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# A sink/source combination against floating pollutions in river – source water supply: the case of Edagberi/Betterland

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## Abstract

The Edagberi/Betterland Communities have been without a good source of water supply. The local population has lived over the years by drinking water from the Taylor Rivers without the due process of water treatment. However, a surface water scheme has never been favored and sunken boreholes have never been brought to function. The former is however, a surer means since both options require water treatment. Special design implications were the avoidance of all 'unnecessary' cost components and to take precautionary steps against possible oil spillage, which is considered as occupying the top layer of an element of flow.

***Keywords*: Water source; Water River; Water pollution.**

## Introduction

Edagberi – the main and older of the two settlements is 2.3km up front of Betterland – the newer and smaller of the two. They are both in Ahoada Local Government Area of Rivers State and play host to the Shell Petroleum Development Company (SPDC) Ltd; whose flow lines transverse the communities. The combined population for the communities for 1992 was 1546 (FOS) and there have been unsuccessful attempts at providing water supply to the communities. One of the latest attempts is 1.5% Derivation Fund of the Federal Government. This fund has since been replaced with the Oil/Mineral Producing Area Development Commission (OMPADEC) with Headquarters in Port Harcourt, the Capital City of Rivers State. The failure of previous attempts coupled with the dire need of the communities to show some physical benefits resulting from the activities related to oil prospecting put urgency on OMPADEC to solve the problem and awarded the design and supervision aspects of the water supply proposals to Unitech Consult. Two major reasons can be deduced for the failure of previous attempts.

(i) The lack of good quality water from previously sunken wells.

(ii) The lack of reference in surface water sourcing in the whole of Rives State.

Whereas the lack of good quality water from Sunken boreholes has always shot up construction costs far above the initial estimates to include treatment plants. The lack of a reference point or pioneer effort at surface water sourcing laid against the background of possible Oil Spills into the rivers has equally discouraged this option in previous design attempts. Unitech Consult took the surer of the two options i.e., river sourcing since sunken boreholes would also require treatment. In principle, decision was taken to improve the quality of the drinking water for the community rather than designing a full-scale treatment package, which may not attract policy-makers in the interim for such a small community.

The problems of cost were tackled by deciding on a mini Scheme whereas the issue of oil spillage was tackled using a sources/sink principle at in-take.

The following line diagram illustrates the system chosen:

1. Sourcing
2. Equalization
3. Aeration

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4. Horizontal flow roughing Filtration
5. Slow – Sand Filtration
6. Chlorination/Storage
7. Distribution

**Equalisation** (2 above): was introduced to eliminate the need for additional pumps whereas reinforced cement concrete (RCC) filters were chosen to reduce maintenance cost. Chlorination only was chosen instead of the requirement of a full-scale chemical treatment.

**Sourcing:** The Taylor Creek is a tributary of the Orashi River which forms a surface flow of the available water table in the region and it is also a tributary of the Rivers Niger. From boreholes sunk within the region. It is easily evident that the water table opens up into the river. This water table spreads over the vast deltaic region (Total-water planning, 1965) and is therefore under no immediate threat of drying up. Gauge-levels at low-low or dry-weather flow (dwf) allow swimming activities to continue and hand-pull canoes to be used. From local history this has been the case for the entire life of the communities.

***In – take Structure*:** A sink/source principle which is illustrated below has been adopted to tackle the problem of possible oil spillage, by using wing walls, a channel and a sump – Fig 1 and 2. This is in combination with an off-stream channel/reservoir technique in the latter, a branch channel fills up a reservoir which when full allows the main river to by-pass it – Thorn (1966). When the reservoirs are placed on elevated platform, pumping will cause a continuous strain and a constant pumping rate will satisfy a constant yield stress condition. Another important consideration would be that plastic yield is higher than elastic yield. Elastic yield

In this case is assumed to be the minimum pumpi9ng capacity or rate and is about ten to twenty times lesser than the plastic yield – a constant velocity or uniform flow being assumed for any given stress value (Rider, 1983).

