LEAKAGES IN WATER SUPPLY SYSTEM

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for the award of an <u>Associateship</u> Civil Engineering Certificate
as approved by the Senate.

BY

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DEDICATION

This work is dedicated to my parents, without whose support and encouragement my education would not have been possible.

ACKNOWLEDGEMENT

I would like to acknowledge my sincere gratitude to my project master, Professor B.Z. Diamant of the Department of Civil Engineering, Ahmadu Bello University, Zaria, for his untiring support and guidance, both morally and otherwise, throughout my period of study.

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Lastly, I thank my state government for allowing me to attend this course in the first place and any other person or group of persons not mentioned, who, in one form or the other, helped to the success of my work. Thank you all.

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LEAKAGES IN WATER SUPPLY SYSTEM

CHAPTER

1.0 INTRODUCTION

Water consumption varies from city to city, depending upon the population growth, climatic condition, industrialisation, habits of the people, rising standard of living, social customs, water pressure in the mains. The demand of water goes on increasing with its purity and ease with which it is available. It has been observed in many developing countries that when the people have to get water on head load from some sources, their requirements are limited, but when the water is delivered to the house, it is a "Fait Accompli." They forget the difficulties and ask for more water. All these add up to make it hard for the engineer to determine the exact per capita per day requirements of water and all assumptions are always mere approximations.

It can be seen that in most cases, while the engineer calculates the percentage of consumption for various sections and purposes, a very important aspect, that is losses and wastage of water, is usually overlooked. This loss and wastage of water is termed as "unaccounted for," which is due to leaks in pipes, plumbing fixtures, pump slipages, unauthorised water connections and careless and wilful waste. Some of it may also represent low flows passing through meters too large for the service. It is therefore advisable to add some percentage while calaculating the consumption in order to cater for the losses and wastages of water. Leaks are undiserable, both because they waste water and because they may undermine pavements and other structures. Abandoned service pipes are a prolific cause of leaks.

The trend of water consumption in various cities of the world is rising daily and the water authorities are facing problems and have to adjust their water consumption and population projection accordingly. The rate of water consumption has a great bearing on the investiments of capital cost for water supply systems required for such consumption. It also affects the time when new facilities are required and the population which such facilities will support before further augmentation is required.

It is true that planning should be based on a water demand that is unrestricted at all times, but it will require a high cost for the system. A striking balance, therefore, has to be provided for the selection of peak hour water consumption, keeping in mind the basic factor of cost.

1.1 WASTE SURVEYS AND WASTAGE CONTROL

A scientific approach is required to launch an extensive programme for finding out the exact water consumption otherwise all assumptions will always remain as unrealistic and guesses. It could be visualised from the following table how much water goes as waste with the wilful and careless opening of taps. (see Table 1).

TABLE 1

Head ft	Diameter of Tap / Gallons per Minute			
	$\frac{1}{2}$"	$\frac{3}{4}$"	1"	$1\frac{1}{2}$"
75	1.42	3.93	8.10	14.10
100	1.65	4.55	9.35	16.30
150	2.03	5.59	11.50	19.90
200	2.63	6.42	13.20	23.00

Waste surveys are conducted by isolating a section of the system by closing the valves controlling the water flow to the section so that the water flows through a single pipe to that section. The flow through this pipe is measured and if it is found to be greater than normal, the isolated section is further divided into smaller ones and the source of the abnormal use is located more closely.

Measurements taken during early hours of the morning, around 3.00 a.m. - 5.00 a.m. are likely to indicate leakage, waste or abnormal use of water, because normal daytime usage is commonly suspended during these hours. The rate of flow is measured by the use of a pitometer, and because this calls for exposing and boring hole in the pipe, another alternative method is employed. In this method, all the valves in the section of the system to be inspected are closed and water is fed to the district in one or more fire hoses, equipped with meters, which are connected to hydrants on either side of the closed valves. When excessive consumption is located in the district, a house-to-house inspection of plumbing may be conducted to locate the waste. Theft of water can sometimes be detected by such surveys.

Illegal use of water is usually not a serious economic matter but should be regarded against as a matter of principle. Illegal methods include bypassing around the meter, called "jumping;" including low, unrecorded flows through the meter, called "dripping;" in flat-rate services, supplying a neighbour through a hose or turning on water without permission of the water company, to mention a few. Alertness and observing meter readers and other waterworks employees, encouraged by renards for the discovery of such practices, chocks such abuses.

1.2 FINDING LEAKS

Methods used for the location at leaks in underground pipes and in subaqueous pipes include:-

1. Direct observation
2. The sounding rod
3. The hydraulic grade line
4. Water hammer
5. Blowing air into the pipe
6. Putting dye, salt or radioactive tracers into the water
7. Studying the quality (change of salinity) of water in a submerged suction pipe.
8. Measuring the volume of water required to fill the pipe; and
9. Listening either directly for the sound or with the aid of a sonoscope or electric sound amplifer.

Each method is best suited to particular conditions. None is universally applicable or infallible.

Direct observation can scarcely be called a method because it does not require any special knowledge. However, some skill is needed in detecting leakage where there is a rich green spot in a lawn, a soft spot in the ground, a melted patch of snow or ice, or where a spot of frost or dew disappears immediately in the early morning. Any of these clues may indicate the position of a leak, as may the sudden or otherwise inexplicable increase in the flow in a sewer or the appearance of a "spring" where there should be no spring. Water does not always appear close to the spot from which it left the pipe. After the general location of the leak, the sounding rod may be used to find the exact point. This instrument is a sharp-pointed metal rod that is pushed into the ground and then taken out for inspection. If it is seen that the rod is moist or muddy, the line of the leak is then followed.

If a pipe leaks so badly that it is possible to empty itself within a short time, after it has been shut off, the leak can be found by draining away the pipe and recording the volume of water that will fill it up again quickly. This figure, if divided by the cross-sectional area of the pipe will give the distance to the location of the leak.

Leaks in water pipes make some sound, unless the leak is submerged. The leak may be heard either directly by placing the ear on the service pipe or a sounding rod may be pushed down to the pipe and, by placing the ear against the rod, it can easily be detected. However, in the case of an unaided ear, one of the many simple instruments for magnifying the sound will make it audible. These include the aquaphone, the detectaphone, and the sonoscope. The aquaphone is similar to a telephone without connections and it works by placing one end of the receiver in contact with the sounding rod or pipe, thus making the sound audible. It is then followed untill the leak is finally located.

A leak may be detected by following the pipe in the direction of diminishing pressures, that is, by following the hydraulic grade line. If two points are found on the hydraulic grade line on either side of a leak on a long pipe line and the hydraulic grade lines passed through these points, the point of intersection of the grade lines will be over the location of the leak.

