the solidification and brick manufacturing trials. The work was carried out to determine if the waste solids could be both treated for contaminants as well as reused after treatment in some form of building construction or as a road building material.

Figure 13



The type of brick that can be manufactured from Waste #1. Note the porosity of the brick, which may be beneficial in some forms of paver or building material.

Figure 14



The type of brick that can be manufactured from Waste #2. Note the porosity of the brick, which may be beneficial in some forms of paver or building material.

Figure 15



The type of brick that can be manufactured from Waste #3.

TABLE 7: LEACHABLE HEAVY METAL CONCENTRATIONS IN WASTE #3 AFTER TREATMENT AND FORMATION AS A BRICK

Parameter	Unit	Total Metals
As	mg/L	<0.05
Cd	mg/L	<0.02
Cr	mg/L	<0.1
Cu	mg/L	<0.1
Hg	mg/L	<0.05
Ni	mg/L	<0.2
Pb	mg/L	<0.2
Se	mg/L	<0.05
Sn	mg/L	<0.5
Zn	mg/L	<0.1

The data in Table 7 show that the concentrations of all metals that can be leached from a brick formed using treated Waste #3 are all low, despite many of the metals having high total concentrations before treatment of the waste (e.g. Ni at 755 mg/kg).

CONCLUSION

> Waste # 1

This waste solid had all the properties of typical “weathered” biosolids. It had the most objectionable odour of all three wastes, ranked at “5”, causing nausea in some people and found objectionable by all. The odour levels were less than those of “active” biosolids, but they were obnoxiously high. After direct addition of the treatment reagents, the odour was reduced to a ranking of “1”. The direct addition treatment therefore successfully demonstrated that objectionable odour can be effectively destroyed by the application of ViroFlow™ Technology.

Waste #1 was also contaminated with coliform bacteria, including faecal coliforms. The direct addition treatment destroyed all but a few residual coliforms, making the treated solids safe, clean and reusable. It was observed that the treated waste contained typical nutrient levels for biosolids, making them valuable as fertilisers, compost additives, soil amendment additives, or other applications in revegetation and municipal development. The work also demonstrated the highly successful germination of grass seeds and grass growth in the treated solids when compared with an untreated control. These findings confirm that once the solid waste is treated with ViroFlow™ Technology, it can be used in agriculture.

Moreover, if these reuse options are not desirable, the treated material is sufficiently inert that it can be used as a clean fill or in other inert additive industrial applications. The manufactured bricks clearly demonstrate that the waste can be used as a construction material.

> Waste # 2

This solid waste is typical of contaminated fly ash mixed with sand. It has a pH close to world seawater averages, and its salt content is characteristic of a waste generated from a power plant and mixed with seawater. Because the waste did not contain any coliform bacteria, bacterial destruction was not relevant. Although the odour of Waste #2 was not particularly objectionable, the application of ViroFlow™ Technology removed all residual smell. Apart from the high concentrations of salts in the solids, the material is largely benign.

Of relevance to this investigation are the possible reuse applications of Waste #2. It has been demonstrated that the material has significant reuse value, particularly as a construction material, and may be used as a road base after treatment. Strength tests will confirm the usefulness of bricks that can be made from the waste, but it is likely they could be used in low-cost housing or other applications, such as bund walls, clay linings for dams, and/or low level construction infrastructure. The main obstacle to using the ash in this way is the high salt content that might adversely affect concrete strength. Because the waste is ash generated from a power plant, the above reuse option would be more practical if the ash was treated and reused prior to seawater discharge thereby greatly lowering the salt content.

> Waste # 3

This solid waste is the most contaminated with regard to inorganic elements. It has a very low pH, but the application of ViroFlow™ Technology has proved effective in raising the pH to near neutral and safe levels. Because the material is so dry and fine, if it is allowed to escape into the environment, dust and soil, groundwater, and air contamination are all likely consequences that could lead to adverse ecological and human health impacts.

Although this waste did not have a particularly objectionable odour, ViroFlow™ Technology eliminated all residual smell. The concentrations of many metals and their leachability were the major problems with this waste and the concentrations for some metals, including zinc and nickel, were particularly high. The metals in the solids are likely to have originated in industrial wastewater and sludge deposited into Briman Lake prior to dredging, and they constitute a threat to human health if ingested; the metals could also bioaccumulate through the food chain. It has been shown that ViroFlow™ Technology bound all these metals in such a way as to prevent leaching.

Of relevance also are the possible reuse applications of the material. The treated material has value as a soil additive. It has also been demonstrated that the treated solid has reuse value as a construction material, and may be used as a road base.

From these data it can be concluded that the application of ViroFlow™ Technology was effective in: destroying the sources of objectionable odour in all three waste materials examined, binding heavy metals into a non-leachable form, neutralising acid, and destroying pathogens. The data also demonstrate the effectiveness of the Technology in converting the three hazardous solid wastes from Jeddah into a medium suitable for both revegetation and as a material for use in construction.

In these ways, ViroFlow™ Technology successfully treated hazardous contaminants and converted the solids into a reusable form, thereby providing the city of Jeddah with a long-term sustainable solution to its solid waste problems.