REPUBLIC OF NAMIBIA

MINISTRY OF AGRICULTURE, WATER AND FORESTRY

DEPARTMENT OF WATER AFFAIRS and FORESTRY

CODE OF PRACTICE: VOLUME 10

REUSE OF SANITATION WASTE PRODUCTS

GENERAL GUIDELINES

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PREFACE

Sanitation plays a pivotal role in economic development of Namibia because increasing the coverage of improved sanitation facilities will contribute significantly to the health of the population which in turn drives the nation's economy. The Namibia National Sanitation Strategy for the 2010 to 2015 has been developed, setting out a course of actions and activities for the implementation of sanitation in a coordinated manner.

As this strategy was developed through a comprehensive consultation process with various partners and stakeholders, the previous uncoordinated approach to sanitation implementation experienced in the past has already improved through initiatives that have brought about a more uniform, consistent and higher quality approach. The major investment in sector capacity building and development that is needed to enhance the delivery of the implementation programme will in turn support the achievement of Vision 2030 and the WATSAN Millennium Development Goals.

A series of Sanitation Codes of Practice have been developed to give further guidance on the planning and implementation of alternative types of sanitation facilities. The additional Sanitation Codes of Practice have filled the gaps in the existing Water Supply and Sanitation Codes of Practice that have been developed over the past two years by the Directorate of Resource Management within the Department of Water Affairs and Forestry of the Ministry of Agriculture, Water and Forestry. The most updated list is given below:

Volume No.	Description	Originator
1	Septic Tank Systems	DRM
2	Pond Systems	DRM
3	Biological Filtration Systems (Trickling Filters)	DRM
4	Biological Treatment Activated Sludge Processes	DRM
5	Bottled Water: Bottled Natural Waters; Processed Water; Mineral Water; Carbonated Water; Flavoured Water	DRM
6	Wastewater Reuse: Greywater, Reclaimed Domestic Effluent; Industrial Effluent	DRM
7	Disposal of Water and Wastewater Solids	DRM
8*	Dry Sanitation Systems	DWSSC
9*	Wet Sanitation Collection, Conveyance and Treatment Systems	DWSSC
10*	Re-use of Sanitation Waste Products	DWSSC

* - It is recommended that Codes of Practice 8 to 10 should be used together because of the close links between them all.

- DRM – Directorate of Resource Management
- DWSSC – Directorate of Water Supply and Sanitation Coordination

It is intended that the Codes of Practice will become obligatory for Ministries, Regional and Local Authorities, Communities, Private and Non-Government Organisations and Donors to follow to achieve the initiatives set out in the five year National Sanitation Strategy.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DEFINITIONS

General:

Dewatering:	Dewatering processes reduce the water content of sludge to minimise transport volumes and improve handling characteristics. Typically, dewatered sludge can be handled as a solid rather than as a liquid;
Effluent:	Liquid waste originating from domestic, industrial, agricultural or mining activities that has been treated in a wastewater treatment facility as a final effluent and released into the environment in a dam, an evaporation pond, an aquifer, a river, the sea or onto the surface of the ground;
Excreta:	Faeces and urine;
Groundwater:	Any water resource found within the bedrock, below the surface of the ground;
Land Application:	Spraying or spreading of sludge or residue onto the land surface; the injection of sludge or residue below the land surface; or the incorporation of sludge or residue into the soil so that it can either condition the soil or fertilise crops or vegetation grown in the soil;
Liner:	Layer of impenetrable material/sheeting placed beneath a landfill and designed to direct leachate to a collection drain or sump. May be made of building construction materials, synthetic materials, or a combination thereof;
Pathogens:	Micro-organisms such as bacteria, viruses and protozoa that cause disease;
Residue:	Substance that is left over after a waste has been treated or destroyed;
Sludge:	Solid waste generated by wastewater treatment plants, predominantly through biological processes;
UDDT:	Urine Diversion Dry Toilet
Vector:	Potential disease carrying organisms such as flies, mosquitoes, rodents, fleas and birds;
Waste:	Includes any solid or material that is dissolved, suspended or transported in water, including sediment;
Water Resource:	Includes a watercourse, an aquifer, the sea and meteoric water.

1. INTRODUCTION

Traditionally, sanitation waste has been seen as a waste product that is of no use due to the following negative aspects:

- Aesthetically unacceptable. The smell of sewage and the fact that it attracts flies and maggots is unacceptable to communities;
- Potential health hazard/unhygienic conditions. Water-borne diseases such as diarrhea and cholera are spread by untreated sanitation waste and unhygienic behaviour (inadequate hand washing). In developing countries a large percentage of child mortality can be directly related to unhygienic conditions caused by contamination from untreated sanitation waste;
- Environmental hazard. When disposed into the environment, there is a high possibility that untreated sanitation waste will contaminate ground and surface water resources to such an extent that it may render these resources unsuitable for further direct or indirect use;
- Costly and difficult to treat and to dispose of. Community wastewater treatment facilities that produce an final liquid effluent and solid waste that may be re-used or disposed of into the environment requires capital, operational and maintenance funding to be raised through sewerage charges, which cannot be afforded by the many poor communities in Namibia.

