WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

CONTRACT NO. EDH–I–00–08–00024–00 ORDER NO. 04

Amount and Characterization of Dairy Cattle Manure and Poultry Litter in Jordan

August 2014

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AMOUNT AND CHARACTERIZATION OF DAIRY CATTLE MANURE AND POULTRY LITTER IN JORDAN
AUGUST 2014

Submitted to:

USAID Jordan

Prepared by:

AECOM

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LIST OF ACRONYMS

AMP	Amount of Manure Production
AU	Animal Unit
DM	Dry Matter
EC	Electrical Conductivity
FS	Fixed Solids
GDP	Gross Domestic Product
HHV	Higher Heating Value
JSMO	Jordan Standards and Metrology Organization
LHV	Lower Heat Value
MoA	Ministry of Agriculture
MoEnv	Ministry of Environment
MoIT	Ministry of Industry and Trade
MoMA	Ministry of Municipal Affairs
NPK	Nitrogen, Phosphorus, Potassium
RSS	Royal Scientific Society
TN	Total Nitrogen
TS	Total Solids
VS	Volatile Solids
WREC	Water Reuse and Conservation

1 Introduction

The USAID Water Reuse and Environmental Conservation (WREC) Project works throughout Jordan in institutional capacity building, pollution prevention for industries, solid waste and wastewater management, and water reuse. The project goal is to protect and conserve scarce resources through regulation, education, and coordination with industry, local communities and the private sector. The project is implemented by AECOM and a team of international and Jordanian partner firms. This five-year project has four primary tasks:

- Task 1 – Institutional and Regulatory Strengthening
- Task 2 – Pollution Prevention and Industrial Water Management
- Task 3 – Disposal Sites Rehabilitation and Feasibility Studies
- Task 4 – Water Reuse for Community Livelihood Enhancement, including Biosolids

As part of Task 4, the project team is to quantify livestock manure from major poultry and dairy cattle farms, and to evaluate methods for processing manure into a beneficial product for agriculture or energy.

Livestock manure production is increasing rapidly due to more intensive production of farm animals (cattle, sheep, goats and poultry) to meet the escalating demand on animal products (milk, meat and egg). Generally, livestock manure is defined as “livestock excreta, unconsumed feed and associate bedding material”. This manure is a valuable by-product of livestock industry and traditionally used as a fertilizer to improve land productivity. Most farms, however, do not own enough land to use animal manure as fertilizers. The staggering amounts of livestock manure create a real problem for human health and the environment.

Improperly stored or applied livestock manure can pollute water resources (surface and underground water) and diminish air quality. The seepage of the contaminants (phosphorous, nitrates, heavy metals, and pathogens) associated with manure can contaminate the sources of drinking water. Gases emitted from the decomposition of manure can pollute the air, increasing vulnerability to respiratory diseases. The stockpiles of manure are favourable environments for proliferation of insects and rodents which can transmit diseases to humans and animals.

In most countries, the animal industry faces the challenge of how to reduce the hazards of increasing production of livestock manure and at the same time optimize benefits derived from this inevitable by-product. This challenge requires careful planning for sustainable, viable and economic utilization of animal manure, which should be environmentally sound and socially accepted. Successful planning requires an updated database on amount of production, chemical composition, handling (collection, storage, transport), and utilization of livestock manure. This database is essential for developing different scenarios for proper management of the ever-increasing amounts of animal manure.

Towards this end, the team of Task 4-WREC Project reviewed literature on livestock manure and collected primary data from local production facilities of dairy cattle and poultry to quantify and characterize the waste. That information is presented in this report. In a subsequent report, the team will evaluate methods for processing waste into a beneficial product and assess the associated market for proper use of livestock manure in Jordan.

2 Livestock Sector in Jordan

In 2012, the estimate of Jordan's Gross Domestic Product (GDP) was around JD19.87 billion: 3.1% agriculture, 30.1% industry and 66.8% services. Over the last few decades, socio-economic factors have led to the rapid development of services and industry sectors, which has resulted in a continued decline in the contribution of agriculture to the GDP: 14.4% in 1971 to 3.1 % in 2012.

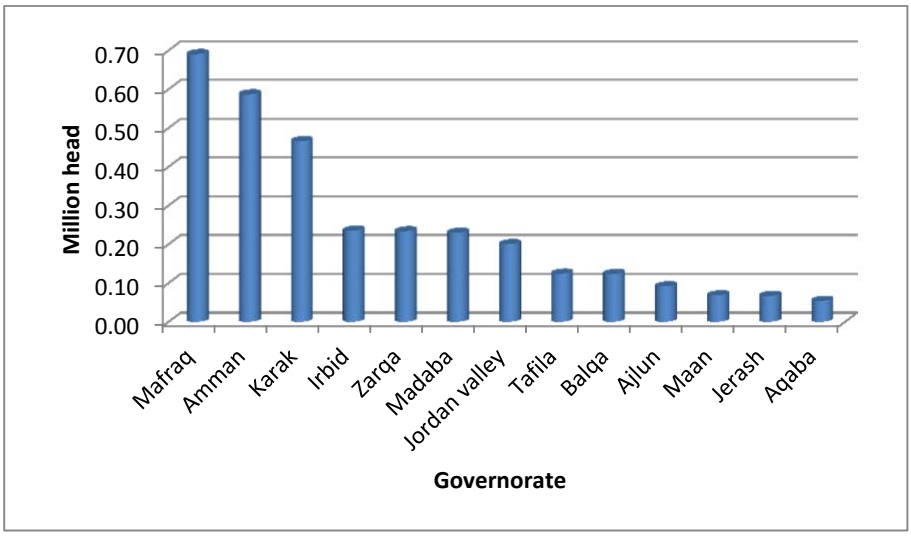
The agriculture sector consists of two main sub-sectors: crop production and livestock industry. Livestock is estimated to contribute to about one-half of the total agricultural GDP. The production of food producing animals is valued to around JD820 million; JD435 million generated from the poultry industry and JD385 million from dairy cattle and small ruminants (sheep and goats) enterprises.

The livestock industry consists of facilities of food producing animals (dairy cattle, poultry, sheep, goats and a few traditional feedlots for beef production from the offspring of dairy cattle) and several supporting services (factories of veterinary medicines, feed factories, milk processing plants, slaughter houses, and marketing services).

2.1 Sheep and Goats

The Ministry of Agriculture (2012) indicated that there were 2.39 million head of sheep and 0.89 million head of goats. The population of sheep and goats is mainly concentrated in Mafraq, Amman and Karak Governorates (Figure 1). Awassi is the local sheep breed whereas Aswad (*Black*) and Shami (*Syrian*) are the main goat breeds. These small ruminants are mostly raised in small flocks under an open production system that is continually vulnerable to shocks because of droughts, outbreaks of diseases, high prices of local and imported feedstuffs, and inability to compete with imported animal products (Abu-Zanat et al., 2005). Because of the frequent mobility and the scattered distribution of sheep and goat flocks in the country, the manure produced from these small ruminants will not be considered in this study.

Figure 1. Population of sheep and goats in the different governorates of Jordan (MoA, 2012)



2.2 Dairy Cattle

According to MoA (2012), the population of dairy cattle is around 66,000, distributed among 596 farms and concentrated in four Governorates, as shown in Figure 2: Zarqa (42.6%), Irbid (21.3%), Mafraq (16.2%) and Amman (7.5%). The two dairy cattle breeds are the imported

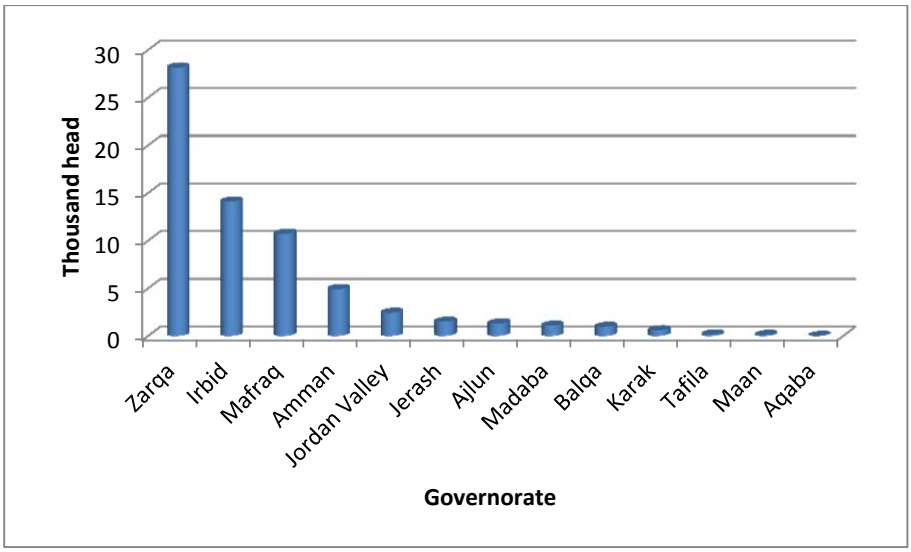
Holstein (91%) and the indigenous *baladi* (9%); in some locations the *baladi* breed is called *shami* or *akshi*. The imported cattle are raised in modern dairy farms while the *baladi* cattle are raised in small herds (<10 heads) by agricultural families (MoA, 2012). The most common dairy housing system in the country is the open and dry lot system.