Applying the above assumption to the Edagberi/Betterland water supply scheme within

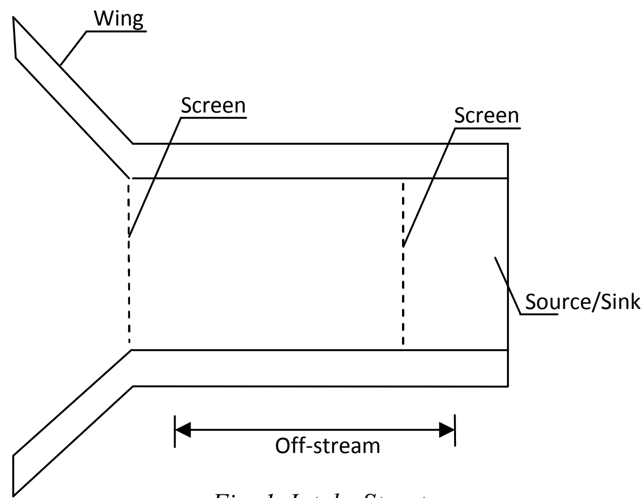


*Fig. 1. Intake Structure*

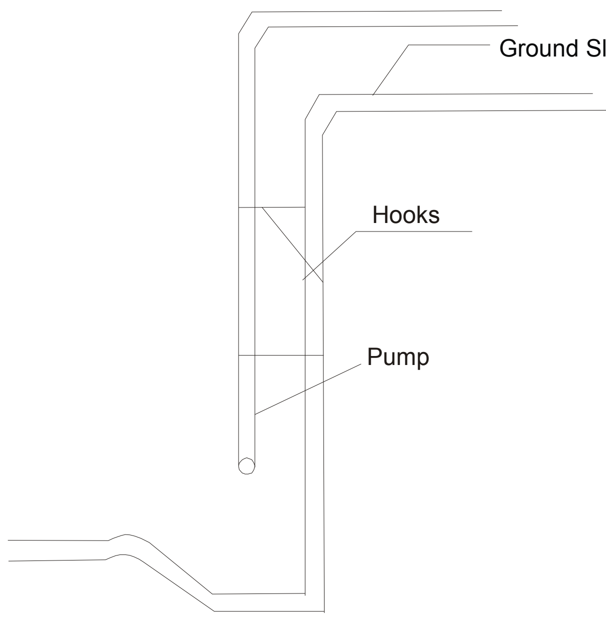


*Fig. 2. Intake Source/Sink Sump*

the context of a source/sink principle gives a picture as below:

1. Partial sink into sump (partial because one side is a concreted vertical wall)
2. A complete inverted sink into the pipe (pump).

If it is assumed that pumping will be continuous and that an inverted sink is the exact replica of a source, then we are faced with the use of a source/sink analysis in the sump where applicable source/sink equations can be listed as below:

$\tau = \lambda(\delta/\delta y)$……………………………………(1)

where τ is shear stress in a perpendicular direction to axes of deformation.

$Q = -k(h_Z - h_1)/1$ where q is unit flow per unit time K is related to liquid (crude oil) Characteristics and medium (river) characteristics $h_1$ is crude oil floatation (Fig.3a) depth h2 is the depth of crude Oil dispersion and 1 is the length between h2 and h1

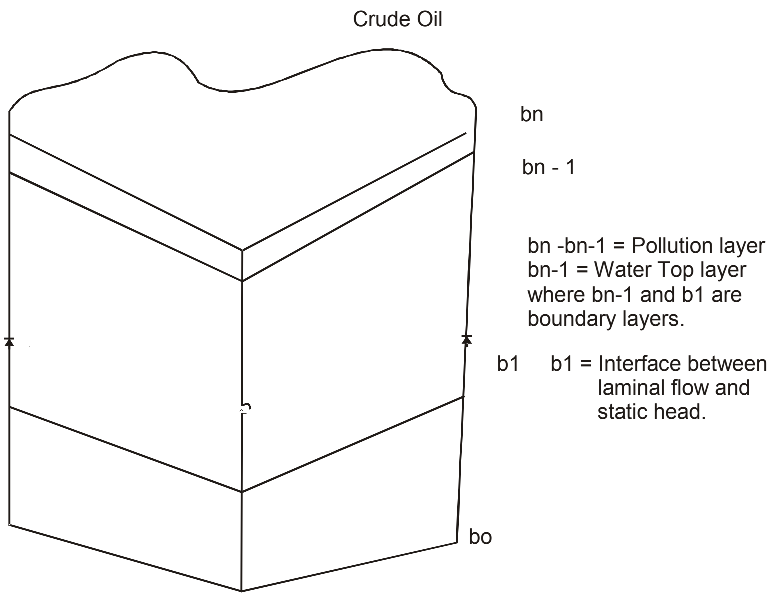


*Fig. 3a. Flow Element*

In the element above (Fig.3a), it is assumed that top-most layer will be spilled oil which is likely to be Crude Oil and not any refined petroleum product since there is no pipeline crossing the area or an area near enough (NNPC, 1996). It is also assumed that Crude oil would behave like froth when pushing against a continuous solid boundary as the sump – wall.

