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HOUSEHOLD SOLID WASTE IN BAMAKO DISTRICT: COMPROMISED BENEFITS FOR URBAN AND PERI-URBAN AGRICULTURE AND ANIMALS (INCLUDING BIRDS)

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ABSTRACT

While waste is an inherent part of our lives, its proper management is essential for our well-being and development. Unfortunately, we observe that its mismanagement in Bamako is detrimental to our health and environment. We have noticed that the numerous transfer landfills are increasingly unregulated. Consequently, they become entrenched rather than being transported to a final disposal site. Because this waste is neither removed nor recycled, it pollutes the environment in all its components (soil, air, water, flora, and fauna). Domestic animals, lacking food, use these transfer landfills as natural pastures. Birds find feeders and nesting materials there. While organic waste is used to produce livestock feed and compost, plastic waste, if not recycled, poses a threat to agricultural soils, animals (including birds), and even the Niger River ecosystem. At this rate, poor management of household solid waste jeopardizes the achievement of SDG 11 (sustainable cities and communities) and SDG 15 (life on land). Hence, the purpose of our studies and work is to capitalize on the benefits and propose appropriate measures to address the drawbacks.

Keywords: Agriculture, Animals, Bamako, Household Solid Waste

1 INTRODUCTION

Household solid waste (HSW) is an inherent part of our lives, and its management is essential for our well-being and development. The situation is much more concerning in developing countries (DCs) suffering from serious pollution problems, due to insufficient resources and their difficulty in addressing the issue of waste with an approach adapted to their context (Chantou T, 2012). If the issue of waste were limited to the disposal of organic matter, it continues to increase in both quantity and type (plastics, trash, bottles, cardboard, metals, glass, wood) from the streets and roads to the hillsides, passing through gutters, transfer landfills, vacant lots, and fields. The riverbanks are occupied by market gardens and/or makeshift piles of household waste. Unfortunately, we observe that its poor management in Bamako is detrimental to our health and our environment. The problem is very complex in Bamako, where the volume of household waste generated per capita is estimated at 0.6 kg per day, representing an annual production of 1,171,432.339 m^3 (INSTAT, 2021), while only a small portion of this household waste is properly managed. Waste recycling is informal, limited, and only covers metals, some compost, and less than 10% of plastic waste. Most of this uncollected waste poses enormous risks to the environment and public health (Ould Aloueimine S., 2006; Ouattara I. et

al., 2021). Some solid waste (organic, plastic, and metallic) is recycled within a circular economy framework. However, other waste is also consumed by animals that live alongside humans. The objective of our studies is to analyze whether the use of this waste is beneficial or detrimental, on the one hand to these animals and on the other hand to urban and peri-urban agriculture.

2 LITERATURE REVIEW

In developing countries, organic waste constitutes more than half of household solid waste (Chevalley I, 2024). This organic waste promotes the proliferation of pathogens, biological indicators of the risks to human and animal health associated with waste. Those biodegradable waste which result from pruning waste, food scraps, animal excrement, sometimes paper and cardboard, woody residues, residues of traditional medicines and remnants of natural constituents, waste from agricultural production (different from pruning waste), and domestic livestock can be used to produce compost, biogas, and animal and poultry feed within the circular economy (Vérité O, 2024).

Aside from the health risks, most organic waste is valuable (Damien A, 2016). Except for animal manure, raw organic matter is not suited to the needs of crops or the constraints faced by farmers. Therefore, composting is essential for soil restoration and fertilization (Bernard A, 2022). Proper composting allows nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) to be incorporated into the process, modifying the physicochemical properties (structure and texture) of the soil by neutralizing carbonic acid and thus promoting the transformation of calcium carbonate into calcium bicarbonate, which is more soluble (Koledzi K E et *al*, 2011; Tahraoui Douma N, 2013; Charney F, 2005). Unfortunately, it has been observed in developing countries that composting of household solid waste (HSW) represents less than 1% (Silpa K et *al.*, 2018). Composting produces organic fertilizers adapted to plant needs and farmers' constraints, which could partially reduce farmers' dependence on imported mineral fertilizers (Wassenaar T et *al.*, 2016). In addition to composting, controlled biomethanization also produces biodigestate, which is a good agricultural fertilizer.