Analysis of dairy cattle population in the last 12 years (from 2000 to 2012) indicated that the average annual increase in dairy cattle population was around 0.7% (450 head of cows of which 330 are milking cows). This minimal increase in the population of dairy cattle may be attributed to lack of local forage resources and imports of powder milk which may be used illegally in the production of dairy products.

The general composition of the dairy herd is 77% milking cows, 21% calves and 2% bulls (MoA, 2012). A large proportion of calves (60%) are used to replace old and infertile cows. The low proportion of bulls reflects the adoption of the artificial insemination as the common method for breeding of dairy cows.

Milk production from dairy cattle and small ruminants (sheep and goats) totaled 365,386 tons in 2012, covering around 61% of national needs. The contribution of cow milk to total milk production was around 77%. There is therefore still room, even under the present conditions, to expect growth in the dairy cattle sector in Jordan, for two main reasons: the continual population increase and the trend of increased milk consumption per capita.

Figure 2. Population of dairy cattle in the different governorates of Jordan (MoA, 2012)



2.3 Poultry

There are three types of poultry (chicken) that are farmed in the country: broilers for meat production, layers for table egg production, and breeders (parent stock) for production of fertilized eggs for the hatcheries. Table 1 summarizes numbers of farms and the populations of broilers, layers and parent stock in Jordan (MoA, 2012).

Broilers are reared for 45-50 days before marketing, which means that 6.8 to 7.3 cycles or batches of broilers can be produced per year. The estimated population of broilers per cycle is around 28 million birds, equivalent to an annual production between 190.4 and 204.4 million birds. Figure 3 shows the distribution of broilers production in Jordan (MoA, 2012). Production of broilers is concentrated in five Governorates: Mafraq (22.7%), Amman (17.9%), Irbid (17.3%), Zarqa (12.4%) and Karak (10.6%). It is worth noting that the number

Table 1. Poultry production types in Jordan

Production Type	Number of Farms	Number of Birds (in million)	Notes
Broilers	1722	28 (per cycle)	6.8-7.3 cycles per year
Egg Layers	290	6.8	
Parent Stock: Broilers Egg Layers	 108 4	 3.92 0.07	

Source: MoA, 2012

of reared broilers varies within the year, as illustrated in Figure 4 (MoA, 2012), in response to increased demand of Religious Occasions (Ramadan) and the risk of high mortalities of birds during harsh weather conditions in hot summer (August-October), and in early winter when *Marbaanyieh* starts (December). The majority of broilers are reared in open houses, which increases production costs due to high costs of heating during periods of low temperatures. This is nevertheless more affordable than cooling the broiler houses in hot summer.

A broiler house (locally called an open house to differentiate it from the controlled closed-house) is commonly used for intensive broiler production in Jordan. The birds are kept on the litter (sawdust and wood shavings) covering the house floor. The droppings of broilers fall on the litter which is removed at the end of each growing period (45-50 days of production).

According to MoA (2012), the **laying chicken** population for production of table eggs is concentrated in three Governorates: Amman (48.9%), Mafraq (21.2%) and Zarqa (8.0%) (Figure 5). The two housing systems for rearing laying hens are the battery cage house and the more common deep litter house. In the battery cage house, the laying hens are kept in cages arranged in long tiers. The droppings fall through the bottom of the cages and are collected and stored underneath it in a deep pit. The droppings from laying hens in battery systems are not mixed with other material such as litter.

In deep litter system, the house-floor is covered with bedding material and laying nests are arranged along the walls. The droppings of birds over the 13-15 month egg-laying period are mixed with the bedding material forming a thick, deep litter.

Figure 3. Population of broilers in the different governorates of Jordan (MoA, 2012)

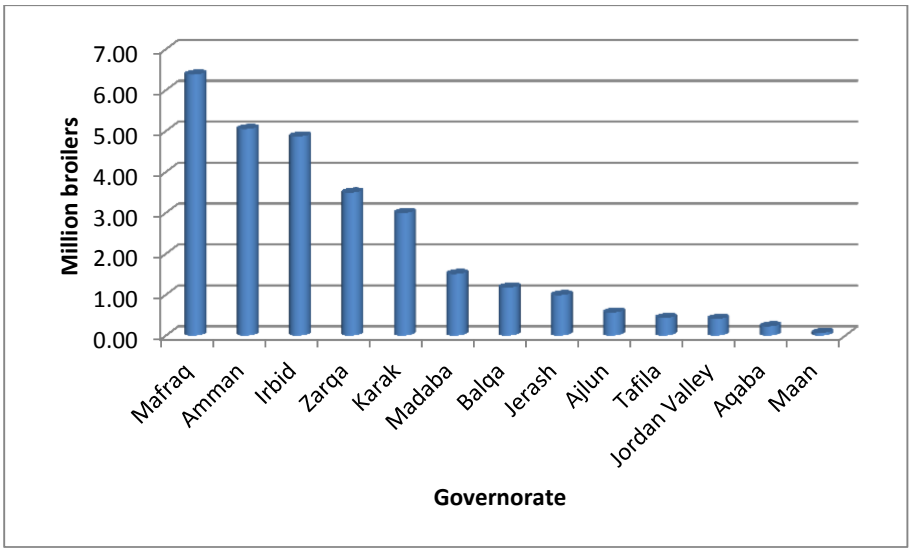


Figure 4. Monthly distribution of one-day-old chicks in Jordan (MoA, 2012)

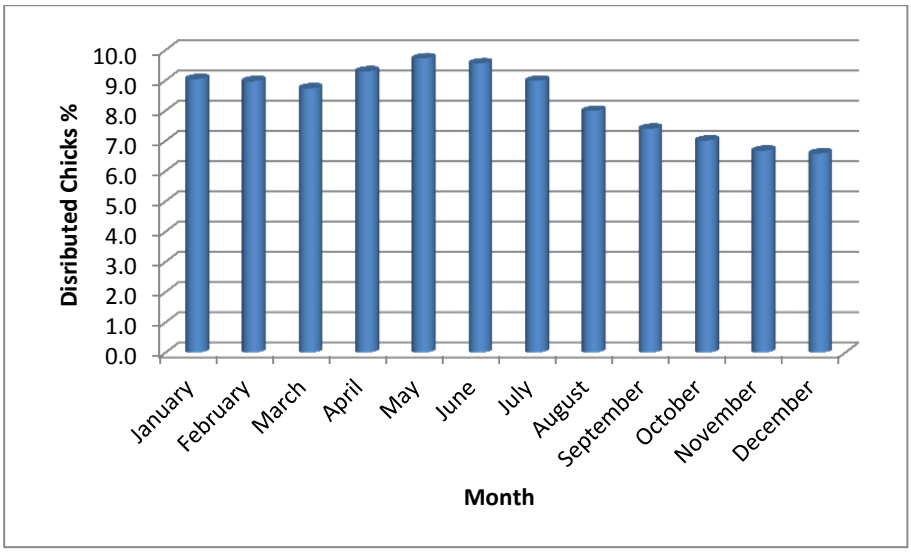
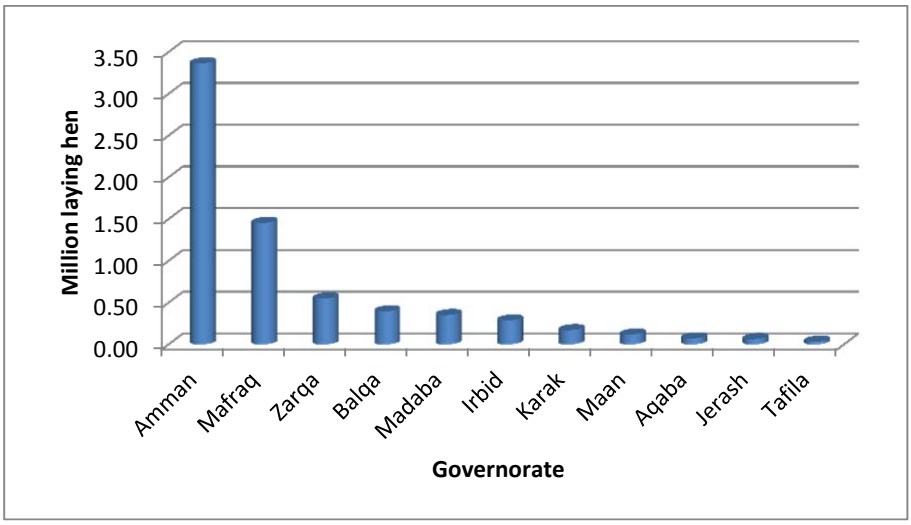


Figure 5. Population of laying chicken hens in the different governorates of Jordan (MoA, 2012)



3 General Literature Review on Animal Manure

This section focuses on reviewing literature pertinent to animal manure in general beyond Jordan.