Yet, urine and faeces contain all the nutrients that plants need to grow. If single households were willing to utilise decomposed human waste to grow crops and basic food, they would not require additional fertilizer to become self-sufficient. Also, if re-use was widely applied by every household in even small communities, the financial burden of an effluent treatment facility could be reduced.

Recognition of the beneficial properties contained in organic waste sludge and urine has lead to an increase use of these wastes as a fertilizer to grow crops rather than simply disposing of the waste without any further use.

Nitrates, phosphates and potassium are prime nutrients needed by plants for proper growth and are widely applied in agriculture in the form of fertilisers, whereas these constituents are naturally contained in sanitation waste. Over-exploitation of the natural resources places a burden on the future availability of naturally occurring phosphorus deposits for use as a fertiliser. For example, phosphorus in the form of phosphate rock deposits which are mined to produce fertiliser are non-renewable, limited resources that are being depleted world-wide at an alarming rate.

There is, however, also an inherent health-risk associated with uncontrolled re-use of sanitation waste products and the purpose of this guideline is to make potential users aware of the possible health hazards and how to minimise them.

This guideline therefore addresses the sanitation waste products (urine and faeces) typically generated by single households. It considers how the waste can be used by the same household with the aim of becoming self-sufficient at least with regards to basic food production.

2. SANITATION WASTE RE-USE

When the words re-use, recycling and recovery are used in connection with sanitation waste, they all refer to the extraction and/or utilisation of nutrients and energy from excreta or wastewater. This mainly refers to urine and faeces – nutrients in excreta have a high fertilising value, excreta can generate biogas and digested excreta can act as a soil conditioner. These aspects will be described further below.

2.1 Characterisation of Excreta

The volume of urine and faeces varies from region to region, depending on climatic conditions (temperature and humidity), age of a person, living standards (including water consumption), diet and availability of water. Table 1 reflects the most important characteristics of urine and faeces.

Table 1: Characterisation of Excreta (Netherlands Water Partnership, 2006)

Parameter	Urine	Faeces
Volume (WHO, 1992)	440 l/cap/y*	44 kg/cap/y
Pathogens	Sterile	High count
Macro Nutrient (N, P, K) Content:		
• % N of total excreted amount	70% - 88%	12% - 30%
• % K of total excreted amount	25% - 67%	33% - 75%
• % P of total excreted amount	71%	29%
Relative Organic Content	Low	High
Hormone, pharmaceutical by-products, endocrine disruptors if present	High	Low

* Litres per capita per year

2.2 Re-use Products

The use of human waste as a renewable energy resource can improve energy security whilst reducing the environmental burden of waste disposal and finding alternative fuel resources e.g. firewood and fertiliser. Whereas basic research has already been done in mainly eastern countries, little has been done in Southern Africa to assess the appropriateness of such systems and adapt them for local conditions.

When considering utilisation of decomposition products from excreta, it is essential to realise that the best results will be obtained when excreta and urine are separately treated. This aspect is further addressed in Section 2.3. Also, there are significantly fewer odours generated when urine and faeces are not mixed. In the following discussions, urine and faeces will be discussed separately.

2.2.1 Faeces

The quantity of faeces produced by an adult is between 80 g and 150 g per day (NWP, 2006). The amount of pathogens in faeces can be very high and faeces are also a direct cause of many water-borne diseases such as diarrhoea and cholera. Direct contact with faeces should therefore be avoided at all times. Useful by-products however that can be obtained from faeces include biogas and biosolids.

- Biogas. Biogas is a fuel (methane gas) which is naturally produced by microbial digestion (degradation) of organic matter when oxygen/air is not present. It is also known as anaerobic digestion. Biogas is produced in small-scale digesters from animal dung, human excreta, crop residue, food waste products and grass (e.g. from mowing lawns).

  Biogas production involves several stages carried out by a variety of micro-organisms: The anaerobic digestion process involves micro-organisms that convert complex organic compounds into less complex organic compounds, which are then converted to organic acids. Methane-forming micro-organisms then utilise these organic acids to form methane, the main constituent of biogas. Biogas is a mixture of gasses containing mainly methane gas (50% to 70%) and carbon dioxide (30% to 40%). The balance is made up of hydrogen sulphide (H_2S) and hydrogen (H_2) gas (NWP, 2006).

  Small-scale biogas digesters provide fuel for lighting, cooling and cooking. One kg of human faeces generates about 50 l of biogas, one kg of cattle dung about 40 l of biogas and one kg of chicken droppings generates about 70 l of biogas. Twenty kg of human faeces produces the same thermal energy as 5.5 kg of firewood. When employing biogas digesters in single households, the human excrement should be augmented with animal waste such as cow dung or chicken droppings in order to produce sufficient biogas for the household’s own use.

  When used in large-scale plants to produce gas for fuel combustion engines to generate electricity, further treatment is necessary to remove water, CO_2 and H_2S from the raw gas. Safety measures are needed to reduce the risk of explosions in case of leakage.