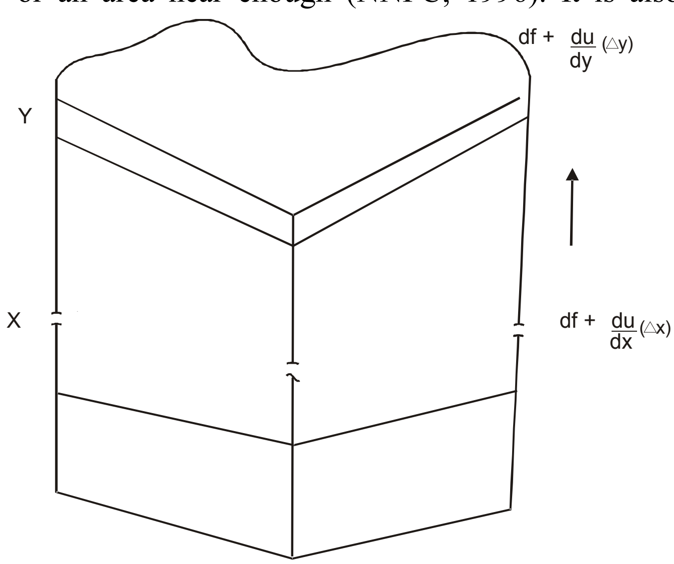


*Fig. 3b. Flow Element in X - Y Plane.*

Various versions of this (Darcy's) law can be developed depending on K.

If Q is source strength

$Q = [\partial f + \partial/\partial\chi\,(\Delta\chi)] + [\partial f + \partial u/\partial y\,(\Delta\chi)]$

and = if Q = -Kt (h2-h1)/L

then

$-kt\,(h2-h1)/L = [\partial f + \partial/\partial\chi\,(\Delta\chi)] + [\partial f + \partial u/\partial y\,(\Delta y)]$

$$h2 - h1 = t\,\frac{[[\partial f + \partial/\partial\chi\,(\Delta\chi)] + [\partial f + \partial u/\partial y\,(\Delta y)]}{-Kt}$$

and

$$-Kt = \frac{t[[\partial f + \partial/\partial\chi\,(\Delta\chi)] + [\partial f + \partial u/\partial y\,(\Delta y)]]}{h2 - h1} \quad\text{…….. (2)}$$

χ is below h2 and should be above top level of sump.

h2 signifies pollution zone.

When the concrete interface between the sump and retaining wall is considered, the source sink is regarded as partial, since redial extensions in the direction of the wall is not continuous. In this case, the dynamic principles of a foundation in half space (Damisah, 1981) can be converted into a solid-state half space in the Boundary Integral Equation (BIE).

$V\theta = \partial\varphi/\tau\partial\theta$ ………………………………….……(3)

V is velocity

Vθ is tangential velocity

ϕ is angle of shear deformation

θ is angle of shear stress

$Q = A_1V_1 = A_2\,V_2$ ………….. AnVn for an element of flow

$V + \partial v/\partial\chi\Delta\chi$ = flow in x axis

$V + \partial v/\partial r\Delta y$ = flow in y axis

$V + \partial v/\partial r\Delta z$ = flow in z axis

:. Flow in (Q) in x-y =

$= [v + \partial v/\partial\chi\,(\Delta\chi)] + [\mu + \partial\mu/\partial r(\Delta\chi)$ ……………..….(4)

For a Non-Newtonian fluid like crude oil: equation 2 can be re-written as shown below depending on the axis under consideration.

$\tau = f\,(\partial u/\partial y)$ where f is a dynamic viscosity

$= f\,(\partial u/\partial\chi)$……………………………………… (5)

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In which case, the flow element can be better represented as shown above.