In the application of the phenomenen of water hammer to finding a leak, favourable conditions require a long pipe line without important branches. A valve on the line is opened until a uniform flow is maintained, and then suddenly closing the valve. The instant of time that the valve is closed and the pressure in the pipe immediately thereafter are recorded. The pressure wave caused by the water hammer will travel along the pipe to the leak, where a part of the pressure wave will be dissipated. The wave of the diminished pressure will then travel back to the pressure gage of the valve, and a drop in pressure will be observed. Since the velocity of travel of the pressure wave is as shown by the equation:

$$V_W = 4,665 \frac{1}{1+(Kd/Et} \quad \text{fps.}$$

where E = modulus of elasticity of pipe material, psi

K = fluid bulk modulus of elasticity, 294,000 psi for water.

d = diameter of pipe, in.

t = thickness of pipe shell, in

and Vw = velocity of the pressure wave through the pipe.

and the wave has travelled twice the distance between the valve and the leak, the distance to the leak, in feet, is equal to:

$$D = \frac{TV}{2}$$

where T = time, sec., for pressure wave to return to valve.

V = velocity of travel of pressure wave, fps.

The blowing of air or the placing of colouring matter in a pipe is useful only in submerged pipe, where air bubbles or the colouring matter will appear over the leak. Fluorescein and the slightly cheaper dye uranin, both coal-tar dyes, are the most commonly used dyes. They are detectable in a concentration of less than 1 ppm by the naked eye and up to 1 part in 10 billion with the aid of fluoroscope. The sample of the water observed must be alkaline since acidity bleaches the colour which is restored by adding alkalinity. Such dyes cannot be used in potable water since their appearance is undesirable. A slightly increased concentration of salt (NaCl) may be used in the detection of a leak by showing, through chemical analysis, an increasedchloride content in the water suspected of escaping from a pipe into which a dose of salt has been added. The salt concentration is however insufficiently increased to be detected by taste.

In the electric sound magnification of leakage detection, the sound emitted by a leak is picked up by a delicate crystal and magnified up to 10,000 times by vacuum tubes or transistors. It is possible to tune the receiver to the pitch of the leak, excluding interferring sounds. In the M-scope leak locator, a very sensitive instrument, the sound of the leak is followed directly. The effectiveness of the instrument is greatly increased by making direct contact at points along the pipe and following the pipe until the sound can be heard without contact with the pipe. Sound will travel faster and a hundred times as far through the pipe as through porous ground.

1.3 PERMISSIBLE LEAKAGE

Some amount of leakage is always to be expected from water pipes laid with the best of care and under favourable conditions. In the Water Works Manual the upper limit for leakage is given by the American Water Works Association as 250 gal per 24 hr. per in. diameter of pipe per mile, and in specification, it is stated that "no pipe installation will be accepted until the leakage is less than $ND\sqrt{P} \div 850$ (expressed in gallons per hr.).

where N = number of joints in the length of pipe to be tested

D = nominal diameter of the pipe in inches and

P = average test pressure in p.s.i.

1.4 REPAIR OF LEAKS

Routine repairs of leaks involve the insertion of a piece of new pipe or encasing the old leaky pipe in a sleeve with rubber or other form of gasket:- Where it is not possible to shut off a leaky pipe for repairs, the water may sometimes be frozen by wrapping the pipe with dry ice in a burlap-wrapper and mixing the ice with ether, alcohol, or other volatile substance. Proprietary substances that can be forced into holes in which the material hardens, such as smoothen, Devcon A, or Gutentite, may be used to close relatively small holes.

CHAPTER

2.0 PIPE MATERIAL

The selection of various pipe materials for water supply always requires a serious consideration before the commencement of projects. Principally it depends on the total annual cost which allows for the difference in anticipated life of the various pipe material, but the other factors such as availability of material, accessibility to site and field laying problems may determine the type and class of pipe ultimately required to be used.

The following other factors also affect the determination of the type of pipe material required:-

(i) Difficult Location: Where access is difficult not only for construction but from maintenance and replacement point of view a steel pipe is preferable.

(ii) Static Pressure and Water Hammer: Materials required to resist water hammer or surge pressure is recognised very critical in determining the suitability of that material capable of taking the effects of water hammer. Ductibility of mild steel plate and the strength of welded joints are ideal for resisting water hammer and surges.

(iii) Velocity in Pipe: Some don't consider this as a criterion in the selection of pipe material. But high velocity and abrasive action inside the pipe, vibration and instantaneous waves result in severe water hammer which ultimately affect the selection of a suitable pipe material.

(iv) Chemical Nature of Soil: Soil survey should be conducted in order to determine the aggressiveness along the route of the pipo line and the treatment required to protect the pipe line.

(v) Chemical Nature of Water: The chemical nature of water causes considerable encrustations in the unlined steel pipe which reduce the discharge capacity and life of the pipe.

Broadly speaking, cast iron and steel pipes with both internal and external protection are expected to have a life at 80-100 years. Difficulties in laying and jointing of pipes should always be brought to a minimum and the choice of material should be such that the pipe is able to take up the thermal expansion and contraction due to the local conditions.

The failure of absestos cement pipes is due to three conditions which may act singly or together.

(i) Deterioration of the pipe due to attack from the the water being carried. This is indicated by softening of the inside of the pipe and longitudinal splitting.

(ii) Deterioration of the pipe due to attack from the soil or ground water in which the pipe is laid. This is indicated by softening of the outside of the pipe and longitudinal splitting.

(iii) Bending stress in the pipe due to traffic loading or soil pressure on badly laid pipes, or stresses arising from actual soil movements. This is indicated by circumferential cracking of the pipe.

The following are the observations extracted from the results:-

1. Internal Attack - This is due to leaching and if it is allowed to continue unchecked in bad areas a life of not more than 20 years is expected from bitumen coated pipes and very less in uncoated pipes. The high density steam cured silica asbestos cement pipes are claimed to be more resistant to this type of attack.
2. External Attack - This can be attributed to a number of forms such as leaching, bacterial, sulphate or other chemical attack. Usually these types of attack flourish in damp and swampy conditions. The coating with bitumen is the only answer to counteract this attack.
3. Mechanical Attack - This is mainly due to bad laying as asbestos pipes require a very careful handling and lying. Sometimes in heavy clay soils subject to severe swelling and shrinkage the pipes are badly stressed. Therefore the flexural strength of the pipes should be according to the specifications and should be tested before laying. It may also be of assistance to lay the pipes a little deeper in heavy clay soils since the soil movement reduces with depth.

2.1 PRECAUTION IN LAYING

1. The pipes should be laid on a proper bedding material in order to avoid an uneven floor which will otherwise result in a poor support and back filling should be done carefully.