  Benefits of using biogas for small households include improved sanitation, reduced deforestation, inexpensive fertilisation, reduced water source pollution, clean air and reduced CO_2 emission. Despite the great benefits of biogas production, it is only widely used in domestic households in China (15 million) and India (3 million) (NWP, 2006). Section 2.3.1 gives more information on mall-scale biogas generation.

- Biosolids. Decomposed excreta, thus the product remaining after biogas has been produced, is rich in the plant nutrients nitrogen (N), phosphorus (P) and potassium (K). It reduces the need for artificial fertiliser and can even provide sufficient nutrients for certain, selective agricultural applications.

  When deciding to use excreta for composting, it should ideally be mixed with organic matter such as grass and be aerated, to induce thermophilic degradation, *viz* composting during which heat is generated. The heat (50^0 to 80^0 C) generated during thermophilic composting kills most of the pathogens present in excreta.

  Thermophilic (high) temperatures are generally not obtained during decomposition when using dry sanitation systems to produce compost *in-situ*, such as the Otji-toilet, Fossa Alterna and Arberloo (DAWF, 2011, Vol 8). They are therefore termed “ambient temperature systems" and the waste product is referred to as "EcoHumus" (Morgan, 2007) and not compost.

When faeces are stored in the absence of moisture (i.e. urine), they dehydrate into a crumbly, white-beige, coarse, flaky material or powder. Dehydration is different from composting because the organic material present is not degraded further or transformed, only moisture is removed. After dehydration, faeces will reduce in volume by about 75%. The degree of pathogen removal/inactivation will depend on the temperature, pH (when using lime) and storage time.

Faeces should be stored between 12 to 18 months before considering re-use. However, pathogens may still exist and helminth eggs and oocysts easily survive during storage. Dehydration vaults are provided in dry sanitation systems to separately collect, store and dry faeces, as typically provided in the Otji-toilet (DAWF, 2011, Vol. 8). When urine is separated from faeces, the latter dry out quickly. In the absence of moisture, micro-organisms cannot grow, smells are minimized and pathogens die off, however helminths eggs and oocysts survive and still pose a health hazard when coming into direct contact with the Eco-Humus.

Cognisance should be taken of the potential health hazard of decomposed excreta, even if properly composted. The World Health Organisation (WHO, 2006) guidelines for safe use of excreta stipulate that the compost should achieve and maintain a temperature of 50^0C for at least one week before it is considered save. For systems that generate Eco-Humus, a minimum of 1 year of storage is recommended to eliminate bacterial pathogens and reduce viruses and parasitic protozoa. However, this will not suffice to inactivate the eggs of many worms, such as helminth-eggs.

The organic material in decomposed excreta when mixed with compost from a compost heap is generally known as compost, which acts as soil conditioner. It improves the structure and water holding capacity of sandy soils and adds structure and permeability to clay soils.

Composted excreta, on its own or combined with other biodegradable material, enhances the fertility of topsoil. It also contains all macro-nutrients that plants need to proliferate and Section 2.3.2 explains the practical application/reuse of biosolids, Eco-Humus and compost as a fertiliser.

2.2.2 Urine

The quantity of urine produced by an adult is between 0.8 and 1.5 l per day. Urine in the bladder of a healthy person is sterile, i.e. it contains no pathogens.

Separately collected, stored urine is a concentrated source of nutrients that can be applied as liquid fertiliser in agriculture to replace commercial, artificial fertilisers. In fresh urine, the main nitrogen compound is urea. 80% of the total nitrogen and 55% of phosphorus that is excreted by a person is contained in the urine, the rest within the faeces. Therefore, urine is more valuable than faeces as fertiliser. Macro-nutrients contained in urine, depends largely on a person's diet, and are approximately as follows (Münch, E. v. and Winker, M., 2009.):

- Quantities: 4 kg N/cap/y; 0.36 kg P/cap/y; 1 kg K/cap/y;
- Concentrations: 7 300 mg/l N; 670 mg/l P; 1 800 mg/l K.

During storage, urea is hydrolysed to ammonia/ammonium and hydro-carbonate by urease enzymes present in the urine storage container or soil in an aquatic system. During hydrolysis, the pH increases, which results in precipitation of struvenite ($MgNH_4PO_4$) and calcium phosphate [$Ca_{10}(PO_4)_6(OH)_2$], both of which are crystalline and can form incrustations, also called "urine stone". In storage tanks, the precipitation products normally form a soft deposit in the form of sludge at the bottom of the tank. The table in Figure 1 a) shows the significant changes urine undergoes during storage and Figure 1 b) shows storage containers that have been used for urine collection (Münch, E. v. and Winker, M., 2009.).

Parameter	Fresh urine	Stored urine
pH	**6.2** →	**9.1**
Total nitrogen, TN (mg/L)	8830	9200
Ammonium/ammonia-N, NH_4^+ and NH_3 (mgN/L)	**460**	**8100**
Nitrate/nitrite NO_3 + NO_2 (mgN/L)	0.06	0
Chemical oxygen demand, COD (mg/L)*	6,000	10,000
Total phosphorus, TP (mg/L)	800 – 2000	540
Potassium, K (mg/L)	2740	2200
Sulphate, SO_4 ($mgSO_4$/L)	1500	1500
Sodium, Na (mg/L)	3450	2600
Magnesium, Mg (mg/L)	120	0
Chloride, Cl (mg/L)	4970	3800
Calcium, Ca (mg/L)	230	0

* COD is a measure of the organic components.

a). Changes in urine composition when stored over time.

b) Urine collection/storage containers

Figure 1: Urine Storage and Degradation (extracted from Münch and Winker, 2009)

The major health-risk of collected urine would be careless users that deposit faeces in the urine compartment of a urine diversion dry toilet (UDDT) thus contaminating the urine with faecal pathogens. Micro-pollutants in pure urine could include natural hormones and pharmaceutical residues, depending on the medication taken by users.