$\tau = [\partial f - \partial u/\partial y, (\Delta y)] + [\partial f - \partial u/\partial \chi,(\Delta x)$………(6)

i.e using the principles of a first order ordinary differential equation in the pattern of Ketter Prawel (1969). Since we are considering existing velocities, equation (2) can be ignored for now. If we say that Q is source or sink strength which is the equivalent of the discharge, then for a given Area (A).

$Q = v + \partial u/\partial \chi, (\Delta \chi) + u\ \partial u/\partial y\ (\Delta y)$

By combining equations (5) and (6), we have

$Q = \partial f + \partial u/\partial \chi\ (\Delta \chi) + \partial f + \partial u/\partial y\ (\Delta y)$ ………. (7)

$= [\partial f + \partial/\partial \chi\ (\Delta \chi) + [\partial f + \partial u/\partial y\ (\Delta y)$ ……at sump

Where $\partial f$ is flow element due to change in applied shear stress ($\tau$)

The implications of this equation are that: -

1. At a velocity (u) with a discharge (Q) for a certain given unit Area (A), the flow element can retain constant boundaries.
2. As a result of (1), the top layer of an element if polluted with crude oil is assumed to be floatation and can therefore be screened out.
3. At a certain unknown depth (X), the effects of oil pollution become insignificant or non-existent, and X can be determined from Darcy's law for a liquid medium.
4. The construction of the sump should be based on the above premise. So should be the operation of the suction pumps.

   $\partial u/\partial r = u$, $u = 0$ where u is velocity vector along x – y plane.

Then linear deformation due to stress in the x – y plane will approach zero in the direction of x at screens or any other solid surface.

$\therefore \Delta \chi \to 0$ and

$Q \to F(f)$

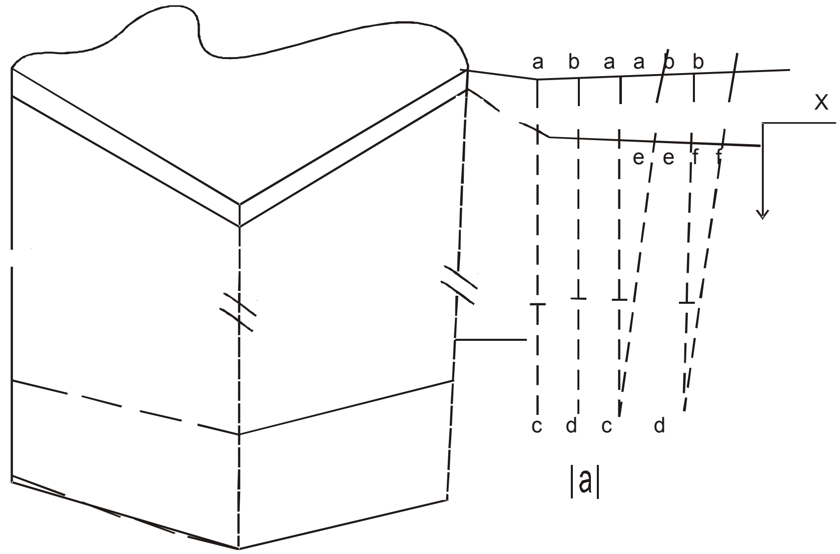


*Fig. 4a. Graphical Displacements*

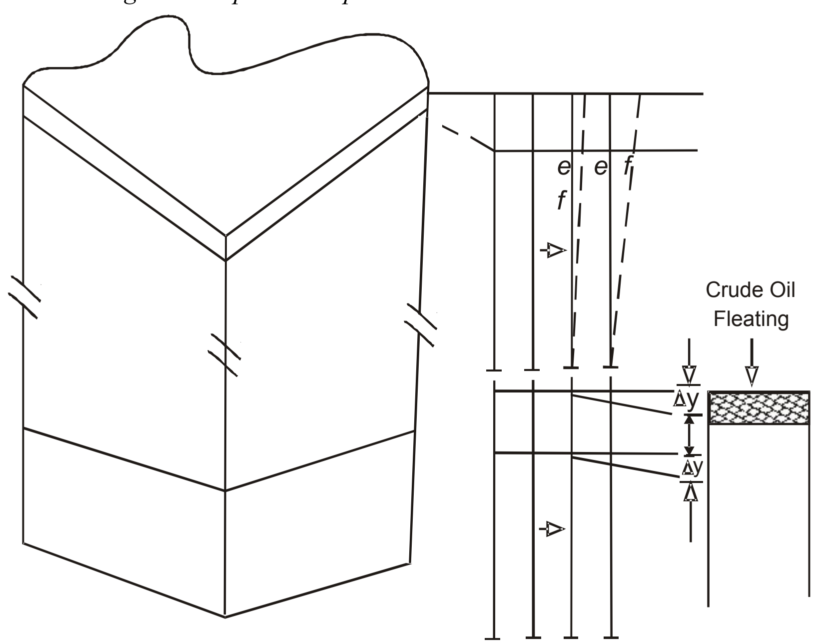


*Fig. 4b. Graphical Displacements*

Where $F$ (f) is in the y and z-axis.