2. The joints should be correctly made with at least 6 mm gaps for expansion of pipes due to saturation.
3. The rubber rings should be rolled home correctly.
4. The piping should be supported along the whole length and to ensure that the floor of the trench is hollowed out at the appropriate places to take the pipe sockets.
5. Thrust blocks of concrete should be provided at all bends, tees, junctions, etc.
6. In clay soil, the pipe should be burried with sand around and at top and with careful backfilling and hand tamping to about 0.3 m above the pipe.

2.2 PIPE CORROSION

The most widely accepted theory of corrosion of metals is that it is electrochemical in nature and proceeds in four well-defined steps as follows;

1. The Anodic Reaction: Metal ions, each carrying one or more positive charges, are released to the water. The same number of electrons, each carrying a single negative charge, are released to the metal. This takes place only at the mental surface and can be expressed as:

$$Fe\ (metal) \rightarrow Fe^{++} + 2e$$

in which e is the negative electron and the reaction is the same for zinc, lead and copper.

2. The Cathodic Reaction: The result of the first step is that negative electrons remain in the metal, and action will soon stop by the building up of a strong negative charge

that will resist further release of positive ions. In the presence of water, however, the negative electrons can be eliminated by reaction with H^+ ions in the water. The reaction is the same for all metals:

$$2H^+ + e \rightarrow H2 \text{ (gas)}$$

When corrosion takes place in strongly acid solutions bubbles of hydrogen gas can be seen escaping from the metal surface. In all other conditions the H^+ ion is removed by the next method called Depolarization.

3. <u>Depolarization</u>: If the hydrogen accumulated permanently on the metal surface, the corrosion chain would be broken (by polarization) if it were not removed quickly, in the presence of dissolved oxygen, by the reaction of the H^+ ions and dissolved oxygen to form water.

$$2H_2 + O_2 \rightarrow 2H_2O$$

4. <u>Reactions of the Metal Ions</u>: Most of the metal ions now in the water react with ions present in the water. Many of these reactions result in insoluble products which coat the metal surface and protect it from further corrosion. Some of the insoluble products, however, crystallize out in such pervious form that they offer little protection. Unfortunately this is the case with iron and the reactions with it are:

$$2Fe^{++} + \tfrac{1}{2} O_2 + 4OH^- \rightarrow 2H_2O + Fe_2 O_3 \text{ (rust}$$

OR $$2Fe^{++} + \tfrac{1}{2} O_2 + 4HCO_3 \rightarrow 2H_2O + 4CO_2 + Fe_2 O_3$$

In the presence of other appropriate ions in the water, as phosphate or silicate, insoluble compounds with the metals are formed but the necessary ions must be present in sufficient quantities.

2.3 CORROSION PROTECTION

This is a difficult problem especially in the small diameter pipes. In large diameter pipes the external and internal protection can be achieved by cement lining or by special wrapping of fibro glass with bitumen, coal tar, epoxy compounds, etc. But in the case of small diameter pipes, it is very difficulty. If they are cement lined, then there will be less chance of corrosion. Sometimes the inside welding at joints is zinc-sprayed for protection.

The main factors causing both internal and external corrosions can be as follows:-

A. Internal Corrosion

(i) Salinity and conductivity of water
(ii) Chlorine and sulphate content
(iii) Carbon dioxide content
(iv) pH value of water
(v) Dissolved oxygen
(vi) Composition and structure of metal.

B. External Corrosion

(i) Soil moisture and resistivity
(ii) Salinity, sulphates, magnesia, lime, etc. of soil and ground water.
(iii) pH of soil and ground water

(iv) Exchangeable acidity and alkalinity, free carbon dioxide in soil and water.

(v) Oxidation reduction potential

(vi) Aeration sulphides.

Internal Corrosion of Cast Iron and Steel Pipes

It has been observed that the corrosion in the Cast Iron pipes are usually at the rate of ¼" in 40 years and it is the same for unlined steel pipe. But in mild steel pipes the corrosion results mostly in pitting and sometimes the localized pits deepen at the rate of 0.05" per year, a rate which could make a hole in 3 to 4 years in ⅛" thick pipe and in 3/16" pipe 4 to 8 years if the pipe is unlined.

In addition to the above corrosion there are other problems which add up to make the system most uneconomical by just not giving internal protection. They are:-

Heavy tuberculation

Disintegration of metal

Discolured water

Reduced flow

Increased pumping cost.

External Corrosion of Cast Iron and Steel Pipes

The underground rate of corrosion of Cast Iron pipes varies with the type of soil and moisture content, aeration, etc.

It is always advisable to conduct a soil survey along the route of the pipe line to be laid in order to ascertain the type and extent of external coating as it will have an economic bearing on the type of coating required for particular area or possibility of keeping pipe along the ground. The corrosing of soil is usually determined by the soil resistivity test.

This consists of a steel tube $18\frac{1}{2}$" long x $1\frac{1}{4}$" diameter. Seperated by 1 cm of insulation form a conical magnesium tip. The magnesium tip and steel tube are connected by insulated wires to the measuring instrument. The corrosion current is measured by connecting a low resistance milliammeter between the steel and the magnesium as the probe is driven into the soil. At intervals, the driving is stopped and the meter is left in circuit to record both maximum and the final steady current values after the steel has polarised. The resistance of the soil is also measured with 1000 cycle bridge and the corresponding soil resistivity can be determined from the calibration charts of the probe device. It is expressed in ohm-cm units. The results obtained are then compared with the following table in order to determine the group in corrosivity of the soil:

TABLE 2

SOIL RESISTIVITY (Ohm-cm)	CORROSIVITY
0 - 1,000	Probably severe
1,000 - 10,000	Severe-moderate
10,000 - 100,000	Mild of Aerated
100,000	Probably not Corrossive

It can be seen from the (graph No.1) overleaf that clay, even with 9-10% moisture content has resistivity of 1000 Ohm-cm and this is in the range of severe corrosive action. Therefore a serious consideration regarding external protection will be required in clay soils.

2.4 METHODS AND SPECIFICATIONS FOR PROTECTIVE COATINGS

In order to preserve the life of steel and cast iron pipes from the detrimental effects of corrosion, it is imperative to place an impermeable barrier between the steel or cast iron and the corrosive elements.

Types of Coatings:

Bituminous coatings include coal tar, enamels, asphalts, cold applied coal tar paints and epoxy coal tar enamels. Basic requirements of a coating on Field Performance have been laid down by American pipe line designers and are known as Standard Criteria:-

(i) Performance of bond to the metal

(ii) Minimum of moisture penetration

(iii) Resistance to bacterial deterioration by soil micro-organisms.