The simplest, cheapest and most common method to treat contaminated urine and to kill all pathogens is prolonged storage in a tank or container. The decomposition of urea leads to an increased pH (over 9), which has a sanitising effect so that bacteria, parasitic protozoa, viruses and intestinal helminths die off over time. This sanitising effect is enhanced by high temperatures (leaving it in the sun), low dilution (no water flushing/dilution water) and prolonged storage time. Section 2.3.3 explains the practical application/re-use of urine in agriculture.

2.3 Re-use - Practical Applications and Considerations

For small-scale applications such as single households, complete utilisation of human waste and re-use of the degradation products can be achieved if separation devices (separate collection of faeces and urine) are employed in each household. Typically, urine diversion (UD) devices that have two outlets and incorporate two collection systems, one for urine and one for faeces, are installed. More information on UD devices can be obtained from the Codes of Practice, Volumes 8 and 9 (MAWF, 2011). In the discussion below, devices that can be used to recover degradation products coming from UD devices will be discussed.

2.3.1 Small-scale biogas generation

Several projects have been implemented for small-scale biogas generation and relatively cheap off-the shelf equipment is available for potential new users. Potential users should be aware that human faeces, if collected from a household that employs the normal water-based flushing toilet, is too diluted to be efficiently employed for biogas generation. Thus, UD devices should be employed and the faeces should be augmented with animal excrement such as cow-dung and/or chicken droppings. Typical biogas generation systems include the fixed-dome biogas system, which consists of the digester itself, a gasholder (tank), and an inlet and slurry outlet. (see Figure 2).

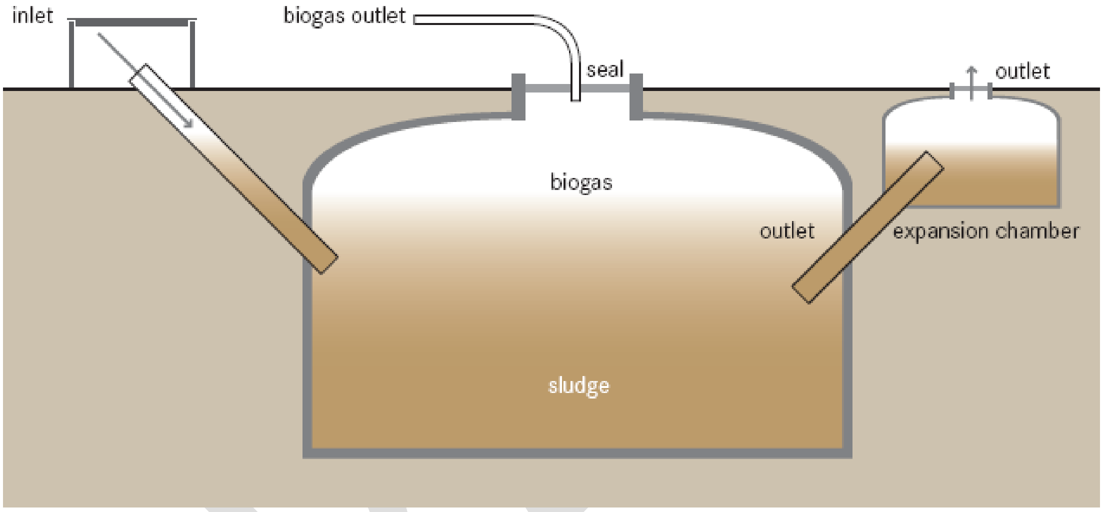


Figure 2: Fixed-dome Biogas Generation System - Schematics (Tilley, et al., 2008)

A daily input of approximately 6 kg of dung and faeces per m^3 of plant (digester) is required for biogas production. For a single household with a smallholder that has at least two cows (from which he collects the dung and adds it to the digester), a biogas digester of 3 to 4 m^3 would already be feasible to provide sufficient biogas for cooking and lighting. Household anaerobic digesters produce approximately 1 m^3 biogas per 3 m^3 digester each day, which would suffice to cook three meals for an average family per day (Burton, et al., 2009).

The slurry will remain in the digester for between 50 to 70 days, after which time it flows to a compost pit, from where it is returned to the fields as fertiliser. The gas that is collected inside the digester builds up sufficient pressure to allow the slurry to be drawn off to a sludge pit without the need to pump it out.

Plastic tanks that are manufactured specifically for biogas generation and collection are available (from South Africa) and research is currently being undertaken by the University of Cape Town (Austin and Melamu, 2010) to establish proper design parameters for local conditions. Figure 3 depicts commercially available tanks that have been designed specifically for this application.