Plastic and metal waste also constitute a significant portion of HSW. It is imperative to avoid the dispersal of plastic waste in landfills, as its non-biodegradability poses a threat to agricultural soils, both terrestrial and aquatic animals, and even humans. When buried in the soil, plastics undergo physical, chemical, and biological processes, releasing various chemical compounds that will only mineralize slowly and partially (Duplessy J C et *al*., 2021). Particularly, in developing countries where there are more illegal dumps, many livestock die because of ingesting plastic bags.

3 METHODOLOGY

3.1 Study area

Bamako city covers an area of approximately 729 km^2 following the recent administrative reorganization by Law No. 2012-017. It is situated in the Niger River valley, which divides it into two parts: the left bank and the right bank (Fig. 1). The Bamako district has a humid tropical climate with high temperatures (average annual temperature ranging between 26°C and 30°C) and annual rainfall varying from approximately 700 mm to 1100 mm.

Vegetation has been significantly impacted by urbanization, but it remains wooded on the hillsides and herbaceous in the plains of the outlying neighborhoods near the wooded areas where traditional healers harvest medicinal plants. During the dry season, the banks of the Niger River and undeveloped residential areas are used for traditional or improved gardening, facilitated by the availability of domestic animal manure and compost from household waste. It is therefore important to draw attention to these agricultural activities, which generate solid waste that litters the streets or floats in the river. Their deciduous leaves, falling directly into homes or carried by the wind, contribute to increasing the amount of household solid waste, as do their branches after pruning. During harvest periods or times of food scarcity, crop residues become the predominant form of organic waste.



Figure 1: New administrative map of Bamako

(IGM, 2024)

In addition to small wild rodents, mammals are more domesticated, even though keeping them as pets is strictly prohibited by decree No. 2017-0326/P-RM. The birdlife is represented by barnyard fowl and wild birds that fly over Bamako and the surrounding areas and/or nest in trees or caves. Most of these birds have adopted an anthropophilic lifestyle, sometimes even benefiting from human-generated waste. Insects are sometimes scavengers and/or detritivores, contributing to the putrefaction and disintegration of dead animals thrown into piles of household garbage. Stagnant water following rains and rotting waste serves as food and breeding grounds for certain invertebrates such as flies and mosquitoes. All these animals contribute to increasing the amount of solid household waste, especially organic waste, through their food scraps, droppings, or outdated shelters.

Gardening and the production of seasonal crops are among the main economic activities. While gardening takes place along the banks of the Niger River or on undeveloped land, short-cycle winter crops are grown in the outlying quarters (Kante M, 2026).

3.2 Methodology

Our research methodology consisted of:

- Visiting units producing organic fertilizers and animal and poultry feed.
- Checking the fertilizers used in urban and peri-urban gardens and fields.
- Surveying illegal dumpsites to observe the presence of animals.
- Analyzing the stomach contents of urban ruminants in butcher shops.
- Observing the feeding practices of urban birds and the materials used to build their nests.

4 RESULTS AND DISCUSSION

4.1 Advantages of household solid waste

4.1.1 Production of livestock and poultry feed

Without specific awareness campaigns on waste sorting, women in low- and/or middle-income families quickly discovered the monetary value of food scraps. Thus, they separate peelings, food inedible for human consumption, and food scraps to sell to specialized collectors who come to their homes to buy them. Spread on rooftops by domestic

workers or on vacant lots (Fig. 2), this valuable waste allows many women to pay their rotating savings and credit associations (tontines) or supplement the cost of condiments. Animal feed production is currently one of the main ways in which organic waste is used to obtain sufficient stocks of animal feed at minimal cost (Ben Amor M L, 2010). Certain organic waste, such as food scraps from restaurants and households, and spoiled fruits and vegetables, are considered by-products. While no longer edible for humans, they are suitable for livestock and poultry after processing to improve their quality. These processed products supplement animal feed for farmers (Verite O, 2024). If not processed, some putrescible food waste promotes maggot production in poultry and fish farming.