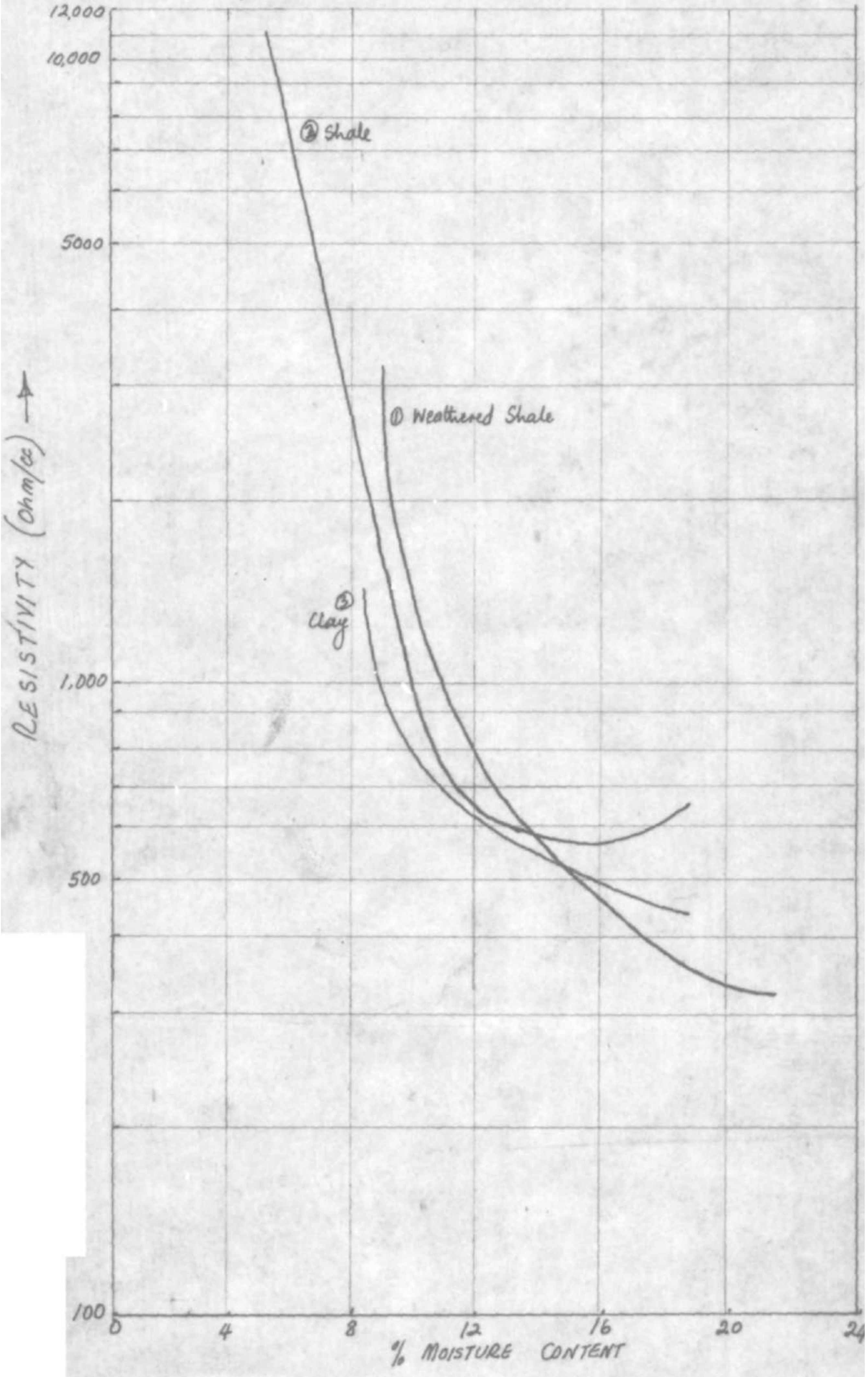
(iv) Resistance to soil stress and deformation

(v) Chemical intertness to action of soil chemicals

(vi) Resistance to aging or physical change for life of structure.

GRAPH NO. 1
EFFECT OF MOISTURE CONTENT ON SOIL RESISTIVITY

(PREPARED BY SYDNEY WATER BOARD).



Jide 106 kamal

final project

Consumption

Documentation

CP 310 water supply
CP 305 sanitary appliances
BS 5572 sanitary pipe work.
CP 301 building drainage.
CP 302 small sewage treatment work

① Africana section (KKL)
Thesis

TH
TC
TA
TD

③ Serials (KKL)

② Building science abstract reference (KKL)

Specifications:

(i) Preparation of pipe surface for priming

(ii) Priming of pipes

(iii) Application of Enamel/Bitumen

  (a) For external coating - In 2 layers, each to be not less than 3/32".

(iv) Reinforcement of Enamel coating.

(v) White washing

(vi) Handling of pipes

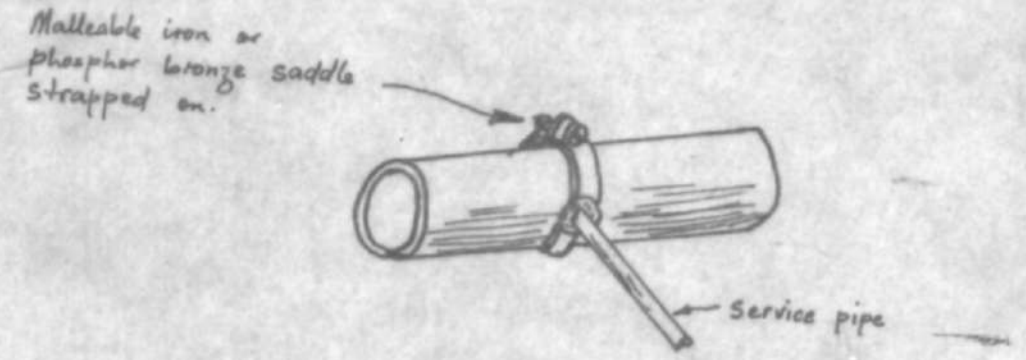
(vii) Spark Testing

(viii) Pipe bedding

(ix) Back filling

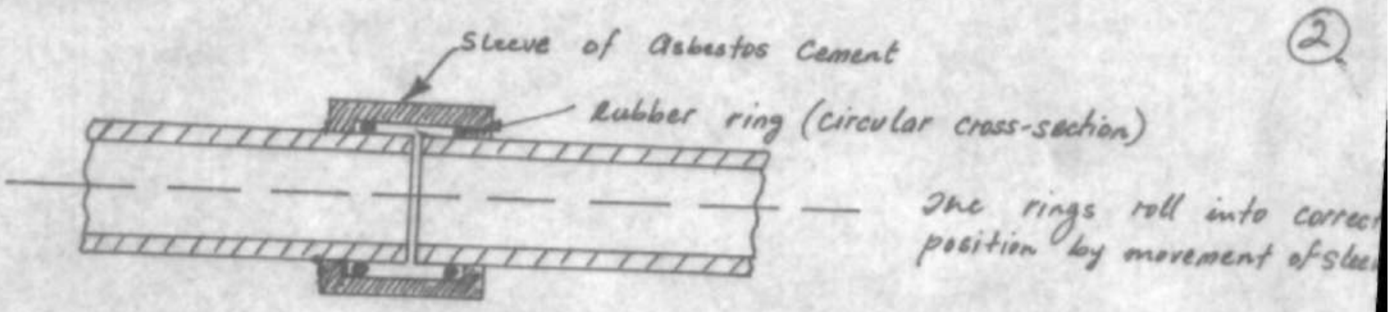
(x) Pipe laying.