Figure 3: Commercially available Biogas Generation System (courtesy Agama, Austin and Melamu, 2010)

Users must be aware that biogas is highly flammable and can even be explosive so special care must be taken to ensure that safety equipment for the gas dome functions properly at all times.

2.3.2 Re-use of Dehydrated Faeces, Biosolids and Compost

The final solids produced by dehydration toilets or composting dry sanitation systems can be re-used, but care must be taken when handling these solids because they may still contain considerable concentrations of pathogens and helminth eggs. In the circumstances, one option is not to handle the final degradation product at all, but to plant a tree in the area that was occupied by the slurry pit (see below).

- Pit Latrines. Typical systems of this kind are the VIP and Arborloo dry sanitation latrines. They employ a defecation pit, which, when full, is planted with a fruit tree to later provide the household fruit. Figure 4 shows this principle.

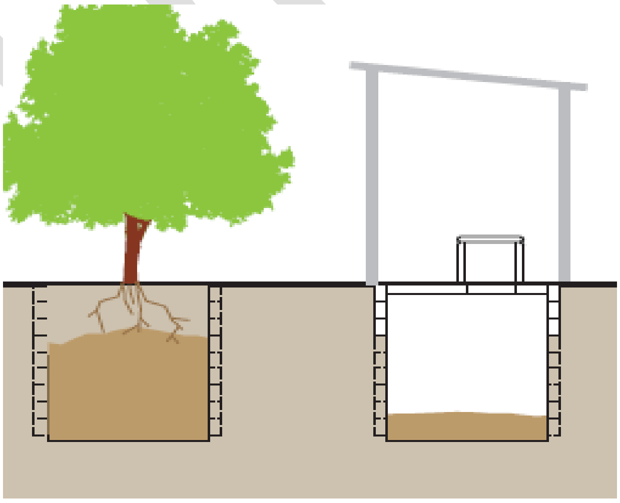


Figure 4: Pit Latrines with Re-use of the Biosolids Produced

Before the pit is used, a layer of leaves should be added to the bottom of the pit. After each defecation, soil, ash or a mixture of both should be put into the pit to cover the excreta. Leaves or grass, when available, can also be added occasionally to improve the porosity and air content of the pile. When the pit is full, it must be covered with 150 mm of soil, left standing for 6 months and a tree can then be planted in the soil (Tilley *et. al*., 2008). A tree should not be planted directly in the raw excreta. Citrus, banana, papaya, fig and guava trees (amongst many) have been grown successfully, as well as tomatoes and pumpkins. Planting a tree in the abandoned pit is a good way to reforest an area, providing a sustainable source of fruit and preventing people from falling into the old pit sites.

- <u>Dehydration Toilet</u>. Dehydration means that the moisture naturally present in the faeces evaporates, is absorbed by the addition of drying material such as soil, ash, sawdust or lime or by intentionally designing a urine diversion system. Double-chamber systems designed with at least six months storage per chamber is a necessary requirement. Each chamber must also be watertight. A family of six will produce approximately 500 l of faeces in six months. Thus, for design purposes a figure of 100 l of faeces discharged per person per 6 months should be used and the chamber must be slightly oversized to allow for airflow (ventilation), visitors and uneven distribution of faeces in the chamber (see Figure 5 - Tilley *et. al*., 2008). When one chamber is full, it is sealed with a lid and the second vault used, while the first chamber dries out. When dry, the material from the first chamber is removed and this chamber is now ready to be used again, once the second one is full. Dehydration toilets would preferably be used with urine diversion systems, so that the speed of the evaporation process is increased.

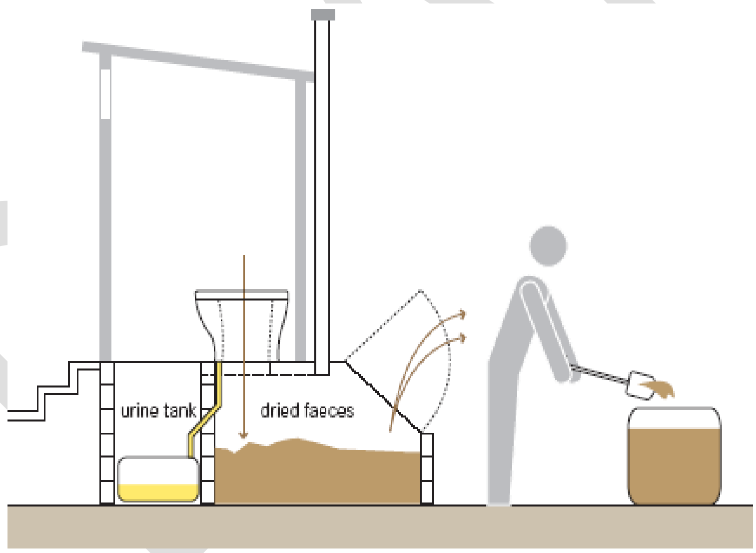


Figure 5: Dry Sanitation system with Dehydration Vault (Tilley, et al., 2008)

When the faeces are completely dry, they will be a crumbly, powdery substance, rich in carbon and nutrients, but may still contain pathogens, helminth eggs and oocysts (spores that can survive extreme environmental conditions and re-grow under favourable conditions). The dry material can be mixed into agricultural soil to grow crops.