A similar exists therefore between solid-state stresses along principal axis x,y,z that satisfy Tresca yield Criteria which states that yielding occurs when maximum shear attains a certain level and for which principal stresses can be ordered as $\sigma 1 > \sigma 2 > \sigma 3$ (Mitchell *et al*., 1988). In our own case however, the principal stresses are ordered, $\sigma y > \sigma \chi > \sigma z$ for the x, y, and z-axis since $\partial y$ approaches maximum and $\partial x$ tends to zero at the sump.

$\tau = f(U)$
$\Delta x \longrightarrow 0$
Q = F(f) where f is deformation due to application of shear stress

The combination of the Tresca yield criteria with the BIE or differential versions of it will be an interesting area for further study. It must be assumed however that the water medium be considered as Plastic in the Channel. An original element a b c d having a top-layer sub-element a b e f will deform to a' b' e' f' when given a stress τ resulting into Δχ and Δy as equivalent deformations in x – y plane. This sis graphically illustrated in Fig. 4a and 4b to show Δχ, Δy. As τ reduces, Δχ, Δy will decrease.

During pumping, a fall in Head represented by the graphical depression Δy will be created which will be taken up by the crude oil. Under these conditions, the top-most layer will tend to 'froth'. The polluted layer accumulates 'froth' which can be taken care of at the screens whereas the bottom layers keep a steady supply to the sump at a safe depth.

If Q = f(τ) …………………….. (9)

And τ is from shear stress associated with a flowing river e.g. from gravitational pull and. τa is shear stress associated with river flow, then τa=τb where τb is shear stress associated with the source/sink phenomenon in the sump. This will be true for a constant pumping rate.

In summary, we can say that if:

$Q = U + \partial/\partial\chi\ (\Delta\chi) + U + \partial U/\partial Y\ (\Delta y)$ …… $U + \partial U/\partial n\ (\Delta n)$

$= \partial f + \partial/\partial\chi\ (\Delta\chi) + \partial f + \partial u/\partial y\ (\Delta y)$ ……………. $\partial f + \partial u/\partial n\ (\Delta n)$

$Q = \partial f + \partial\tau a/\partial\chi\ (\Delta\chi)\ \partial f + \partial\tau a/\partial y\ (\Delta y)\ \ \partial f + \tau a/\partial\chi\ (\Delta n) + \partial f + \tau b/\partial y\ (\Delta n)$… (10)

Where Q = Qa = Qb
Q = is strength of source
τa = shear stresses from river
τb = shear stresses from sump

At sump: the first part of equation (10) is zero and if we consider X and Y-axis, we can rewrite equation (10) as

$Q = \partial f + \partial\tau a/\partial y\ (\Delta y) + \partial f + \partial\tau a/\partial z(\Delta z) + \partial f + \partial\tau b\Delta y/\partial y + \partial f + \partial\tau b(\Delta z)/\partial z$….(11)

$= [\partial f + \partial\tau a/\partial y\ (\Delta y)] = [\partial f + \partial\tau a/\partial y(\Delta y)]$ ie $\Delta z \rightarrow$ zero.

Oil pollution now taken care of the next design strategy was to provide such a mini – water treatment that would be as cost effective as earlier stated. This was handled in accordance with the process diagram.

Pump House: Installed pump supply is 3No. (6" x 6") diesel pumps with each capable of serving the scheme on its own. This leaves a reserve capacity of 2No. (6" x 6") when pumping is on. Available Horse Power (HP) in the Port Harcourt area were 64 and 38 with cost at N1,124,812.56 (One Million, One hundred and twenty four thousand, Eight hundred and twelve Naira, Fifty six Kobo) and N679,763.75 (Six hundred and Seventy nine thousand, seven hundred and Sixty three Naira and Seventy five Kobo) respectively.