①



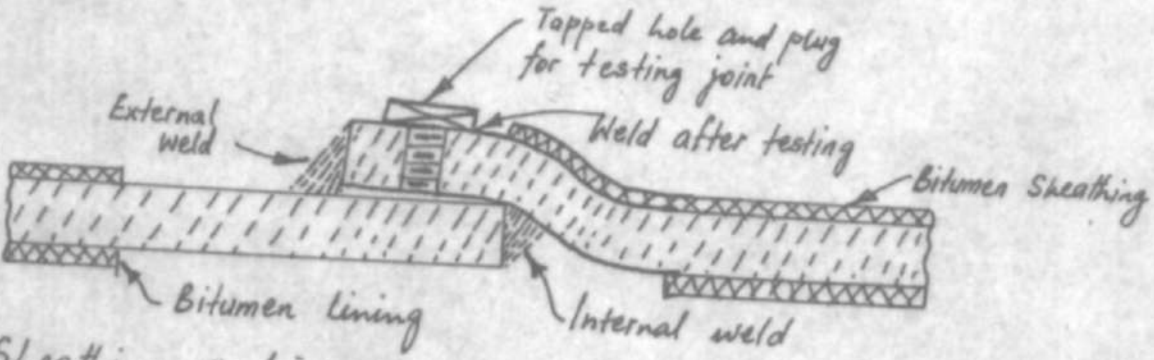
Service Connection to Asbestos Cement Pipe.

②



Simplex Joint for Asbestos Cement Pipes.

③



(Sheathing & Lining made complete after test).

Welded Socket & Spigot Joint for Steel Pipes.

CHAPTER

3.0 EFFECTS OF LEAKAGES ON WATER QUALITY

Besides bacteriological, chemical and physical, and biological pollution of water - supplies, pollution by radioactive materials represents an increasing hazard with regard to water quality. Each type of pollution named can be encountered through leakages in one form or the other.

It is important to keep radioactivity in drinking water to a minimum and it is therefore recommended that radioactive wastes should not be admitted to sources of potable water. However, this is not possible in certain cases, and therefore limiting concentrations of radioactivity are suggested for water to be used for domestic and dietetic purposes.

Radioactive materials comprise all isotopes, the nuclei of which undergo spontaneous disintegration. Natural radioactivity in water originates in small amounts of naturally occurring potassium - 40, radium - 226, thorium - 232 and uranium in igneous rocks. The disintegration of these rocks and of the sedimentary formations derived from them, forms the soil. This, therefore, also contains traces of radioactivity due to the same four naturally occurring elements. Small quantities of soil are washed off the land into rivers and laes, and rock fragments are broken up by wave action on the coastline. In this way the radioactivity originally contained in the igneous rocks becomes distributed in the soil, in rivers and lakes and in the sea. The quantity of radioactivity is measured by the number of disintegrations that take place in a unit of time.

The standard unit, called a curie, is 3.7×10^{10} disintegration per second. This is the rate of nuclear transformation of 1 gram of radium. Each radioisotope decays at a characteristic rate that is unaffected by heat or pressure.

Radioactive waste waters originate primarily:

1. in hospitals and research laboratories and in laundries serving them and
2. in water-cooled nuclear reactors and in chemical plants that process reactor fuels.

The limiting values of radioactivity given below are merely intended to indicate that, if the levels are lower than those given, then the water is safe for use without further investigations, if, however, the levels exceed these figures, radiochemical analysis will be required to determine the nature of the radionuclides present before deciding on the safety of the water for use as a public supply. The figures given are intended to include naturally occuring radioactivity, as well as any radioactivity that may reach the water from the effluents and fall-out. It is possible that naturally occuring radioactivity may be just as dangerous to health as that which may be discharged in effluents from nuclear reactors or other sources, and it is considered that, in drinking water, it is the total radioactivity that is of importance from the point of view of possible danger to the health of the community.

3.1 SAMPLING

Samples should be taken not only at the taps but also at the sources of supply and at relevant points throughout the system. Samples from sources such as reservoirs and collecting basins should be taken from the bottom, since many radioactive substances settle rapidly to the bottom, from which they may later be released and find their way throughout the system. Such samples should at least be of 1-litre volume; collected in polyethylene bottles to eliminate the possibility of adsorption of the radioactivity by the container; and examined with as little delay as possible. Routine surveys of water-supplies for radioactive containation should be carried out, and samples collected and examined as frequently as possible to determine if the maximum acceptable limits have been exceeded.

3.2 MAXIMUM LIMITS OF CONCENTRATION

The following values are only established to serve as a guide to the maximum acceptable limits in drinking - water as supplied to consumers for lifetime use for large populations.

Strontium - 90	30 µµc/litre
Radium - 226	10 µµc/litre
Gross beta concentration (in the absence of Strontium - 90 and alpha-emitters)	1000 c/litre.

These figures are derived from the values published by the International Commission on Radiological Protection for occupational exposure, modified for mutual consistency and for application to whole populations.

Should the International Commission on Radiological Protection publish further information concerning the maximum permissible concentrations of radioactivity in drinking-water, the limiting values given above should be used in the light of the recommendations of the ICRP. If the value indicated for gross beta contamination is exceeded, and the concentrations of Sr - 90 and Ra - 226 are known to be insignificant in comparison with the values given, supplementary radiochemical analysis should be undertaken to determine the radionuclides present in the water-supply.

In case the radioactivity in the drinking-water supply is continuously above the maximum limits given, consultations should be made with any national organisation responsible for deciding on maximum total population doses of radioactivity for any community. (see Table 3).