3.1 Terminology

The literature contains numerous definitions of livestock wastes and manure. The most comprehensive reference on terminology of manure is the "Glossary of Terms on Livestock Manure Management", funded by the Department of Environment, Food and Rural Affairs, UK and the Swiss College of Agriculture, compiled and edited in 2003 by Brian Pain and Harald Menzi. The definitions below were extracted from this Glossary, after minor modification to serve the purpose of this report.

Livestock waste	**Livestock manure, unconsumed feed and associated bedding materials and animal carcasses from normal mortalities of livestock on a farm.**
Bedding	**Material placed on the floors of livestock houses to provide some comfort to the animals and to absorb moisture. Materials such as straw, chopped straw, sawdust, and wood shavings are commonly used for bedding.**
Manure	**A general term to denote any organic material that supplies organic matter to soils together with plant nutrients, usually in lower concentrations compared to inorganic fertilizers.**
Animal manure	**Feces and urine, wasted feed, and bedding materials. (See Clarification discussion below.)**
Feces	**Solid waste or undigested material voided by animals.**
Urine	**Wastes removed from the blood stream via the kidneys and Voided as a liquid.**
Excreta	**Waste expelled from the body: feces and urine.**
Excrement	**Solid waste matter discharged from the body. Similar to definition of feces**
Dung	**Feces from mammalian livestock.**
Droppings	**Waste voided by poultry.**
Liquid manure	**A general term that denotes any manure from housed livestock that flows under gravity and can be pumped.**
Slurry	**Feces and urine produced by housed livestock, usually mixed with some bedding material and some water during management to give a liquid manure with a dry matter content in the range from about 1 – 10%.**
Solid manure	**Manure from housed livestock that does not flow under gravity, cannot be pumped but can be stacked in a heap. There are several different types of solid manure arising from different types of livestock housing, manure storage and treatment.**
Farmyard manure	**Feces and urine mixed with large amounts of bedding (usually straw) on the floors of livestock housing.**
Deep litter	**Feces or droppings and urine mixed with large amounts of bedding (e.g. straw, sawdust, wood shavings) on the floors of buildings housing any type of livestock or poultry.**
Yard scrapings	**Mixture that may contain feces, urine, waste feed, water from cleaning a**

	hardstanding by mechanical means (e.g. with a tractor mounted or hand-held scraper); can be liquid or semi-solid.
Fresh solid manure	**Solid manure immediately after removal from the livestock housing.**
Stored solid manure	**Solid manure that, following removal from the livestock housing, has undergone a period of storage in a heap.**
Composted manure	**Solid manure that has undergone a composting process; compost.**
Poultry litter	**Droppings mixed with a layer of (for example) sawdust, on the floors of buildings housing poultry.**
Broiler litter	**Droppings mixed with a layer of absorbent material, for example sawdust, wood shavings, straw, on the floors of buildings housing broiler chickens (i.e. birds raised for meat).**
Laying hen manure	**Droppings collected in buildings housing chickens for egg production.**
Deep pit manure	**Droppings collected in a pit beneath cages housing laying hens.**

Clarification:
"Animal manure" consists of feces and urine voided by livestock or consists of droppings (feces and uric acid) excreted by poultry. The term "manure" means "feces and urine: stand alone" and not necessarily mixed with bedding material. If the manure of livestock is mixed with small amounts of bedding material, the term "manure" still applies. It is common to use the term "manure" in relation to dairy cattle.

"Poultry litter" refers to the droppings of birds that are mixed **with large amounts of bedding** material. The physical, chemical and biological attributes of poultry manure and poultry litter are different.

In Jordan, the majority of chickens (layers and broilers) are raised on floors covered with sawdust or wood shavings as bedding material; the term "poultry litter" and not "poultry manure" is therefore commonly used.

3.2 Dairy Cattle Manure (Feces and Urine with a Small Amount of Bedding Material)

In this section, the quantity of manure from dairy cattle is estimated, followed by characterization of the manure for agriculture use, energy use and value added chemicals.

3.2.1 Estimating Quantity of Manure Excreted by Dairy Animals

The common procedure to estimate the quantity of manure excreted by livestock is based on animal weight. The relationship between animal weight and feed intake is linear and well established (Mertens, 1987). Daily feed intake of ruminant animals relative to body weight is around 2-3%. Dairy cows feed on good quality roughages and concentrate to meet the nutrient requirements for milk production and pregnancy. This means that the feed digestibility given to dairy cows should not be less than 50%. The quantity of manure excreted per cow can be estimated from the relationship of animal weight, daily feed intake relative to animal weight, and feed digestibility. It was assumed that feed digestibility by dairy cattle is 50% or more, regardless of the feed ingredients. These high-producing animals are fed high-quality diets to meet their nutrient requirements.

Manure (kg DM per cow per day) = cow weight x relative daily feed intake x feed digestibility
= 500 kg x2.5% x 50%
= 6.25

The moisture content in fresh manures excreted by dairy cattle ranges from 80 to 85%; dividing the computed amount of manure dry matter (DM) by 15 to 20% yields the fresh weight of excreted manure (6.5 kg DM/20% DM in manure =32.5 kg per cow per day).

This approach requires all weights of animals in a certain confinement (farm) to be summed and then divided by 500 kg to calculate the total number of animal units. The animal unit (AU) concept presupposes a mature cow weighing 500 kg. To calculate the quantity of manure excreted by 100 dairy head of dairy cattle (milking cows, non-lactating cows, claves, bulls, and heifers), the weights of all animal classes are summed and then divided by 500 to determine the number of animal units.

Manure (kg DM per farm per day) = (weights of all animal classes in kg) x 2.5% x 50%/500 kg

Each AU of dairy animals produces around 2.28 ton dry matter (6.25 kg dry per day x 365 days) of manure annually. Estimates of animal manure are important when planning and designing dairy facilities, storage facilities to hold the quantity of manure produced by a dairy operation, and for designing anaerobic digesters.

Recently, the level of milk production procedure is used to estimate the quantities of manure and nutrients excreted by dairy animals. It is widely documented that milk production is related to feed intake: high-producing cows have a larger dry matter intake and consequently a larger volume of excreted manure than lower-producing cows. The following equations were developed by Nennich *et al*., 2003 to estimate manure production on wet (equation 1) and dry (equation 2) weight basis and its constituents (NPK) from milk production data (equations 3, 4 and 5).

1. Total excreta (feces + urine) (kg/day) = [milk (kg/day) × 0.616] + 46.2
2. Dry matter excretion (kg/day) = [milk (kg/day) × 0.0874] + 5.6
3. N excretion (g/day) = [milk (kg/day) × 2.82] + 346
4. P excretion (g/day) = [milk (kg/day) × 0.781] + 50.4
5. K excretion (g/day) = [milk (kg/day) × 1.476] + 154.1

3.2.2 Characterization of Dairy Cattle Manure

The characteristics of manure primarily depend upon the composition of the feed given to the animal. The animal metabolizes the feed to provide itself with energy and produce new body tissues and products. The waste products of metabolism are largely collected in urine and passed out with the feces (which may contain unused feed).

The chemical composition of animal manure is usually addressed from three different perspectives: agricultural use, energy production, and value-added chemicals.

Agricultural Use

Animal manure has traditionally been used for improving agricultural lands. The arable lands in Jordan, however, have limited capacity to absorb the mountains of daily produced manures. Over-application of animal manure could lead to serious environmental problems such as increased nutrient loss through leaching, erosion, and runoff from agricultural fields.

Since the main use of animal manure is for land application to improve soil composition and structure, physical properties (total solids and moisture content) and chemical constituents (N, P, and K) are routinely analyzed to characterize the nature of organic matter and evaluate the availability of its nutrients. Although animal manure contains all 13 of the essential nutrients for plants (N, P, K, Ca, Mg, S, Mn, Cu, Zn, Cl, B, Fe and Mo), NPK content is more emphasized. In addition, mineral composition of manure is of interest to evaluate the types and levels of heavy metals in it especially in case of using animal manure for agricultural purposes (Table 2).

Typical characterization of fresh manure “as excreted” is 86.61% moisture, 2.90% nitrogen, 0.48% phosphorous, 2.86% potassium, and 45.37% carbon (Chen et al., 2003).

Table 2. Mineral composition of dairy cattle manure

Elements	Unit	Content in Dry Manure	Elements	Unit	Content in Dry Manure
Calcium	%	1.2	Cadmium	ppm	-
Magnesium	%	0.55	Cobalt	ppm	0.89
Sodium	%	0.47	Chromium	ppm	2.1
Copper	ppm	30	Manganese	ppm	510
Zinc	ppm	320	Molybdenum	ppm	2.6
Iron	ppm	300	Nickel	ppm	9.7
Sulfur	ppm	0.31	Lead	ppm	-
Aluminum	ppm	140	Vanadium	ppm	4.7

- below detection limit
Source: Chen et al., 2003

Energy Production

Manure can be an alternative energy source for livestock farmers. The manure is easily collected on dairy farms where cows are routinely confined. An anaerobic digester will partially convert manure to energy in the form of biogas which contains methane. Biogas is most efficient when used directly for heating, and dairy farms have a year-round demand for hot water.