Faeces that are dried and stored between 2^0 and 20^0 C should be stored for 1.5 to 2 years before re-applied for agricultural purposes. Shorter periods may be considered if stored at higher temperatures or if lime is added to increase the pH above 9. Dried faeces are not as nutritious (for plants) as composted faeces. However, they are useful at replenishing poor soils and for boosting the carbon and water-storing properties of a soil with low-risk of pathogen transmission.

Compost and Eco-Humus can be mixed into the soil before crops are planted, used to start seedlings or indoor plants or simply mixed into an existing compost pile for further treatment. For poor soils, equal parts of compost and top soil can be applied to improve productivity. The output from one family (6 person household) every 6 months should suffice for application on a piece of land of approximately 10 m^2 in area for growing a vegetable garden. In particular, the following points should be taken into account when re-using decomposed faecal matter:

- Apply only before sowing or planting – not during the growth phase;
- Cover the decomposed material with an upper layer of soil;
- Do not apply to vegetables eaten raw;
- Wear gloves and personal protection equipment when handling and applying the decomposed material;
- Prevent coming into direct contact with the decomposed material.

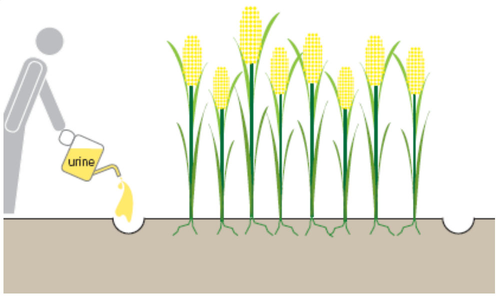
2.3.3 Re-use of Urine

Urine application is ideal for rural and peri-urban areas where agricultural land is close to the point of urine collection. Households can use their own urine on their own plot. Urine is beneficial where crops are lacking nitrogen. Examples of crops that grow well with urine and are also grown in Namibia include maize, sorghum, mahango, cabbage, lettuce, bananas, paw-paws and oranges.

- <u>Safe Re-use</u>. Urines should always be stored in an airtight container to minimise smells. Safe re-use of urine in agriculture (even if cross-contamination with faeces has occurred) can be re-assured if the storage times are followed as advised below (see WHO, 2006, Vol. 4):
    - No storage time required when urine from personal production, or from systems where no cross-contamination with faeces is possible. Urine is used for crops grown for personal consumption;
    - It is still recommended that urine is stored for one month before it is re-used at household level particularly if crops are eaten by those other than the urine producer;
    - Six months storage duration is preferable if cross-contamination with faeces cannot be ruled out and the urine is used on food or fodder crops that are processed for personal consumption.
    - Six months is also recommended if originating from larger systems, e.g. community level and where cross-contamination with faeces cannot be ruled out for crops produced for the community in general.
- <u>Volume when used as a Fertiliser</u>. If all urine produced by one person is collected, it will be enough to fertilise 300 to 400 m^2 of crop per year, e.g. producing approximately 250 kg of maize per year, which roughly equals the food intake of one person per year. Thus, urine that one person produces per day can be applied to approximately 1 m^2 of soil per cropping season, i.e. approx. 1.5 l of undiluted urine per m^2 (Münch, E. v. and Winker, M., 2009).

- Recommendations for application as Fertiliser. Urine is a quick acting fertiliser and can be used for any crop that requires the macro-nutrients N (Nitrogen), P (Phosphorus), K (Potassium) or even micro-nutrients S (Sulphur), Na (Sodium) and Cl (Chloride). Because of its high pH (see Section 2.2.2) and concentration, stored urine should be applied to plants or soils under crop production as follows (Münch, E. v. and Winker, M., 2009):
  - Application is best done early in the morning or last thing at night to avoid scorching by the sun;
  - Mixed undiluted into the soil 2 to 4 weeks before planting;
  - Apply close to the ground and directly incorporated or watered into the soil in order to minimise ammonia losses to the air;
  - Pour undiluted urine into furrows about 150 to 250 mm away from plant roots and cover immediately with soil – this can be done once or twice during the growing season. Urine should not be applied directly to the plant but to the soil next to the plant, otherwise it might lead to fertiliser burn due to its concentrated nature;
  - Diluted urine can be applied several times and used frequently (twice weekly) directly around plants. A 3:1 (water:urine) to 5:1 mix, applied twice weekly, is an effective dilution for vegetables;
  - Between the last fertilisation and harvest, a period of at least one month should be left in-between applications;
  - In climates with heavy rainfall or sandy soils and to avoid leaching, frequent application of small amounts of urine is favourable, but not essential;
  - Urine should not be applied in areas of high salinity.

Figure 6 a) depicts the difference in results when urine was/ was not used as a fertiliser and Figure 6 b) shows how to apply the diluted urine (not directly onto plants).



a) Urine added as fertilizer (Münch, E. v. and Winker, M., 2009).

b) Correct application of diluted urine (Tilley *et. al*., 2008).