Figure 2: Drying food scraps

Unlike other types of recyclable waste, food waste is not part of a structured recycling network in Bamako. This lack of structure hinders quality control of household food waste, making industrialists relatively skeptical about its introduction into their production lines. However, everyone agrees on the need for quality control to prevent toxic effects from these products, hence the need to equip all stakeholders with the knowledge and/or skills for efficient food waste management (CCAC, 2024). Recycling food waste into animal feed offers economic advantages (for livestock farming in general and fattening in particular) and environmental benefits (reduction of production waste volumes, methane, and other gases). Furthermore, a CCAC publication (2024) indicates that more than 174 million tons of organic waste are produced annually in sub-Saharan Africa. In the same strain, Roussel F (2014) published that globally, one-third of the food produced for human consumption is lost or wasted, totaling 1.3 billion tons per year. The chemical composition of this waste shows that it can constitute an additional source of feed that could contribute to the security of urban and peri-urban livestock, particularly ruminant livestock (Coulibaly F et *al.*, 2022). Given the quantity of food waste (especially fruits and vegetables that rot due to lack of processing) in Mali, a country with an agro-pastoral focus, transforming this waste into animal feed could significantly reduce the country's dependence on imports.

4.1.2 Waste and Agriculture: Production of soil and compost

Beyond the reuse of certain non-biodegradable waste to protect vegetable gardens against insect pests and stray small ruminants (Fig. 3a), organic waste eventually mixes with sand and leachate. The enriched or fertilized soils are then dried and sifted to produce soil. This product is in high demand among nursery growers throughout the year. Soil collectors see their sales peak during the rainy season when the product is used for reforestation and planting fruit trees on farms.



Figures 3: a) Protection by used mosquito nets and b) Bagging of compost

In the field, we only observed windrow composting (natural or slow), the compost produced from which creates porosity in the soil, improving its water absorption and retention capacity. In Mali, artisanal or traditional composting is the most widespread because it is simple, meaning it is easily assimilated by farmers and allows for improved soil fertility at a lower cost while reducing dependence on chemical fertilizers for low-income farmers. Furthermore, Blanchard M and Vall E (2008) described composting household waste as a simple method of producing organic fertilizer. With less environmental impact than chemical fertilizers, it also has the advantage of being produced locally while allowing for quality control and the creation of local jobs (GFM, 2020; Di Biase, 2006).

As for industrial composting in Mali, it is a large-scale process for producing improved compost. The industrial unit operates using organic waste from stabilized landfills. This waste has had time to ferment, combining with leachate and topsoil in the landfills from which it originates. Unlike simple sieving, the compost is mixed with poultry manure and animal excrement, molasses, and wood ash (Fig. 3b). The composting sector in Mali suffers from a lack of structural state support mechanisms, like other developing countries such as Algeria, as discussed in the studies by Tahraoui Douma N (2013). Established businesses struggle to operate effectively because they encounter difficulties with municipal structures, which themselves, paradoxically, are genuinely suffering from the overwhelming mountain of waste.

4.2 Risks and threats related to household solid waste

4.2.1 Risks of agricultural soil degradation

43 out of 50 fields observed, or 86%, are infested with waste, primarily plastic (Fig. 4), compared to 7 fields, or 14%, that are not infested. The uninfected fields are used for gardening during the dry season. Consequently, they are properly fertilized by the users. In contrast, all the garden plots are fertilized with organic inputs (domestic animal excrement) and compost. A plausible explanation is that the gardens, mainly tended by women on small plots, are located close to the users (along the banks of the Niger River and in outlying neighborhoods). The fields are larger and somewhat further away (in distant outlying neighborhoods), although many are currently in developed areas with some initial development due to urban sprawl.