TABLE 3

MAXIMUM PERMISSIBLE CONCENTRATIONS IN DRINKING WATER FOR NON-OCCUPATIONAL EXPOSURE

ISOTOPE	MAXIMUM PERMISSIBLE CON. (uc/ml)	HALF-LIFE (days)	SPECIFIC ACTIVITY (curies/gram)	M.P.C. OF RADIOACTIVE ISOTOPE IN DRINKING WATER* (p.p.m.)	LIMITING-CONCENTRATIONS OF STABLE ISOTOPE IN DRINKING WATER (p.p.m.)
F^{18}	2×10^{-2}	0,078	9.3×10^{7}	2.2×10^{-10}	1.5
Na^{24}	8×10^{-4}	0,62	$8,8 \times 10^{6}$	9.1×10^{-11}	
P^{32}	2×10^{-5}	14.3	2.9×10^{5}	6.9×10^{-11}	
Cl^{36}	4×10^{-4}	1.6×10^{8}	2.3×10^{-2}	1.7×10^{-2}	250
Ca^{45}	1×10^{-5}	152	1.9×10^{4}	5.3×10^{-10}	
Cr^{51}	2×10^{-3}	26.5	9.7×10^{4}	2.1×10^{-3}	0.05
Mn^{56}	3×10^{-4}	0,108	$2,2 \times 10^{7}$	1.4×10^{-11}	
Fe^{55}	5×10^{-5}	1.06×10^{3}	$2,2 \times 10^{3}$	2.3×10^{-7}	0.3
Fe^{59}	1×10^{-5}	46.3	4.8×10^{4}	2.1×10^{-10}	
Co^{60}	4×10^{-5}	1.9×10^{3}	1.1×10^{3}	3.6×10^{-8}	
Cu^{64}	5×10^{-4}	0.54	3.8×10^{6}	1.3×10^{-10}	3.0
Zn^{65}	2×10^{-4}	250	$8,1 \times 10^{3}$	2.5×10^{-8}	15
Sr^{89}	7×10^{-6}	53	2.8×10^{4}	2.5×10^{-10}	
$Sr^{90} + Y^{90}$	8×10^{-8}	9.1×10^{3}	1.6×10^{2}	5.0×10^{-10}	
I^{131}	6×10^{-6}	8	1.3×10^{5}	4.6×10^{-11}	3
Au^{198}	6×10^{-5}	2.69	2.5×10^{5}	2.4×10^{-10}	
Pb^{210} + drs	2×10^{-7}	9.1×10^{3}	69	2.9×10^{-9}	0.1
Ra^{226} + 55% drs	4×10^{-9}	5.9×10^{5}	1.0	4.0×10^{-9}	
U(natural)	2×10^{-7}	1.64×10^{12}	6.6×10^{-7}	0.3	

* A revision of these levels is expected to be published shortly.

3.3 METHODS OF TREATMENT

Radioactive substances can be removed from water and waste-water in a number of different ways, the selection of which must depend on the nature of the substances involved and their physical condition in the water and waste water. Strauls lists the following methods:

Evaporation,
Carrier precipitation (coagulation),
Sand filtration,
Ion exchange (including natural clays),
Electrolysis,
Metallic displacement or scrubbing,
Differential voltility,
Electrolytic seperation,
Solvent extraction,
Biological processes, and
Crystallization.

The maximum removal of radioactivity in biological sewage treatment systems is about 95%. A much lower removal is experienced for radioisotopes that are not utilized by, or readily adsorbed on, biological slimes, or that occur in company with an abundance of non radioactive atoms of the same element. When an untreated liquid waste is discharged into the sea or into a river, a certain amount of each form of pollution is purified naturally. Solids are settled out, organic matter oxidised and chemicals are diluted until their concentrations are negligible. Pollution is reduced by the natural half-life decay of the active isotopes. Half-life, $t_{\frac{1}{2}}$, is simply defined as being the time required for the number of atoms of the active species to diminish to one-half its present value, thus:

$$n = \tfrac{1}{2} no$$

when $t = t_{\frac{1}{2}}$

and thus $\log_e \left(\frac{n_o}{\frac{1}{2} n_o}\right) = t_{\frac{1}{2}}$

$$t_{\frac{1}{2}} = \frac{\log_e 2}{\lambda}$$

$$= \frac{0.693}{\lambda}$$

where n = no. of atoms of a given radioactive species present

λ = the radioactive disintegration constant of the species.

The half-life and the radioactive disintegration constant are characteristics of the radioactive species.

All this takes place without any assistance from man. Only when man discharges wastes in concentrations greater than Nature can deal with, does treatment become necessary. The point at which this occurs depends, in any given locality, on the volume of natural water available to receive the wastes, the pollution density and the extent of industrialisation.

Table 4 gives a summary of the polluting characteristics of wastes and the means by which these are dealt with in the natural environment.

TABLE 4

POLLUTING CHARACTERISTICS OF LIQUID EFFLUENTS AND THEIR PURIFICATION IN THE NATURAL ENVIRONMENT

POLLUTING CHARACTERISTICS	CAUSE OF THE POLLUTION	NATURAL PURIFICATION
Physical	Solids	Sedimentation
Biological	Organic matter	Oxidation
Chemical	Toxicity	Dilution
Radioactive	Ionizing radiation	Half-life decay

3.4 THE HAZARDS OF RADIATION

When ionizing radiations (alpha, beta and gamma rays) pass through matter, energy is absorbed by the material. The dose received by the medium is defined as the energy deposited in unit mass of the specified substance. The unit of dose is the rad, the absorption of 100 ergs/gram.

When the radiation pass through living matter, the resulting ionization may produce profound effects. Although the energy absorbed by a single cell is small it becames, in effect, centred in a few molecules, resulting in an essential structure in the cell being destroyed. The cell may die or its subsequent process of division may be delayed or otherwise affected.

The effects of radiation upon the human body are of two main types:

(a) Somatic effects which affect the individual who has been irradiated.

(b) Genetic effects which do not affect that individual, but which do affect his offspring, perhaps after several generations.

The effect of radiation upon the individual may be acute, appearing within a few weeks of the radiation, or they may be long-term effects, which do not become apparent for several years afterwards. Comparatively, large doses of radiation delivered in a short period to the gonads may affect the ability of the germinal cells to divide and may induce sterility therefore, which is a somatic effect. Much smaller doses may produce no noticeable effect in the individual but may cause damage to the genes located along the chramosomes in the reporoductive cells. These changes or mutations may affect the inherited characteristics, not usually of the immediate offspring, but of later descendants. Such changes are, it is considered, generally deleterious although they may vary in severity. Thus the possible effects of irradiation of the gonads are, in subsequent generations, a lower standard of mental and physical health and, less frequently, some serious impariment of bodily function or death. As well as individual misfortune there is, therefore, a burden imposed on the society.