Figure 6: Addition and application of diluted urine to soil

3. SUMMARY AND CONCLUSIONS

In these guidelines for the re-use of sanitation waste products, the potential value of waste products than can be reclaimed from the re-use of excreta should be noted.

Nitrates, phosphates and potassium are prime nutrients needed by plants for proper growth and are widely applied in agriculture in the form of fertilisers, whereas these constituents are naturally contained in sanitation waste. Over-exploitation of the natural resources places a burden on the future availability of naturally occurring phosphorus deposits for use as a fertiliser. For example, phosphorus in the form of phosphate rock deposits which are mined to produce fertiliser are non-renewable, limited resources that are being depleted world-wide at an alarming rate.

There is, however, also an inherent health-risk associated with uncontrolled re-use of sanitation waste products and the purpose of this guideline is to make potential users aware of the possible health hazards and how to minimise them.

This guideline therefore addresses the sanitation waste products (urine and faeces) typically generated by single households. It considers how the waste can be used by the same household with the aim of becoming self-sufficient at least with regards to basic food production.

An explanation of the composition of faeces and urine, especially with regards their potential for re-use, is included in the report.

The advantages of collecting faeces and urine separately is also discussed for example:

1. Biogas production from faeces can be used as a fuel source for cooking and lighting;
2. Biosolids production from faeces to rehabilitate poor quality soils for application as a fertiliser for agricultural use;
3. Urine re-use with special guidelines for application to serve as valuable fertiliser for agricultural use.

<u>The potential health hazard when handling and re-using especially faeces is highlighted</u> and guidelines are given to minimise the risk to humans.

The organic material in decomposed excreta when mixed with compost from a compost heap is generally known as compost, which acts as soil conditioner. It improves the structure and water holding capacity of sandy soils and adds structure and permeability to clay soils.

Composted excreta, on its own or combined with other biodegradable material, enhances the fertility of topsoil.

<u>Dehydrated faeces are not as nutritious (for plants) as composted faeces</u> taken from the different types of dry sanitation toilets. However, dehydrated faeces are useful at replenishing poor soils and for boosting the carbon and water-storing properties of a soil with low-risk of pathogen transmission.

Compost and Eco-Humus can be mixed into the soil before crops are planted, used to start seedlings or indoor plants or simply mixed into an existing compost pile for further treatment. For poor soils, equal parts of compost and top soil can be applied to improve productivity. <u>The output from one family (6 person household) every 6 months should suffice for application on a piece of land of approximately 10 m^2 in area for growing a vegetable garden</u>.

Separately collected, stored urine is a concentrated source of nutrients that can be applied as liquid fertiliser in agriculture to replace commercial, artificial fertilisers. In fresh urine, the main nitrogen compound is urea. 80% of the total nitrogen and 55% of phosphorus that is excreted by a person is contained in the urine, the rest within the faeces. Therefore, urine is more valuable than faeces as fertiliser.

Although the main thrust of this Code of Practice focuses on household waste and considers the opportunities for rural, agricultural households to re-use both human and animal waste arisings, Appendix A also introduces the re-use of sludge from a wastewater treatment plant and the restrictions on the application of this source of sludge to land.

In conclusion, individual users and households especially in rural areas in Namibia see excreta as a nuisance product only, whereas these users can benefit the most by re-using faeces and urine to grow agricultural produce. More emphasis should be placed by authorities to sensitise rural households and small communities to select the most appropriate dry sanitation system so that excreta can be seen as a resource and if faeces and urine are separated then they can be safely re-used instead of having to purchase expensive fertiliser.

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APPENDIX A – GUIDELINES FOR LAND APPLICATION OF SLUDGE

A1. LAND APPLICATION OF SLUDGE

The use of sludge produced during wastewater treatment for agricultural use is encouraged due to the high levels of nutrients contained in the sludge. However, such use must be strictly controlled and monitored with restrictions on specific uses in order to ensure the health and safety of both the producers and the consumers of agricultural products to which sludge has been applied. The information given below is an extraction from the MAWF guidelines on Disposal of Water and Wastewater Solids (MAWF, 2010, Vol. 6) that should also be considered by communities as producers and users. This guideline should be used if communities intend to reuse and apply sludge on a large scale or for commercial application/gain. For small-scale use, where detailed classification of sludge in terms of microbial, stability and pollutant parameters is not possible, sludge can be reused if the following minimum requirements are met:

- Faecal coliform concentration in the sludge should be less than 10 000 colony forming units per gram of dry sludge.
- Helminth ova concentration should be less than 1 viable ova per gram of dry sludge.

If the sludge does not conform to these minimum requirements, then complete classification of the sludge will be necessary before it can be safely used (refer to Disposal of Water and Wastewater Solids (MAWF, 2010, Vol. 6)).