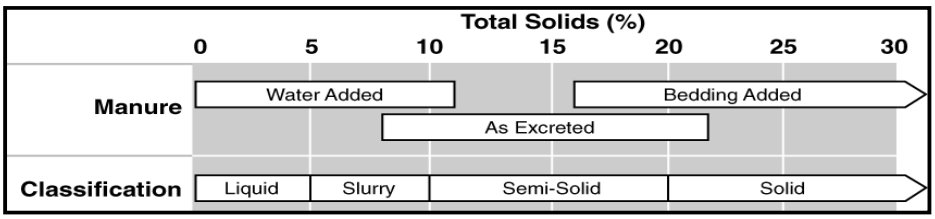
The characteristics of manure should be understood before making decisions on using it for energy production. The relevant characteristics can be described by physical, biological, chemical parameters and lower heat value (LHV) of manure.

Manure can be partitioned into different physical characteristics: total solids (TS), volatile solids (VS), and fixed solids (FS). The solids content of dairy manure varies from farm to farm based on the type of housing, manure collection practice, bedding usage and environmental conditions. The TS content of manure “as-excreted” ranges from 8% to 15% which governs manure handling systems. Washing the manure excreted by animals in feeding, milking and resting areas reduces the TS to 0.5% and 1.2%. The VS is the portion of organic matter that is degradable and must be stabilized during treatment. The VS component of dairy cattle manure is 80% to 86% of TS (Longhurst et al., 2000). The FS constitute the ash or the residual inorganic compounds (N, P, K, Ca, Cu, Zn, Fe).

According to solids content, cattle manure is classified into four categories: liquid, slurry, semi-solid and solid for handling purposes (Figure 6). Manure as excreted is either in the slurry or semi-solid phase. If water is added, the excreted manure becomes slurry or liquid state. When bedding is added, the manure becomes mainly solid.

A typical composition of manure solids data is 13.3% TS, 2.0% FS, and 85% VS: TS. Animal manure with 1-14% total solids is recommended for biogas production.

Figure 6. Total solids classification (USDA-NRCS, 1996)



Value-Added Chemicals Perspective

Recently, there is a trend towards more detailed chemical analysis of animal manure to obtain information on manure constituents, such as cellulose, hemicellulose, lignin, and protein. This information may help in exploration of technologies to convert these constituents to value-added chemicals. This approach, still in the research stage, focuses on medium-volume commodity chemicals such as glycols or diols, and protein-based products such as chemicals or feed supplements (Chen et al., 2003).

3.3 Poultry Manure (Bird Droppings or Excreta Without Bedding Material)

In this section, the quantity of manure from poultry is estimated, followed by characterization of the manure for agriculture use, energy use and value added chemicals.

3.3.1 Estimating Quantity of Poultry Manure

As a rule of thumb, the estimated fresh weight of excreta voided by chicken is about 115 percent of the total dry feed weight (from OSU). Typical values of poultry manure output for laying chicken and growing broilers are presented in Table 3. A laying chicken hen produces around 51.1 kg of fresh manure annually compared to 50.6 kg by a broiler chicken (0.165 kg per bird x 306 days of production per year for 7.3 cycles of 42-day each). Fresh manure of laying hens contains around 75% water which will evaporate from the accumulating manure while it is in the deep pit of poultry houses. The evaporation of moisture reduces the calculated weight of the fresh manure to about 35%.

Table 3. Feed intake and output of fresh excreta by poultry

Poultry	Daily Feed Intake (kg/bird)	Daily Fresh Manure Output (kg/bird)	Manure: Feed Ratio
Laying hens	0.1-0.13	0.13-0.15	1.0-1.31 (average=1.15)
Growing broilers at 6 weeks of age	0.1-0.17	0.15-0.18	1.15-1.17 (average=1.16)

Source: Poultry manure management and utilization problems and opportunities, Bulletin No. 804, The Ohio State University.

3.3.2 Characterization of Poultry Manure

Typical characterization of poultry manure is shown in Table 4. Storage of manure will result in loss of nitrogen in the form of ammonia. An overview of fresh manure properties (physical properties, nutrients, heavy metals, and bacteria) across cattle and poultry by a common unit of livestock mass/day is presented in Table 5.

Table 4. NPK typical composition of fresh excreta of poultry

	Unit	Laying Chicken	Growing Broilers
Total nitrogen	%	1.0-1.8	1.4-2.2
Phosphorous, P_2O_5	%	0.8-1.2	0.9-1.2

Potassium, K_2O	%	0.5-0.7	0.5-0.8

Table 5. Fresh manure production and characteristics per 1000 kg live animal mass per day (ASAE, 2003)

Parameter	Units	Dairy Cattle	Poultry	
			Layer	Broiler
Total Manure	Kg	86/17	64/19	85/13
Urine	kg	26/4.3	-	-
Density	Kg/m^3	990/63	970/39	1000/--
Total Solids	kg	12/2.7	16/4.3	22/1.4
Volatile Solids	kg	10/0.79	12/0.84	17/1.2
BOD_5	kg	1.6/0.48	3.3/0.91	-
COD	kg	11/2.4	11/2.7	16/1.8
pH		7.0/0.45	6.9/0.56	-
TKN	kg	0.45/0.096	0.84/0.22	1.1/0.24
NH_3-N	kg	0.079/0.083	0.21/0.18	-
Total Phosphorous	kg	0.094/0.024	0.30/0.081	0.30/0.053
Ortho-phosphorous	kg	0.03/**	0.092/0.016	-
K	kg	0.29/0.94	0.3/0.072	0.4/0.064
Ca	kg	0.16/0.059	1.3/0.57	0.41/--
Mg	kg	0.071/0.016	0.14/0.042	0.085/--
S	kg	0.051/0.010	0.41/0.066	0.085/--
Na	kg	0.052/0.026	0.10/0.051	0.15/--
Cl	kg	0.13/0.039	0.56/0.44	-
Mn	g	1.9/0.75	6.1/2.2	-
B	g	0.71/0.35	1.8/1.7	-
Mo	g	0.074/0.012	0.3/0.057	-
Zn	g	1.8/0.65	19/33	3.6/--
Cu	g	0.45/0.14	0.83/0.84	0.98/--
Cd	g	0.003/--	0.038/0.032	-
Ni	g	0.28/--	0.25/--	-
Pb	g	-	0.74/--	-
Total coliform bacteria	colonies	1100/2800	110/100	-
Fecal coliform bacteria	colonies	16/28	7.5/2.0	-
Fecal streptococcus bacteria	colonies	92/140	16/7.2	-

Notes on Table 5:

- Numbers are reported as means/standard deviation.
- All nutrients and metals are given in elemental form.
- The high values of standard deviations associated with means of manure production (86±17 kg for cattle, 64±19 kg for layers and 85±13 kg for broilers) reflect the great variations in the amount of excreted manure between animals of the same species.
- The reported value of manure output by dairy cattle is equivalent to 43 kg wet or 6.5 kg DM per animal unit per day on the basis that fresh cattle manure contains around 15% solid matter.
- The manure of laying hens contained slightly more calcium than that of cattle and broilers. This type of manure is useful where soil liming is needed.

4 Characteristics of Animal Manure in Jordan

The Task-4 Team designed and conducted a survey to fulfill the following objectives:

- To quantify the amount of dairy and poultry manure produced in the country
- To determine the physical, chemical and biological characteristics of dairy and poultry manure
- To develop a clear picture about manure handling in terms of collection, treatment, storage, and disposal or reuse in the country

The approach adopted by the Team included:

- Conducting internet search for articles and reports on characterization of manure in Jordan
- Conducting field visits to the Governmental (Ministry of Agriculture, Ministry of Environment, Ministry of Water and Irrigation) and Non-Governmental institutions (Cooperative for Retired Military, Dairy Cattle Growers) to collect data on the different aspects of manure in Jordan
- Visiting large dairy and poultry facilities in the country and interviewing the farm managers to obtain information on the different issues of manure
- Sampling manure from selected dairy and poultry farms for physical, chemical and biological characterization

The following sections describe results obtained from the above mentioned activities.

4.1 Reviewing Previous Studies

The sources consulted to collect data on animal manure in Jordan included the internet (journals, technical reports, proceedings, and gray literature), Ministries of Agriculture, Environment, and Water and Irrigation.

The collected documents, addressing manure characterization in Jordan, included the following:

Abu-Ashour, J, Hani, A, and Mohammad, A. 2010. Estimation of Animal and Olive Solid Wastes in Jordan and their Potential as a Supplementary Energy Source: An Overview, Renewable and Sustainable Energy Reviews, 14:2227–2231.