The most visible and widely acknowledged form of degradation after waste is dumped in fields is that caused by plastic components. As noted by Ouedraogo G N (2011) in Burkina Faso, plastic bags end up in fields due to farmers' demand for household waste to be used as fertilizer. Along roadsides, a few days after rain, we observe stagnant water on these bags, creating breeding grounds for mosquitoes, which transmit numerous diseases to humans and animals.

Specifically, here, the focus is on the negative impact of plastic pollution on soil. Soil pollution leads to the formation of microplastics and nanoplastics, resulting in changes to the soil's physicochemical characteristics (pH, temperature, organic matter content) and a decrease in its fertility and, consequently, its productivity (Giebel B et *al.*, 2022; Erny I et *al.*, 2020). This soil degradation will only worsen year after year, as plastic decomposes very slowly in the environment and remains there for a long time. Heavy metals and persistent organic compounds can also be released into the soil, polluting it. This pollution, affecting human well-being and the environment, compromises the soil's capacity to filter, absorb, and transform mineral and organic contaminants and can influence other physical, chemical, or biological properties of soils, leading to repercussions on soil ecosystems and the positive functions they perform (agricultural production, filtration and purification of groundwater, among others) (FAO, 2019). These nanoplastics and microplastics can even reach groundwater, especially if the soil is sandy. While the application of agricultural pesticide inputs directly exposes soils to chemical pollution, the use of household waste as fertilizer can alter their texture. It is

primarily the fertilizing aspect of organic waste that attracts the attention of agricultural producers, but they are unaware of the harm that inappropriate chemical constituents can cause.



Figure 4: Waste dumped in a cornfield

4.2.2 Uncontrolled transit sites: grazing lands at risk for mammals

Driven by their instinct to search for pasture, stray animals graze in uncontrolled transit sites (Fig. 5a). Observation of 40 ruminant stomachs revealed that 13 stomachs, or 32.50%, contained plastic bags (Fig. 5b). Our results are relatively consistent with those of VSF (2017), which estimated this damage at 30%. Barro B (2000) and Diene A (2014) highlighted the extent of the phenomenon of ingestion of identical plastic bags in the three breeds of domestic ruminants (cattle, sheep, and goats). Ouédraogo A et *al* (2022); Erny I et *al.* (2020) highlighted that 86% of livestock farmers surveyed in various countries (Burkina Faso, Nigeria, Ethiopia, Kenya) had experienced livestock deaths due to plastic bag ingestion. A study showed that fattened animals, and especially crossbred cattle, are more at risk of plastic bag ingestion because of their higher nutritional needs and larger size compared to native breeds (VSF, 2017; Priyanka M and Dey S, 2018). Indigestible plastic bags remain in the digestive tract, preventing the animal from ingesting enough other feed and causing a progressive deterioration of its health and subsequent severe malnutrition (Ouedraogo A et *al*., 2022; Erny I et *al*., 2020).



Figures 5: a) Animals on a landfill and b) plastic bags in a tripe

The problem of plastic pollution is complex and requires coordinated action to address it. To respond to food insecurity, urban and peri-urban livestock farming must place greater emphasis on housing animals indoors rather than allowing them to roam freely and raise awareness of good husbandry practices (culling of unproductive animals, establishment of feed banks, grazing centers and watering facilities for animals, and the launch of public health awareness programs) (Ouedraogo A et *al*., 2022). Beyond plastic bags, animals can also ingest other types of waste that obstruct their tracheas and damage their digestive tract, among other effects (Hira A et *al*., 2022).