A1.1 Restrictions based on Microbiological Classification

Crops where wastewater sludge can be applied are divided into different categories, according to the risk of direct contact of the edible part of the crop with the applied sludge. The three crop categories along with several examples are described below, according to the harvested or edible parts that:

- **Usually do not touch the soil/sludge mixture (Class A):** includes grains and trees such as wheat, barley, corn, soy beans, oats, cotton, apples, bananas, citrus, peaches, pineapples, grapes and avocados.
- **Usually do touch the soil/sludge mixture (Class B):** includes fruit and vegetables grown above the ground such as cucumbers, tomatoes, spinach, lettuce, cabbage, celery, melons, strawberries, eggplants and squash.
- **Usually are within the range of use soil/sludge mixture (Class C):** includes fruit and vegetables grown below the ground such as potatoes, sweet potatoes, onions, beetroot, peanuts, leeks, turnips and radishes.

i. **Microbiological Class A: Restrictions for Agricultural Use**

No restrictions and requirements apply. Sludge in this class can therefore be safely applied to any type of crop providing the Stability and Pollutant Classifications are acceptable for that application.

ii. **Microbiological Class B: Restrictions for Agricultural Use**

Sludge producers are encouraged to achieve Microbiological Class A classification so that no restrictions and requirements for the sludge application apply. For Microbiological Class B sludge, the following restrictions apply:

Table A1 - Restrictions of Microbiological Class B Sludge for Agricultural Use

Sludge Application	Site Restrictions
1) Food crops with harvested parts that touch the sludge	Food crops with harvested parts that touch the sludge/soil mixture and are totally above the land surface shall not be harvested for 14 months after application of sludge.
2) Food crops with harvested parts below the land surface	When the sludge remains on the land surface for 4 months or longer prior to incorporation into the soil, food crops with harvested parts below the surface of the land shall not be harvested for 20 months after application of the sludge. When the sludge remains on the land surface for less than 4 months prior to incorporation into the soil, food crops with harvested parts below the surface of the land shall not be harvested for 38 months after application of the sludge.
3) Food crops with harvested parts that do not touch the sludge, feed crops and fibre crops	Food crops with harvested parts that do not touch the sludge/soil mixture, feed crops and fibre crops shall not be harvested for 30 days after application of sludge.
4) Animal grazing	Animals cannot be grazed on the land for 30 days after application of sludge.
5) Turf growing	Turf grown on land where sludge is applied shall not be harvested for 1 year after application of the biosolids. This applies to lawns and land with high potential for public exposure. .
6) Public Access	Public access to land with a high potential for public exposure shall be restricted for 1 year after application of sludge.. Public access to land with a low potential for public exposure shall be restricted for 30 days after application of the sludge.

iii. Microbiological Class C: Restrictions for Agricultural Use

Microbiological Class C sludge is only suitable for use if Stability Class 1 or 2 is achieved. In such cases the following restrictions apply:

Table A2 - Restrictions of Microbiological Class C Sludge for Agricultural Use

Sludge Application	Site Restrictions
1) Food crops with harvested parts that touch the sludge	Use of Microbiological Class C sludge is not permitted.
2) Food crops with harvested parts below the land surface	Use of Microbiological Class C sludge is not permitted.
3) Food crops with harvested parts that do not touch the sludge, feed crops and fibre crops	Food crops with harvested parts that do not touch the sludge/soil mixture, feed crops and fibre crops shall not be harvested for 90 days after application of sludge.
4) Animal grazing	Animals shall not be grazed on the land for 90 days after application of sludge.
5) Turf growing	Turf grown on land where sludge is applied shall not be harvested for 1 year after application of the sludge. This applies to lawns and land with high potential for public exposure. .
6) Public Access	Public access to land with a high potential for public exposure shall be restricted for 1 year after application of sludge. Public access to land with a low potential for public exposure shall be restricted for 90 days after application of the sludge.

A2. GENERAL RESTRICTIONS AND REQUIREMENTS

Irrespective of the classification, general restrictions apply for the agricultural use of sludge.

A2.1 Sludge Storage

Sludge that is not utilised immediately after production must be stored in adequate storage facilities that minimise the impact on the environment. Storage facilities must be designed to be shielded from wind, minimise odour production, vector attraction and prevent leachate run-off.

A2.2 Sludge Application Rates

Sludge should not be applied in excess of the agronomic rate for the specific crop type concerned. The agronomic rate is a measure of the nitrogen requirement of the plant. This rate should not be exceeded so as to prevent nitrogen from passing through the root zone of the crop and entering the groundwater. The nitrogen content of the sludge must be confirmed before each major planting season and the application rate determined according to the specific crop’s agronomic rate. Note that only 30 to 50% of nitrogen becomes available after the first year of sludge application. However, the maximum application rate of 10 tons dry mass sludge per hectare per year may not be exceeded unless special permission is obtained from MAWF.

A2.3 Buffer Zones for Groundwater and Surface Water

Areas to which sludge is applied for agricultural purposes must meet the following requirements:

- Distance to surface water or borehole > 300 m
- Depth to aquifer > 10 m

The above requirements may be relaxed by the MAWF for specific cases if it can be shown that groundwater and surface water is adequately protected.

A2.4 Buffer Zones for Urban Areas and Settlements

Sludge should not be applied to areas that are within 500 m from inhabited settlements, in order to protect the community against unpleasant odours and vectors. This requirement may be relaxed by the MAWF for specific cases if it can be shown that odour control and vector attraction reduction can be successfully implemented.