Abu-Hamatteh Z.S.H., S. Al-Jufout, B. Abbassi, and S. M. Besieso, 2010. Biogas Energy: Unexplored Source of a Renewable Energy in Jordan, International Conference on Renewable Energies and Power Quality (ICREPQ'10), Granada (Spain), 23rd to 25th March, 2010.

Al-Rousan A. and A. Zyadin. 2014. A Technical Experiment on Biogas Production from Small-Scale Dairy farm. Journal of Sustainable Bioenergy System, 4:10-18.
Assam, S., W. Tentscher, A. Kaupp, M. Broege. 2010. Assessment of Feasibility and Biogas Roadmap 2020 for Development of Biogas Projects in Jordan, Fourth Draft. Support for the enhanced integration and the improved security of the Euro-Mediterranean energy market (MED-EMIP) VN 81127910.

Ministry of Agriculture 2012. Annual Report of the Department of Animal Production (in Arabic).

Ministry of Agriculture 2013. Internal Memo on animal manure production in Jordan (in Arabic).

Literature available on animal manure characterization in Jordan is very limited. The extracted information from the few collected documents on animal manure characterization is summarized under two sub-headings: amount of production, and physical, chemical and biological attributes.

4.1.1 Amount of Manure Production

Table 6 shows clearly the discrepancy between reported data on animal manure production in Jordan. Abu-Ashour (2010) reported that 72,000 head of dairy cattle and 40 million hens generated about 5.3 million ton of solid waste (as excreted) per year with 200,000 ton per year of estimated BOD_5. Assam *et al*. (2010) estimated the annual production of wet manure from dairy cattle and poultry facilities to be 980,775 tons. The reported estimates were based on dairy cattle population of 96,917 head compared to 66,000 head of dairy animals reported by MoA (2012). As a result, the reported values of wet manure production were overestimated. Another study by Abu Hamatteh *et al*. (2010) indicated that the generated animal manure in Jordan according to the study conducted by the Greater Amman Municipality in 2009 was 800,000 ton of cattle manure and 350,000 ton of chicken litter, a total of 1.15 million ton.

The above three studies were all published in 2010, but the reported data on animal manure is greatly different. This could be attributed to the following reasons:

i) Source of data concerning the populations of dairy cattle and poultry upon which the estimates were based. Officially, the National Numbering Program is the most accurate reference for the population of livestock in the country.

ii) Lack of clear methodology explaining how estimates were computed, particularly the assumption concerning the level of daily manure output per animal.

iii) Misuse of the terms commonly used to express or characterize manure (wet, as excreted, dry, air dry, poultry manure, poultry litter). For this reason, to avoid ambiguity, section 3.1 of this report was devoted to terminology of manure attributes.

iv) Tailoring the outcomes of conducted surveys on manure to fit the objectives of reports or conferences (energy production, climate change, production of organic fertilizers)

v) All the above reports overlooked a very important issue which is how much of this produced manure is recoverable (collectable). It is worth noting that substantial amounts of washed manure from feeding, milking and resting areas of dairy cattle facilities are disposed of outside the sewer system.

Therefore, this study used the official records of MoA concerning the populations of dairy cattle and poultry; published papers and reports were used when data were not available. The methodologies described in items 3.2.1 & 3.3.1 were used to estimate manure production from the populations of dairy cattle and poultry in the country.

Table 6. Reported data on manure production from dairy cattle and poultry farms

Source of data	Dairy cattle		Poultry (in million)				Notes
	No.	AMP (ton)	Layers		Broilers		
			No.	AMP	No.	AMP	
MoA, 2013 Internal Memo	65,020[a]	160,151[b]	-	-	-	-	Cow: 8 kg manure/day (air dry)

							Calves: 3 kg manure/day (air dry) Poultry: 180 million bird produced 193,517 ton of dry manure (80% DM)
MoA, 2012 Agricultural Annual Report	63,744[c]	-	10.7 [d]		205.4	-	28.139 million broiler per cycle. 7.3 cycles per year 50 days (42+8) production cycle
Abu-Ashour, 2010	72,000	-	40	-	-	-	5.3 million ton of wet manure
Azzam et al., 2010	68,781	149,943	7.99	-	24.98	-	499,826 ton of wet manure
Abu-Hamatteh, 2010	-	800,000	-	-	-	-	350,000 ton of chicken litter

AMP: Amount of Manure Production in tons.
a: 48742 milking Holstein cows + 16278 calves
b: 142327 + 17824 ton of dried manure from milking cows and calves, respectively
c: 48742 milking cows + 8875 female calves + 4887 male calves + 1240 bulls
d: 6.8 million layers + 3.9 million parent stock
-: data not available

4.1.2 Physical, Chemical and Biological Attributes of Manure

The published papers by Abu-Ashour *et al*., (2010), Abu-Hamatteh *et al*., (2010) and Assam *et al*., (2010) focused on the potential of using the different types of organic wastes (animal manure, olive pomace, landfills waste) available in Jordan for energy production. These studies were interested in the estimation of volatile solids and biochemical oxygen demand; consequently no detailed analyses of organic and inorganic constituents of wastes were reported.

4.2 Field Survey

4.2.1 Interviewing Managers of Selected Dairy and Poultry Farms

Field visits were conducted to three commercial dairy cattle farms, with herd size between 1,500 to 4,000 head, to investigate the management, handling and utilization of cattle manure generated from these farms. Two farms (Baladna Dairy and Teeba Dairy) located in Dhlailin Zarqa Governorate were visited; and one farm (Hamoudeh Modern Dairy Farm) located in Al Khalidiyain Al-Mafraq Governorate was visited. Two broiler farms in Irbid Governorate (one Al-Esh and one in Hebraas) and one layer farm in Amman Governorate (in Zizya) were visited.

Interviewing Managers

The visits to dairy cattle farms aimed to obtain specific information on the following issues/operations:

-Amount of manure excreted by cow per day expressed in kg DM/day.
-Volume of water used for washing manure in feeding, resting and milking areas to help estimate the volume of generated slurry
-Reuse of wastewater on the farm
-Collection of manure from dry-lot areas of farms (manual and/or mechanical)
-Onsite processing of manure (drying, composting, gasification)
-Onsite storage of manure (stockpiling)
-Disposal of manure (tariff for dumping in landfill, selling to local contractors)

The visits to poultry farms aimed to collect information on the following:

-Daily output of excreta per bird (hen or broiler)
-Number of production cycles per year
-Type of bedding material
-Disposal of poultry litter

4.2.2 Collecting Manure Samples from Dairy Cattle and Litter from Poultry Farms

In addition to collecting information, the Project team collected manure samples from the visited dairy and poultry farms.

Fresh manure excreted by dairy animals in the dry dairy lot was sampled. A shovel was used to collect five sub-samples which were mixed thoroughly to generate a composite sample of about 2 kg, kept in an ice box and sent immediately to the Royal Science Society (RSS) for characterization. This sampling procedure was performed for the three visited dairy cattle farms.

The poultry litter from the three visited poultry farms was sampled. Fifteen sub-samples of litter were collected from the different parts of each broiler house to get a representative sample: five samples from the top of the litter (this stratum includes fresh excreta, spilled feed, and feathers); five samples from the middle of the litter (old or decayed manure); and five from the bottom of litter (decayed manure and bedding material). A composite sample of about 2 kg was collected from all the sub-samples, and then sent to RSS for analysis. The same sampling procedure was applied for sampling the litter of the laying hen house in Zizya.

4.2.3 Analysis of Collected Manure and Litter Samples

The collected samples from dairy cattle manure and poultry litter were analyzed for moisture content, dry matter, solid matter components (TS, VS, FS), ash, bulk density, biological oxygen demand, chemical oxygen demand, electrical conductivity, pH, total Kjeldahl nitrogen (TKN), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N)/ dissolved, elements (As, Cd, Cr, Hg, Mo, Ni, Se, Pb, Zn, Cu, Mn, P, Cl, Mg, Na, Ca, B, K), and biological (intestinal worm eggs, *E. coli*, *Salmonella*).

4.2.4 Results and Discussion

4.2.4.1 Handling of Manure

The managers of the three visited dairy cattle farms indicated that the average daily output of manure per cow was around 6 kg of DM, which is slightly lower than the estimated value provided by the first methodology previously discussed in section 3.2.1 (6.25 kg DM per cow). The defecated manure in the dry lot is scraped up by a tractor. The fate of collected manure can be summarized as follows:

On-farm

i) Disposal of raw manure. Stockpiling of manure at the farm without any treatment waiting for off-farm trucking by local contractors. The disposed manure could be fresh or old depending on the storage period at the farm.
ii) Disposal of fermented manure. Fermenting of manure and then marketing it through local contractors or distributers for using in horticulture and floriculture enterprises.
iii) Disposal of manure compost. One farm composts manure which requires large capital for investment and large production of manure on-farm. Low price of manure compost is the main obstacle hindering the flourishing of this enterprise.
iv) Disposal of slurry. The slurry is either disposed via the sewer system if farms are connected to the system or collected in special lagoons waiting for proper disposal.