In considering the quantities of radiation to which human beings may reasonably be exposed, as well as the evidence of radiation damage mentioned, there is another yardstide - the unavoidable environment of radiation in which we live. The dose received from cosmic radiation varies with altitude. That from radioactivity in the ground or from walls of buildings depends upon our habits and habitat. In the United Kingdom, these two sources of external radiation typically deliver to the whole of our bodies about 30 and 50 millirads/year respectively. To this is added the internal radiation from the radioactive substances which have been incorporated in the body from the diet. In total, the gonads receive about 100 millirads/year from natural radiation. Genetic damage is determined by the total dose received up to the average age of reproduction (30 years in the U.K.) and this is about 3 rads.

3.5 THE LAW OF RADIOACTIVE WASTES IN GREAT BRITAIN

Legislation applicable to the United Kingdom Atomic Energy Authority, to licensed operators of nuclear reactors and to other users of radioactive materials.

The atomic energy industry, although new in the United Kingdom, has grown to its present size along with the demand for and the use of radioisotopes and, consequently, the waste disposal problem has increased steadily. The need for strict control of the disposal of radioactive waste has been reflected in all the atomic energy legislation which has been passed since 1946 by the Parliament. It is indeed only in December, 1959, with the introduction to Parliament of the Radioactive Substances Bill, that there is a prospect of the whole field of the disposal of radioactive effluent in the United Kingdom being adequately controlled by legislation.

The development of the law on radioactive wastes is best followed as it has applied to the three main classes of users of radioactive materials, i.e. the United Kingdom Atomic Energy Authority, Licensed operators of nuclear reactors, and other users of radioactive materials.

3.5.1 LEGISLATION APPLICABLE TO THE U.K.A.E.A.

By far the greatest amount of radioactive waste material arises as the result of the operations of the United Kingdom Atomic Energy Authority. The legal position of the Authority is, however, quite clear and is laid down in the Atomic Energy Authority Act, 1954. Section 5(3) of this Act stipulates that "It shall be the duty of the Authority to secure that no ionizing radiations from anything on any premises occupied by them, or from any waste discharged (in whatever form) on or from any premises occupied by them, cause any hurt to any person or any damage to any property, whether he or it is on any such premises or elsewhere." Further, in Section 5(4)(a) it is provided that "no radioactive waste shall be discharged otherwise than in accordance with authorizations to be given by the Minister of Housing and Local Government and the Minister of Agriculture and Fisheries, after consultation, in each case, with such local authorities, river boards, local fisheries committees or other public or local authorities as appear to the Minister in question to be proper to be consulted by him." In Scotland, the authorisations are given by the Secretary of state.

In Section 5(4)(d) it is provided that " for the purposes of any statutory provision conferring or imposing powers or duty on any local authority, river board, local fisheries committee or other public or local authority ....., all waste discharged on or from any premises occupied by the Authority shall be conclusively presumed not to be radioactive to any significant extent." The act then makes clear that the restrictions imposed by Section 5(4) on the Authority are in addition to and not in derogation of their duty under Section 5(3).

The provisions of Section 5(4) of the Act were temporary and it is proposed that they should be given permanent effect by a clause in the Radioactive Substances Bill (Clause 8(1) "Supplementary provisions as to authorisation of disposal and accumulation of radioactive waste").

3.5.2 LEGISLATION APPLICABLE TO OPERATORS OF NUCLEAR REACTORS

The Nuclear Installations (Licensing and Insurance) Act, 1959 requires the licensing of nuclear reactor operators. It replaces the common law liability of license holders not to cause hurt or damage to others, and their liability under the law governing normal waste disposal by an absolute liability, similar to that of the Atomic Energy Authority, together with an obligation to take out cover, by insurance or other means, of up to five million pounds in respect of each site to which a nuclear site licence applies. The licence is obliged (Section 1 (5)) to obtain authorisations for the disposal of radioactive waste in the same way as the Atomic Energy Authority and Clause 8(1) of the Radioactive Substances Bill, proposes to give permanent effect to this temporary provision.

3.5.3 LEGISLATION APPLICABLE TO OTHER USERS OF RADIOACTIVE MATERIALS

Presently, users of Radioactive material, other than the U.K.A.E.A. and licensed reactor operators, are governed in the disposal of radioactive waste only by the law governing normal waste disposal. Since this legislation has been evolved gradually, as the need arose, to deal with nuisances from ordinary waste products, the position is complex and there are some seventeen Acts which could be considered to apply to the discharge of radioactive wastes. These Acts are listed under references 4 to 20 and, generally, place responsibility for enforcement on local authorities, river and water boards and the Alkali Inspectorate.

Any nuisance arising from the discharge of radioactive waste may become evident only when a considerable time has elapsed since the discharge of the effluent and when the possibility of tracing the offender is remote. The particular dangers of the incautious release of radioactive material make the necessity to prove existence of a nuisance before remedial action is taken undiserable and, indeed, unacceptable and some more positive legislation is obviously necessary. In attempt to improve the position was made in the Radioactive Substances Act, 1948 which enabled the responsible Minister, as designated by Order in

Council, to make regulations for the safe disposal of wastes from premises in which radioactive substances were manufactured, treated, stored or used. The responsible Minister was not, however, designated and no regulations were issued. The rather unsatisfactory position which has obtained to the present time will be radically changed with the passage into law of the Radioactive Substances Bill.

The Bill results from a report of a Panel of the Radioactive Substances Advisory Committee. This committee was appointed under the Radioactive Substances Act 1948. The terms of reference of the expert Panel were: "To ascertain the nature and quantity of radioactive waste likely to arise in the foreseeable future; to advise on the best methods of securing that the waste is disposed of safely; and to advise whether any new legal provisions or amendments to existing legislation are necessary to ensure safe disposal and, if so, to advise on the the form which the new provisions or amendments should take."

The passage of the bill will enable effective control to be exercised over the discharge and disposal of radioactive waste, and, which is also important, will make clear to users of radioactive materials precisely what are their obligations and responsiblilities. The Act will constitute a considerable advance in what is admittedly a difficult subject, and one which is not confined to the United Kingdom. The present legal position in other countries varies widely and in a number legislation is also pending. The situation in 1958 was given very fully by Stason, in a paper presented at the second United Nations Conference on the Peaceful Uses of Atomic Energy.

CHAPTER

4.0 CAMPUS LOSS OF WATER THROUGH THE SYSTEM.

The population served in the campus with water is about 10,000 - 12,000 people, including both the students and the staff. In this case, it is assumed that only about half the population of the staff lives within the campus. Using the old Ahmadu Bello University waterworks in connection with the Zaria waterworks, about 300,000 gallons is pumped daily. This ofcourse is never enough as can be seen from the daily shortage at supply experienced. In most cases there happens to be shortage of water in one section of the campus or the other. Without the students, when they go on leave, the supply of 100,000 gallons per day from the Ahmadu Bello University waterworks is just enough.