4.2.3 Waste: Food, building materials, and traps for urban and peri-urban birds

From 40 bird nests observed (all species combined, especially *Streptopelia senegalensis* and *Pleoceus cucullatus*), 31 nests or 77.5%, contained household waste as building materials (Fig. 6). This can be explained by the fact that urban birds have adapted to our environment and tend to use our residual materials. Urban birds used natural materials such as twigs, dry grass, leaves and palms. Since it is difficult to find these natural materials in urban areas, birds use what

they find in waste to build their nests. Like Premont C (2024) with birds in Europe and Australia, we also observed that birds are increasingly using human-generated waste to build their nests. However, Martel A (2024) draws attention to this in the following terms: *''In fact, the real danger posed by the fibers is to the nestlings. A hair wrapped around the neck, wing, or leg is a deadly danger to the chicks.''*



Figure 6: Wires in a nest of *S. senegalensis*

Observation of 40 gizzards from domestic chickens (*Gallus gallus domesticus*) revealed that 37 gizzards, or 92.5%, contained household waste (plastics, beads, pieces of aluminum foil …). Putrescible organic waste promotes the production of maggots, insects, caterpillars and earthworms which are sought after by birds to feed their chicks. Thus, landfills have become feeding grounds for certain species, much like urban landfills worldwide, where even wild birds sometimes come to feed (Melle E M, 2022; Leprovost J, 2022). While our waste provides food and materials for birds, it can also pose physical and health risks. Ingesting small pieces of plastic inflames their digestive tract and causes a disease called plasticosis, which affects their ability to reproduce and raise their young (Woolley S, 2023). Spoiled food or food mixed with chemicals can poison them. We noticed that turtledoves, domestic hens and their chicks had legs entangled in plastic threads, sometimes even losing a leg.

Moreover, during World Migratory Bird Day, UNEP (2019) drew attention to the triple threat (entanglement, ingestion of plastic waste, and nest accidents) that plastic pollution poses to all birds (marine and terrestrial, wild and urban, migratory and resident).

4.2.4 The Niger River becomes a final landfill

We can conclude from our interviews with local fishermen that waste has both benefits and drawbacks for fish production. This waste can provide food and hiding places for fish during spawning season. However, the toxicity of some waste can cause mass die-offs in certain areas.



Figures 7: a) Waste in a collector and b) Dumping on the riverbank.

As Possiletya J K-B et *al* (2019) demonstrated in Anyama/Ivory Coast, during the rainy season, household solid waste is dumped into gutters, drains (Fig. 7a), and streams due to a lack of awareness about the long-term consequences or a lack of civic responsibility, in violation of law No 2021-032/CNT (concerning pollution and nuisances). The situation is particularly concerning when this law is violated collectively, with the establishment of temporary dumping sites on the riverbanks (Fig. 7b). This waste eventually reaches the river, where it is carried along its course, washed ashore, or filled in the Niger River's channels, causing an imbalance in aquatic life. Contributing not only to increased flood risks, but this waste also pollutes the waters of the Niger River in Bamako. To address this recurring problem, coordination among all stakeholders is essential, along with raising public awareness about the consequences of their behavior. More attention must also be paid to users of handcarts and carts who secretly dump waste when no one is watching.

5 CONCLUSION

Based on our research and several previous studies, we can conclude that the benefits of household solid waste are indeed mixed, although recycling contributes to boosting the informal circular economy in a fragile country. The accumulation of this waste in unsuitable locations poses a threat to humans, animals, and agricultural soils. Even domestic wastewater and rainwater no longer flow normally due to the obstruction of their drainage systems by illegal dumping of household solid waste, which ultimately ends up in the river. This increased accumulation of household solid waste can be reduced by integrating recycling, raising awareness among users about the law banning plastic bags, and supporting households in sorting waste at the source. Good management of household solid waste will contribute to partially achieving target 11.6 of SDG 11 (Sustainable Cities and Communities) by reducing the negative impact of waste and pollution, and target 15.3 of SDG 15 (Life on Land) by preventing the degradation of agricultural soils.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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