Off-farm

i) Dumping of raw manure. Local contractors collect the raw manure from the farms and dump it either in the nearby areas or at Al-Ekeder landfill.
ii) Processing of collected manure. This is a dynamic activity where local contractors collect manure from livestock farms and fermented it at mini-fermentation units. This fermented manure is mainly marketed for horticulture.
iii) The slurry collected in lagoons at the farms is collected by tankers and dumped either at landfill (e.g. Al-Ekeder) or in the nearby places. The majority of farms are not connected to the sewer system; the slurry is conveyed to the nearby places causing serious environmental problems (odor, insects, rodents, etc.).

From an environmental perspective, the current practices related to disposal of livestock manure are creating serious problems such as pollution of the surrounding areas with manure and slurry. Moreover, they lead to massive populations of flies and rodents which are threatening human health. The root causes of these practices could be:

i) Licensing of livestock farms overlooks the issue of on-farm processing of manure. The licensing must emphasize that only the processed manure is permissible to be trucked outside the farm.
ii) Lack of close oversight of manure collection, treatment, storage and disposal at the farm and location levels. Enforcement of legislation related to disposal of animal wastes is not happening.
iii) Lack of infrastructure and lack of structured mechanism for collection, treatment and disposal of livestock manure.

The secondary causes for poor handling of manure are:

i) High costs associated with collection and disposal of manure. The current transport cost ranges between JD 1-3 per m^3 for raw manure.
ii) Lack of space to store and process manure at the farm.

The odor and sight of the small scattered mountains of dumped manure and the rivulets of slurry dissecting the wadis are very unpleasant. A comprehensive strategy is needed to convert this manure and slurry into a beneficial commodity. Effective mechanisms for handling manure could attract local and international investors to establish a wide array of enterprises in this sector.

4.2.4.2 Amount of Manure Production

Dairy Cattle Manure

The total amount of manure production is estimated using two scenarios.

Scenario 1: Using Official Numbers of Dairy Animals and Results of Field Survey

This scenario assumes the following:

- Number of dairy animals is 66,000 (according to official records).
- Herd structure is 80% milking cows and 20% other animal classes (calves, replacement heifers and bulls).
- Daily fecal output is 6 kg DM per milking cow as furnished by the visited local farm manager (actual value used rather than the 6.25 previously estimated in section 3.2.1)
- 3 kg DM per head for other animal classes.

The annual manure production from dairy cattle facilities is around 0.13 million ton dry matter as shown in Table 7. Collectability of manure produced is around 85-90% in large modern dairy farms and around 75-85% in medium and small dairy facilities.

Table 7. Annual manure production from dairy cattle in Jordan

Dairy Animals	Number	Daily Fecal Output (kg DM per animal)	Manure Production (DM)	
			Daily (ton)	Annually (million ton)
Milking cows	52,800	6	316.8	(316.8x365)/1,000,000 = 0.12
Other classes	13,200	3	39.6	(39.6x365)/1,000,000 = 0.01
Total	**66,000**		**356.4**	**(356.4x365)/1,000,000 = 0.13**

Scenario 2: Using Milk Production Data as Described Previously in Section 3.2.1

The assumptions of this scenario are:

- Average daily milk production is 15.8 kg per milking cow.
- Percent dry matter content of defecated manure is 15%.

The annual dry matter production of manure from milking cows only, without taking into consideration the manure output of calves (13,200), ranges between 0.124 and 0.15 million ton as shown in Tables 8 and 9.

Table 8. Annual fresh manure production from milking cows

Average Milk production (kg milk per milking cow)	Fresh Manure Production (kg/cow/day)	Dry Manure (kg DM/head/day)	Total Manure Production (DM)	
			Daily	Annually
(281356 ton of milk/48742 milking cow) x (1000/365 days)	{Milk (kg/cow/day) x 0.616} + 46.2	55.9 kg X 15%	(8.36 kg x 48742 milking cow)/1000	408.7 ton x 365 days
15.8 kg	**55.9 kg**	**8.36 kg**	**408.7 ton**	**0.15 million ton**

Table 9. Annual dry matter production of manure from milking cows

Average Milk production (kg milk per milking cow)	Dry Manure Production (kg DM/cow/day)	Total Manure Production (DM)	
		Daily	Annually
(281356 ton of milk/48742 milking cow) x (1000/365 days)	{Milk (kg/day) x 0.0874} + 5.6	(6.98 kg x 48742 milking cow)/1000	340.2 ton x 365 days
15.8 kg	**6.98**	**340.2 ton**	**0.124 million ton**

The computed amount of dairy cattle manure was 0.13 and 0.124 million ton DM per year for Scenarios 1 and 2, respectively. The other animal classes (calves and bulls) in dairy farms produced around 0.014 million ton DM of manure. Dairy manure production totaled to 0.144

and 0.138 million ton DM per year, for Scenarios 1 and 2, respectively, which is close to the estimates (0.16 million ton) reported by the MoA (2013).

Broiler Litter

Using Feed Intake Data

Assumptions:

- Number of reared broilers per growing cycle 28 million birds
- Length of growing cycle 42 days; 7 cycles per year
- Feed consumption 4 kg per bird per growing cycle
- Stocking is 20 birds/m^2
- Weight of bedding material (wood shaving) 3-5 kg per m^2
- Manure moisture content 75%

Using these assumptions, the manure and bedding production was calculated as shown in Table 10.

Table 10. Annual production of broiler litter in Jordan

Excreta per bird (kg per bird per cycle)	Manure Production (DM per cycle)	Manure Production (DM per year)	Weight of Bedding Material (kg DM)	Annual Production of Broiler Litter (million ton DM)
Fresh: 4 kg x 115% = 4.60 kg Dry: 4.6 kg x 25% = 1.15 kg	(28 million birds) x (1.15 kg DM per bird per cycle)	0.0322 million ton per cycle x 7 cycles per year	28 million birds per cycle x 7 cycles per year = 196 million birds (196 million birds/20 birds per m^2) x (3 kg per m^2/1000)	Manure = 0.2254 Bedding = 0.0294
	0.0322 million ton	**0.2254 million ton**	**0.0294 million ton**	**0.255 million ton**

The production of broiler manure totaled 0.2254 million ton DM and the weight of bedding material totaled 0.0294 million ton DM. The total weight of poultry litter is therefore estimated at 0.255 million ton DM. The relative weight of bedding material to weight of broilers manure is 13%. Total production of broiler litter could be estimated by multiplying the weight of manure by 113%.

Laying Hens and Parent Stock Litter

Using Feed Intake Data

Assumptions:

- Population of birds: laying hens (6.8 million) + parent stock (3.99 million) = 10.79 million
- Feed consumption 36 kg per hen per year
- Litter moisture content 75%

Using these assumptions, the manure and bedding production was calculated as shown in Table 11.

Table 11. Annual production of layers litter in Jordan

Excreta Output (kg per bird per year)	Manure Production (DM per year)	Weight of Bedding Material (kg DM)	Production of Layers Litter (million ton DM/year)
Fresh: 36 kg x 115% = 41.4 kg Dry : 41.4 kg x 0.25 = 10.35 kg	(10.35 kg DM/1000) x (10.79 million bird)	(10.79 million birds/10 birds per m^2) x (3 kg per m^2/1000)	Manure = 0.112 Bedding = 0.0004
	0.112 million ton DM	**0.0004 million ton**	**0.1124 million ton**

The estimate of annual manure production from hens (layers and parent stock) was around 0.112 million ton DM. The weight of associated bedding material was 0.0004 million ton. The farms of layers and parent stock produced around 0.1124 million ton of litter (manure and bedding material). Our estimate of poultry litter (0.1124 million ton DM) was lower than those estimated by MoA in 2013 (0.194 million ton air dry x 80% DM = 0.1552 million ton DM).

4.2.4.3 Manure Attributes: physical, chemical and biological

The analysis of the physical, chemical and biological attributes of collected manure samples is shown in Table 12.