About 25 km length of piping is being served but it is very sad to know that the piping never flows full and as such some data like average daily consumption, maximum hourly consumption, can never be accurately determined. Therefore, the exact per capita per day requirements of water in the campus and all other assumptions relating to the water flow will always be mere approximations. However this will soon be overcomed when the new waterworks starts functioning with the completion of the new dam under construction. The old waterworks was supposed to be pumping at 3.5 atmospheres, but, with the new waterworks in operation, it will be 7 atmospheres, with two main rings of pipeline round the campus serving as the main feeder pipes (see map of the campus). With the old waterworks now demolished and the new one still under construction, the water board is to supply 1.2 Mg daily. When the A.B.U. Lake is completed, about 2 Mgd will be pumped and, mounted with all the modern facilities for flow measurements, the new waterworks will enable accurate and dependable determination of all the data needed about the water flow in the system.

The maximum hourly consumption occurs at 7-8 and this is given as a percentage of the total daily supply as can be seen from the tabulated result (see table 5). The zero hour starts at 12 midnight.

TABLE 5

23-24	HR	0-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23
0	%(gal)	0	1	2	10	10	2.5	2	4	3	7	7	6	5	5	2	8	13	7	4	3

Waste surveys, unfortunately, are never conducted by the waterworks officials in the campus and, because of this, it is really difficult to know exactly how much of the water supplied is actually wasted. Leaks in the pipes may continue until such a time when they show visible signs in the ground. In fact, it is only when there is a pipe burst will there be action taken immediately, otherwise everything is taken lightly. There is no particular method adopted for leakage detection since it is never conducted at all. Therefore, in the case of pipe burst, only direct observation is done or until a report is made to the officials.

As the piping is mostly done with Pressure Class B Asbestos Cement Pipe, the pipe-bursts that occur result mostly through deterioration of the pipe due to attack from either the water being carried or the soil or ground water in which the pipe is laid or due to bending stresses resulting from traffic loading or soil pressure on badly laid pipes or stresses arising from actual ground movements. The pipe burst in each case may be in the form of longitudinal splitting or circumferential cracking of the pipe. Although leaching is highly resisted by this class of asbestos cement pipe, external and mechanical attack can still affect the stability of such piping. This is effected by both bacteriological and chemical attack and also through careless handling and bad lying. In some areas within the campus, however, the piping was done with plastic pipes. This was done to some of the residences at the early days of the university and, because of this, some residences have no supply at all due to blockage of such pipes. Most of the delivery piping, however, is done with steel pipes and the usual welded socket and spigot joint is adopted. With the main service pipes, on the other hand, the Asbestos Cement Pipes, Gilbert joint is used where there is a T-connection otherwise push joints is adopted. The main service pipe is of different diameters, depending on the area being supplied. The diameter ranges from 15" to 10" to 8" to 6" and to 4".

The general expenses for the Ahmadu Bello University waterworks is about ₦40,000 per annum. This is made up of:

₦10,000 on chemicals
₦12,000 on labour
₦10,000 on electric bills

Add 20% of the total for maintenance.

About 60 Mg of water is consumed annually at the cost of, say, 50K per 1000 g. based on the public supply.

Actually, the loss through leakage comprises only about 1% of the mass in flow. However, losses through careless and wilful opening of taps are also considered, although they are not included in the 1% loss. Taking the 1% of the daily mass inflow as the percentage loss, the waterworks is therefore losing about ₦400 annually. The 1% of mass inflow is taken as a measure of the loss through leakages alone and if found to be exceeded, the maintenance team is called for to check and repair any leakage to be reported taking place. With the new waterworks completed, the supply will run at the cost of 30K per 1000 g – about 60%

of the public supply. This, of course, is based on the old prices of materials and labour, and due to inflation, however, the final cost may not be known by the time the waterworks starts functioning.

The waste survey was done by only going round and making visual inspection of all taps and other related plumbing fixtures within the Halls, Departments and some of the residences within the campus. The measurement was done by using a container to capture the dripping water for a noted period and measuring such captured water and an average of 1% of the mass inflow has been assumed.

CHAPTER

5.0 MAINTENANCE AND OPERATION OF WATER SUPPLY SYSTEM

For expertise management of distribution storage, reservoir levels must be known at all times of the day and night. In the case where levels cannot be recored directly by gages or floats, electrically operated sensors and recorders can be used to transmit the necessary information to operating headquarters.

Well-kept records and maps of pipes and appurtemances are essential to the efficient operation and maintenance of distribution systems. To avoid the occasional discharge of roiled water, piping should be flushed systematically usually through hydrants. Dead-ends need particular attention - a bleeder on the dead-end will counteract the effects of sluggish water movements. Disinfecting newly a laid pipe, or pie newly repaired, is very important. Control of pipe corrosion and the cleaning and relining of water mains are also essential.

Pipes deprived of adequate cover by the regrading of streets or subjected to protracted and exceptionally cold weather can be protected by drawing water from them through services. Pipes exposed on bridges or similar crossings should be insulated. In very cold climates, water and sewer pipes are often laid in a heated box like conduit, known as "utilidor." Loss of water by leakage from distribution systems and connected premises of consumers should be kept under control by leakage surveys.

In the case of the water supply system of the campus, careful handling and lying of pipes is very essential and before lying, the trench should be carefully and accurately dug according to the specifications and supervised by a competent person from the staff of the waterworks. A regular and thorough leakage survey should be adopted and carried out by competent persons. In case there is leakage detected or a pipe burst occuring somewhere, this should be reported immediately to the official concerned and measures taken for its repair without delay.

Modern sophisticated instruments should be employed and manned by better trained labour force for the regular and thorough waste surveys and leakage detection. There should be a provision for an in-service training programme for the waterworks personnel so as to enable them know of any recent developments in such things as the use of chemicals, use of new instruments both for the use of such instruments in the waterworks and in leakage detection and wastage control and other related problems.

Good workmanship is very essential, and, as such, all plumbing fixtures and works should only be handled and supervised by properly qualified waterworks personnel so that poor workmanship which is the main cause of all failures, is brought down to a minimum. The pipe materials should be carefully selected and used according to the manufacturer's specifications. The ground along the pipeline should always be inspected and tested in order to reveal any incorporated chemicals that may bring about corrosion to the piping materials. The water carried in the system should be frequantly tested for detection of both bacteriological, chemical and physical, biological and radioactive pollution. Radioactive pollution should, in fact, be checked every now and then and samples should be taken not only at the taps but also at the sources of suppy and at relevent points throughout the system. Provisions should be made for the measurements of such radioactive wastes. With the new waterworks in operation however, most of the present difficulties will be solved.

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