**Equalisation:** The idea behind this facility was to keep a constant head for feeding the system. Two Cylindrical tanks with diameter of 13.82m and effective height of 4m were provided thus leaving a maximum capacity of $600m^3$ x 2.

**Aeration:** An aeration chamber 7.00m x 1.00m and concrete thickness of 0.12m was provided to introduce enough oxygen such that ferrous ions ($Feo^2$) can change into Ferric ions ($Feo^3$) for sedimentation, which takes place at the filter beds. A modest chamber was chosen with a dush sprinkler as an additional aid in mind. The aeration chamber feeds the filtration process via a value chamber.

**The Filtration Process:** The filtration process is started by the Horizontal – flow Roughing filter Tank of 3 No. Compartments. The dimensions are 3.5m, 3.0m and 2.3m respectively in length with a common width of 2.5m and depth of 1.5m. One major consideration was the fact that chemical additives should be reduced to zero if possible and since the untreated water quality was far from safe, it was decided that the 'necessary' coagulation/flocculation process be replaced with a further filtration process using slow – sand filters.

Ferric ions will cause to sediment, some of the dissolved particles after the aeration process. The inadequacies will then be taken care of by the expanded filtration process. The Addition of Aluminum sulphate (ALSO4) as softener at the point of usage is a very familiar thing to the local population. A bank wash mechanism is to be designed for the filtration beds as well as the aeration chambers.

**Slow – Sand – Filters:** As said earlier, the slow-sand-filters are to provide further filtration and they are in two chambers with each chamber acting as a separate filter bed. The in-let has two value compartments and there is one out-let compartment. The design capacity (Q) is $0.278m^3$/sec. to $0.25m^3$/sec for the value compartment. This gives a supply capacity range of $1.2 \times 10^7$ for a 12 – hr working day.

**Chlorination Chambers:** The slow – sand filters are actually housed together with the chlorination unit and final pumping station.

**Storage and Distribution:** A 20,000 gal. (90.9201) overhead tank was already in place as a result of previous attempts at providing the community with water. If about $91m^3$ of treated water is available each hour, for a 24hr day, $12184m^3$/day is available.

According to Chaturvedi (1987); the urban water demand for USA is an average of 680 1ped within a range of 227 to 22530 1ped. Also the relevant range using selected cities for Europe has been put at 545 to 3,000 1ped. For Edagberi/Betterland, the following distribution of daily per capital demand is made.

| | |
|---|---|
| Drinking | 35 |
| Cooking (Actual cooking + preparation) | 10 |
| Washing of clothes | 40 |
| Bathing | 50 |
| Farming Activities | - |
| Toilet (Flushing and clean up) | 50 |
| Others (wastes, local crafts etc.) | 20 |
| | 205 1ped |
| Use | 300 1ped |

If this value is used, then Q changes to the relevant population multiplied by 300 that will be $6 \times 10^5$t for 2,000 and $1.5 \times 10^6$ t for 5,000 people. This demand against a pump capacity supply for $1.2 \times 10^7$ t to $1.08 \times 10^7$ t and storage capacity supply of $1.2184 \times 10^7$ t gives a guaranteed adequacy for the years ahead. It is assumed that pumping will take place outside the 12-hr working day i.e. in the night hours.

## Discussion

A full-scale surface water treatment plant would require chemicals like lime, Aluminum of Ferric Sulphate (as coagulants), Chlorine, Carbon Slurry, Sulphur Dioxide in various dimensions and quantities. To cut down the extent of usage was a principal target. Also to accommodate the effective use of these chemicals, special provisions must be made in the design in form of mixers, chambers, etc. so by cutting on these chemicals, a lot of such features were naturally done away with, supporting the action with fact that the community had lived or survived on this raw water for its life. It was obvious therefore, that if the plant could reduce impurities (especially biological impurities) and turbidity, far better water would be made available for drinking and this is what this plant was made to achieve.

On the sump: a source/sink principle has been adopted. But since oil pollution has never occurred, it is safe that this sump should be considered a trial, pending a case of oil sillage or further developments in the use of the principle.

## Conclusion

Two basic operating equations have been put forward i.e. equations (7) and (10) to support the use of source/sink principle as a check against oil spillage. The sump depth, channel characteristic, and operating velocities that will cause a steady flow through the system will determine effective design, with x (safe depth) being kept above sump.

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