Table 12. Characterization of collected dairy and poultry manure

Parameters	Unit	Dairy Cattle			Poultry Manure Samples		
		D1	D2	K3	ZLH4	ABR2	HBR3
Physical							
Moisture content	%	48.2	66.2	62.9	38.6	24.5	20.5
Dry matter	%	51.8	33.8	37.1	61.4	75.5	79.5
TVS, in the dry matter	%	70.1	72.2	73.8	84.6	82.0	74.3
Ash, in the dry matter		29.9	27.8	26.2	15.4	18.0	25.7
Chemical							
pH (1:5)	-	8.76	8.54	8.77	6.14	6.95	5.66
EC (1:5)	µs/cm	12090	10040	10510	12540	15860	17060
NH_4-N	%	0.105	0.108	0.146	0.471	0.670	0.606
NO_3-N	mg/kg dry weight	2.11	19.1	4.93	1.02	1.52	1.56
Total Nitrogen	%	2.55	2.62	2.59	4.54	3.27	3.96
Organic Carbon	%	6.5	14.0	4.0	1.0	5.1	4.0
C:N ratio	-	6:3	14:3	4:3	1:5	5:3	4:4
Potassium (K)	%	2.3	2.2	1.9	2.0	1.6	1.2
Calcium (Ca)	%	1.0	9.5	2.0	0.8	1.6	2.1
Magnesium (Mg)	%	1.2	1.3	1.2	0.96	0.84	0.72
Sodium (Na)	%	0.55	0.56	0.52	0.19	0.15	0.13
Boron (B)	mg/Kg dry weight	36	40.8	16.8	57.3	38.1	20.1
As	mg/Kg dry weight	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cd	mg/Kg dry weight	<0.25	<0.25	<0.25	0.260	0.28	0.36
Cr	mg/Kg dry weight	4.24	3.99	4.99	11.70	12.40	4.33
Hg	mg/Kg dry	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

	weight						
Mo	mg/Kg dry weight	11.5	9.68	18.8	8.5	13.2	12.5
Ni	mg/Kg dry weight	5.04	2.70	4.23	2.50	3.29	2.20
Se	mg/Kg dry weight	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Pb	mg/Kg dry weight	4.77	<4.5	<4.5	<4.5	<4.5	<4.5
Zn	mg/Kg dry weight	123	141	112	468	265	248
Cu	mg/Kg dry weight	21.4	22.8	18.3	35.9	28.5	24.1
Mn	mg/Kg dry weight	283	236	212	522	473	319
Biological							
Intestinal worm Eggs	viable eggs/4g	<1	<1	<1	<1	<1	<1
E. coli	MPN/g	1.8×10^3	1.3×10^3	6.3×10^4	3.9×103	2.78	11.7
Salmonella	MPN/g	<3	<3	<3	<3	<3	<3

D1 & D2 from Dhulail, K3 from Khalideyah, ZLH4: Zizia Layers, ABR5: Al Esh Broilers, HBR6: Hebraas Broilers.

Solid Matter
Percent TS varied from 48.2% to 66.2% for cattle manure and from 20.5% to 38.6% for poultry manure. According to USDA classification, both types are considered solid manure. Because the water content of these manures was more than 20% it is prohibited to use them as organic fertilizers as mandated by the MoA/Natural Organic and Synthetic Fertilizers Specifications.

Percent VS averaged 72.0% and 80.3% for cattle and poultry manure, respectively. The VS represents the organic matter which yields energy upon combustion; poultry litter is expected to yield more energy than cattle manure. Manure VS helps in the planning and in the design of certain biological treatment procedures.

Percent ash in the dry matter of cattle manure was higher (28%) than that of poultry litter (20%). This may be attributed to the scraping manure from dirt lots in dairy farm facilities.

Bulk Density
Bulk density (g/cm^3) averaged 0.27, 0.36 and 0.33 for cattle manure, layers litter and poultry litter, respectively. The age ranged from a few days for cattle manure, to 38 days for broiler litter and 19 months for the layer litter. The ruminants' manure (i.e. that of cattle, sheep, and goats) is characterized by low bulk density because of the straw component: the long pieces of straw increase the volume of the manure and reduce the density.

Knowing bulk density of manure is important for storage and handling purposes but, because of the great variability of bulk density even in the same batch of manure, it is not a useful criterion to compare between the different types of manure.

Organic carbon
Percent organic carbon varied from 4.0% to 14.0% for cattle manure and from 1.0% to 5.1% for poultry litter. Overall means of organic carbon were 6.1% and 3.1% for cattle manure and poultry litter, respectively. The low content of organic carbon in the tested manures makes it difficult to meet the Jordanian licensing specifications of at least 50% organic carbon in any natural fertilizer.

Carbon: Nitrogen ratio
The relative proportion of C:N was 3:1, 5:1 and 2:1 for cattle manure, and 1:1, 2:1 and 0.2:1 for poultry litter. These C:N ratios are low and composting of these manures will not be complete. The compositing micro-organisms require the correct proportion of carbon for energy and nitrogen for protein production. Practically, composting requires an initial C:N ratio of 18:1 for cattle manure and 7:1 for poultry manure.

Higher Heating Value (HHV)
The HHV (gross energy, heat of combustion, calorific value) varied between 2.694 and 4.045 Kcal/g and averaged 3.192 and 3.160 Kcal/g for cattle and poultry manures, respectively. It was surprising that the HHV for cattle manure and poultry litter are similar knowing that the percent ash was higher (28%) in cattle manure compared to poultry litter (20%).

Manure Acidity
Cattle manure was alkaline (pH=8.7) whereas poultry litter was acidic (pH=6.3). The acidity of poultry manure could be attributed to the secretion of uric acid (the white crystal material which is results from the disposal of surplus end products of protein metabolism) with the droppings of birds. Acidic manures reduce ammonia volatilization.

Electrical Conductivity
Electrical conductivity (EC), which is an indication of soluble salts, was higher for poultry manure (15,153 µs/cm) than that of cattle (10,880 µs/cm). Long term or excessive application of manures with high EC can lead to a build-up in soluble salts in the soil, particularly in medium and fine textured soils having low infiltration rates, especially in arid areas receiving low precipitation.

Manure Nitrogen Content
The total nitrogen (organic and inorganic N fractions) averaged 2.6% and 3.9% for cattle and poultry manures, respectively. The TN is not an informative criterion, either for availability of N to plants or as an indication of N losses through volatilization, denitrification or leaching after application. The ammonium-N (NH_4-N) represents the inorganic N fraction commonly occurring in manure, which is plant available. It ranged from 0.11% to 0.15% for cattle manure compared to 0.47% to 0.67% for poultry manure. It is worth noting that all the excreted end products (uric acid) of protein metabolism in birds are trapped in the litter and gradually volatilize depending on house conditions (such as humidity, temperature, ventilation, and moisture content of manure). In cattle, the urine (urea) is the end product of protein metabolism and cows can urinate in feeding, resting and milking areas and in the dry lots; this means that a small quantity of urine is trapped and mixed with feces.

The inorganic nitrate-N (NO_3-N) was low, which is typical, but higher in cattle manure (8.71 mg/kg DM) compared to poultry manure (1.37 mg/kg DM).

Manure Phosphorous Content
Percent P was 1.1 in cattle manure and 1.6 in poultry litter, which could be attributed to diet composition of cattle versus poultry. The diet of poultry is made up primarily of corn and soybeans which contain P bound in the phytate-phosphorous form which is unavailable to the bird.

Elemental Constituents in Manure
Mineral composition of cattle and poultry manures varied widely. Potassium, Magnesium and Sodium concentrations were higher (21454, 12376 and 5234 mg/kg DM) for cattle manure than those for poultry manure (15935, 8426, 1563), respectively. The concentrations of Calcium, Boron, Zinc, and Manganese were higher (14905, 39, 327 and 438 mg/kg DM) in

poultry manure compared to those of cattle manure (13223, 31, 125 and 244 mg/kg DM), respectively.

5 Legislative Framework of Organic Fertilizers

The legislative framework that governs the entire cycle of licensing, producing, handling, storing, transporting and finally using organic fertilizers involves a number of entities and can therefore be very complex. The details of the legal framework governing organic fertilizers will be discussed in more detail in a subsequent report prepared under the "Poultry and Livestock Waste Management" activity of the USAID WRECP. The detailed legal review to be carried out will look into legislation issued by MoA, MoEnv, MWI, WAJ and JVA, MoIT, MoH, MoMA, and JSMO as well as any other legislation deemed relevant by the team.

However, for the purposes of this report specific to the amount and characterization of the poultry and livestock waste in Jordan, only three main pieces of legislation will be referred to since these specify the characterization of organic fertilizers:

- MoA's Instructions for the Requirements of Licensing, Preparation, Storage, Handling and Trading of Fertilizers and Plant Growth Regulators for 2011
- MoEnv's Instructions for Organizing the Storage, Transport and Treatment of Organic Fertilizers and their Trading for 2009
- Technical Regulation JS 962:2011 on Organic Fertilizers and Soil Conditioners

The JS 962:2011 references both the "MoA Instructions which define and characterize the types of agricultural fertilizers" and "MoEnv's Instructions for organizing the storage, transport and treatment of organic fertilizers and their trading". Furthermore, both MoA and MoEnv Instructions either refer to the JS 962:2011 explicitly (Articles 4 and 20-A of the MoEnv's Instructions for Organizing the Storage, Transport and Treatment of Organic Fertilizers and their Trading for 2009), or implicitly (Article 4 of the MoA's Instructions for the Requirements of Licensing, Preparation, Storage, Handling and Trading of Fertilizers and Plant Growth Regulators for 2011).

JS 962:2006 differentiates between organic soil conditioners and organic soil fertilizers, stating that organic soil conditioners are "organic matter that is applied to the soil to improve its physical and biological characteristics and include small amounts of the three main macro-nutrients N, P, K often less than 2% of the total product mass." Organic Soil Fertilizers, however, are defined as "the fertilizer that results from the addition of the three main macro-nutrients or any other nutrients to the organic soil conditioner by a percentage that is beyond 2% but does not exceed 20% of the total product mass."

Furthermore, MoA's Instructions define two types of organic soil fertilizers: natural organic fertilizers ("animal and plant wastes which are fermented or not fermented and which contain nutrients in various degrees"), and produced organic fertilizers ("animal and plant wastes which are fermented and are produced through drying, sterilizing and packaging"). The Instructions also add the following definition for soil amendments: "substances used to reclaim the soil natural and chemical characteristics and improve its productivity" (Article 2).

MoEnv's Instructions, on the other hand, elaborate on the methods of organic fertilizer treatments to be considered "treated". The Instructions define the treated organic fertilizers as "animal waste or plant waste or any composition of the two that has been treated biologically through composting (aerobic treatment) or fermentation (anaerobic treatment) in which the sterilization has taken place through the increased temperature to 55°C for a period of two weeks or 65°C for a period of one week during the time of treatment. This

process should result in the decomposition of organic matter and the elimination of worms and seeds as the production of a homogeneous product."

All pieces of legislation reviewed under this section agree that organic fertilizers and organic soil conditioners should be free from weed seeds and other plant parts that could germinate, and should not pose any harm to the public health through unpleasant odors. JS 962:2011 further specifies that pesticides should not be used in the process of sterilizing organic fertilizers (Article 5-1).

While JS 962:2011 and MoA's Instructions quantify specific constituents of organic fertilizers as a product (Tables 13 and 14), JS 962:2011 also explains the methods for packaging, storage and transport (Article 7). It specifically requires that the packaging material should not react with the product contained within and should ensure its protection from humidity. MoA's Instructions, on the other hand, deal with trading in organic fertilizers and the facilities established for this purpose. MoEnv's Instructions offer more detailed provisions related to the collection, handling, transport and treatment processes. MoEnv's Instructions also address the licensing of organic fertilizer industries and their operation, and also emphasize environmental inspection and control.

Table 13. Specifications for organic soil fertilizers and organic soil conditioners

Parameter	MoA Instructions	JS 962:2011	
	Natural and Produced Soil Fertilizers	Organic Soil Conditioner	Organic Soil Fertilizer
Minimum percentage of organic matter (dry weight for local product)	50%	50%	45%
Minimum percentage of organic matter (dry weight for imported product)	60%	Not specified	Not specified
Maximum moisture content	20%	20%	15%
Nitrogen (weight percentage)	2% (Maximum)	1.5% (Minimum)	Not specified
P_2O3 percentage	0.9% (Minimum)	Not specified	Not specified
K_2O percentage	0.5% (Minimum)	Not specified	Not specified
C:N ratio	15:1	15:1	Not specified
Salinity (measured through EC in a 1:5 extract)	15 mmho/cm	15 mS/cm	Not specified
pH (measured in a 1:5 extract)	Not specified	7.5	7.5
Total weight percentage of added nutrients	Not specified	Not specified	20%

Table 14. Maximum permissible limits for heavy metals in organic soil conditioners and organic soil fertilizers

Element	Maximum Permissible Limit (mg/kg)	Reference (MoA Instructions and/or JS 962:2011)
As	15	Both
Cd	3	Both
Cr	100	Both
Se	4	Both
Pb	120	Both
Hg	1.5	Both
Ni	50	Both

Sn	10	JS 962:2011
Cu	150	MoA Instructions
Mo	18	MoA Instructions
Zn	350	MoA Instructions

Furthermore, JS 962:2011 and MoA's Instructions also specify the labeling of organic fertilizers and conditioners (Articles 8 for JS 962:2011 and Article 9 for MoA Instructions). The product labels should include the following information: (1) name of the product and its trade mark if any (2) name of the manufacturer (3) home country (4) net weight and gross (in International Units) (5) origin of the organic matter (poultry, cattle, etc.) (6) added nutrients and the percentage for each (7) batch number (8) production date (9) product form (plates, granules etc.) (10) registration number at the MoA, and (11) product application.

6 Conclusions and Next Steps

6.1 Summary of Manure Production from Dairy Cattle and Poultry

Table 15 summarizes manure production in Jordan:

- Manure production from dairy cattle and poultry (chickens) was around 0.52 million tons in 2012.
- The contributions of cattle and poultry to total manure production were 29.1% (0.151/0.5184) x 100% and 70.9% (0.2254+0.112)/ (0.5184) x 100%, respectively.
- The proportions of bedding material in broilers and laying litters were 11.5% (0.0294/0.255) X 100% and 0.36% (0.0004/0.1124) x 100%, respectively.

Table 15. Dairy cattle manure and poultry litter production in Jordan

	Population	Manure Production (million ton DM)	Bedding Material (million ton DM)	Total (million ton DM)	Manure Collectability %	Potential Collected Amount of Manure (million ton DM)
Dairy cattle	Milking cows: 48,742 Others: 17,258	0.151	-	0.151	70-75	0.106-0.113
Broilers	196 million birds per year (28 million per cycle, 7 cycles per year, 42-day growing period)	0.2254	0.0294	0.255	90-95	0.230-0.242
Layers and parent stock	10.79 million birds (6.8 million layers and 3.99 million parent stock)	0.112	0.0004	0.1124	90-95	0.101-0.107
		0.5184		0.5184		0.436-0.462

6.2 Potential Uses

Animal manure has routinely been used to provide essential plant nutrients (NPK) and to improve soil quality. Most animal operations are now concentrated near urbanized areas, are becoming larger in size, and are producing large quantities of livestock manure. Therefore, diverse options should be explored to dispose of and utilize the produced animal manure properly without causing problems and in environmentally sound, socially accepted and economically viable manners. Given the significant agronomic and energy value of livestock manure in Jordan, potential uses exist.

Agricultural Purposes

Livestock manure is normally spread on agricultural fields as fertilizer. As more large intensive livestock operations develop in the country, and larger quantities of manure are produced, it is important to know how much manure can be spread on agricultural fields without causing problems. This requires detailed analysis of manure (raw and fermented) marketing in Jordan. The assessment of market capacity should be followed by detailed characterization of livestock manure to evaluate the levels of its main constituents (NPK) in order to determine safe manure application rates for the different agricultural activities on different soils.

Rehabilitation of Degraded Rangelands

Degraded rangelands are characterized by low soil fertility due to depletion of vegetative cover and active erosion by wind and water. The vast extension of rangelands in Jordan can absorb large quantities of fermented manure especially in locations where barley is continuously cultivated. The first challenge is how to apply animal manure and incorporate it into the soil profile without disturbing the vegetation at the surface. The second is how to reduce the prohibitive costs of hauling manure associated with transport from production sites and fermentation plants to the remote areas of rangelands. Fermented manure and more preferably manure compost could be incorporated in the potting media for production of forest and rangeland transplants at the different nurseries in the country if these costs were not so prohibitive.

Energy Production

Based on the analysis of the collected manure samples, estimates of total HHV values for produced dairy cattle manure and poultry litter were 0.243 x 10^{12} and 0.837 x10^{12} kcal per year, respectively, as shown in Table 16. These values are important when considering incineration of the waste material.

Table 16. Estimates of Higher Heating Value from animal manure generation in Jordan

Farm Animals	Manure Production (Million ton DM)	Collectability %	Potential Collected Manure (million ton DM)	Volatile Solids in Manure (%)	HHV (Kcal/g)	HHV (Kcal x 10^{12})
Dairy cattle	0.151	0.7	0.1057	72.0	3.192	0.243
Broilers	0.255	0.9	0.2295	78.2	3.160	0.567
Layers	0.1124	0.9	0.10116	84.6	3.160	0.270
Total	0.5184		0.43636			1.08

6.3 Next Steps

With wastes quantified and characterized, it is recommended that a review of current manure waste management from source to end use, which focuses almost solely in agriculture, be undertaken. Investigation of existing waste management streams should address:

- Technical practices, including methods of treatment/stabilization of wastes, and application in agriculture
- Environmental concerns
- Regulatory framework and enforcement
- Stakeholder assessment including MoA, MoEnv, farmers, processers, and transporters
- Farmer understanding of waste cycles
- Any ongoing manure waste to energy pilots

Potential modifications to existing waste management streams and with a focus on alternate approaches should then be investigated. The review should include associated transportation, storage, treatment and reuse methods which that are environmentally, technically and economically viable. Items such as manure stabilization and benefits to plant production, and socio economic impacts of alternate approaches should also be covered.

Animal waste as an alternate fuel source should also be investigated further, potentially through support of other donors and demonstration pilots.

Upon completion of the above investigations, workshops with stakeholders should be held to disseminate information and gain stakeholder feedback. With feedback from workshops, draft recommendations could be reported including proposed piloting of alternate manure treatment and application in agriculture approaches.

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